

# The Internal Process of Time Deviation in Anxious State

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**Abstract:** A large number of studies have shown that emotions have an impact on subjective time perception, yet little is known about how individuals perceive time retrospectively when they are in an anxious state. Three experiments were conducted to investigate the moderated mediating effect of engagement and memory bias on the relationship between state anxiety and retrospective time perception. In Experiment 1, state anxiety (high and low) was manipulated by a standardized induction procedure, and retrospective time perception was tested by the visual analogue mood scale. In Experiment 2, memory bias was tested by the visual analogue mood scale and analyzed as a mediator between state anxiety and retrospective time perception. In Experiment 3, the sound of a neutral heartbeat was introduced as the measurement object of memory bias, engagement and retrospective time perception to test the moderated mediating role of engagement and memory bias in the relationship between state anxiety and retrospective time perception. The results suggested that (1) high state anxious individuals subjectively experienced a retrospective duration as proceeding more slowly than low state anxious individuals, (2) memory bias mediated the influence of state anxiety on retrospective time perception, and (3) engagement moderated the mediation effect of memory bias. Our findings contribute to understanding the roles that engagement and memory bias play in retrospective time perceptions in an anxious state.

**Keywords:** Retrospective Time Perception, Memory Bias, State Anxiety, Engagement

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## 1. Introduction

### 1.1. Background

Pleasant and fascinating events often lead to the experience that “time flies”; in contrast, painful and boring events often lead to the experience of “living for a year” or the even more extreme experience that “time stays still”. A large number of studies have shown that emotions have an impact on subjective time perception [1-4]. These effects have been confirmed by previous empirical studies on different populations, such as adults, children [5-7], individuals with negative emotions [8, 9], and individuals with depression [10]. However, until recently, few studies have particularly focused on how individuals perceive time when they are in an anxious state. In fact, some very recent work has examined the influence of state anxiety on prospective timing [11, 12], yet little is known about how individuals perceive time retrospectively when they are in an anxious state.

In this article, we explore how people retrospectively

perceive time when they are in an anxious state. This work addresses an important gap in the anxiety and time perception literatures. This omission is striking both theoretically and practically. Although theoretical work has identified a number of factors likely to influence retrospective time perception [13, 14] and many consequences of state anxiety [11, 12] for timing, few studies have further explored the consequences of state anxiety on retrospective timing. Hence, it remains an open question as to how individuals perceive time retrospectively when they are in an anxious state. This question is open for contexts in which people estimate the time spent on some important tasks, such as an examination, public speaking or a job interview, differently from how they estimate the time spent on some common tasks (e.g., reading at home or replying to an email from a friend). This difference is explained by important tasks being more likely to activate high state anxiety [15, 16], whereas common tasks are more likely to correlate with low state anxiety; these two states differently influence people’s retrospective time perceptions.

## 1.2. Literature Review

In the relevant literature, time perception can be divided into prospective and retrospective timing according to the measurement paradigm [17, 18]. Prospective timing is the process of requiring participants to perform the timing at the beginning of an experimental task. In this paradigm, participants intentionally and diligently encode the time information, which is also known as “experiencing duration”. Retrospective timing is the process of requiring participants to perform the timing at the end of the experiment task while not paying attention to timing during the experiment. In this paradigm, participants automatically and accidentally encode the information in the environment and then try to extract the relevant information from memory only when timing is needed, so it is also called “remembering duration”. Prospective and retrospective timings involve different cognitive processes. Prospective timing is mainly related to stimulus arousal and attention resource allocation, while retrospective timing mainly relies on memory processes [17, 18]. That is, if state anxiety affects prospective timing through attention [11, 12], it would affect retrospective timing through memory [19, 20]. Thus, the underlying mechanisms of these two timing paradigms are quite different.

Although few studies have focused on how people perceive time retrospectively when they are in an anxious state, some previous studies on the relationship between anxiety and prospective timing might be relevant. Some studies showed that anxiety leads to the underestimation of prospective time durations. For example, Whyman and Moos used a verbal estimation task to find that both high and low anxious individuals underestimated 15 s, 30 s and 90 s durations [21]. Mioni and his colleagues used a time production task and a time reproduction task to find that trait anxious individuals underestimated durations of 500 ms, 1000 ms and 1500 ms compared with normal individuals [22]. On the contrary, some studies have suggested that anxiety leads to the overestimation of prospective time durations. For example, Bar-Haim et al. used a time reproduction task to explore the time perception of fear and calm stimuli for 2 s, 4 s and 8 s. The results showed that compared with neutral stimuli, trait anxiety individuals overestimated the duration of 2 s fear stimuli [23]. Yoo and Lee used a verbal estimation task to further explore the time perception (2 s, 4 s or 6 s random occurrence) of socially anxious individuals for different stimuli (positive high arousal, positive low arousal, negative high arousal, and negative low arousal). They found that compared with other stimuli, individuals with high social anxiety overestimated the negative high arousal stimuli, while those with low social anxiety overestimated the positive low arousal stimuli [24]. Liu and Li explored the effects of state anxiety on the time perception of different valences (negative and neutral) and durations (2 s, 4 s and 8 s) and analyzed the mediating role of attentional bias. The results showed that compared with neutral stimuli, the individuals with high state anxiety showed an attentional bias

towards negative stimuli, which led to an overestimation of the negative stimuli presented for 2 seconds [11].

Indeed, we found only one study on the influence of state anxiety on retrospective timing in the literature, and it was completed by an undergraduate [25]. In this study, participants were asked to be speakers or audiences to successfully activate their high or low state anxiety. Then, they were asked to watch a video of the speeches for 8 minutes and 58 seconds. Finally, the participants were asked to estimate the duration of the video. The results showed that there was no significant difference in the retrospective time perceptions between the high and low state anxiety groups. However, based on previous studies of prospective timing [11, 12], we think that state anxiety should also affect retrospective timing, though the underlying mechanisms differ. Thus, the non-significant results reported by the only study we found are probably caused by inappropriate execution regarding the experimental and confounding variables, such as the video content, the time duration, and the measurement of time perception.

Actually, a number of theoretical and empirical works have been performed on retrospective time perception, though none of them refer to anxiety. We believe that this work can be an important basis for the current study. Among them, a classical theory of contextual-change model describes how memory affects retrospective time perception. This model argues that changes in the environment and cognitive strategies or emotional states are codable background changes in memory. The more changes that occur in perception and coding background, the greater the overestimation of time durations [26, 27]. Other studies have further clarified that the estimation of retrospective time depends on the encoding, storage and extraction processes of memory [13, 14]. In fact, an important effect that anxiety has on memory function was reported several decades ago [19, 20], but few studies have been conducted to further explore whether and how anxiety affects retrospective timing through memory. We believe that it is worthwhile to conduct a rigorous and systematic study to explore the influences of anxiety on retrospective time perception.

## 1.3. The Aim of Present Study

The central aim of the present study was to investigate how individuals perceive time retrospectively when they are in an anxious state. We conducted three experiments to explore the roles of memory bias and engagement on the influence of state anxiety during retrospective time perception.

In Experiment 1, the relationship between state anxiety and retrospective time perception was preliminarily explored. According to the contextual-change model, the more contextual changes are perceived and coded, the longer the time duration is perceived to be [26, 27]. Therefore, we propose hypothesis 1: the retrospective time estimation of high state anxious individuals is slower than that of low state anxious individuals (H1). State anxiety was manipulated as an anxious state (high state anxiety) or a calm state (low state

anxiety) by induction procedures. The visual analogue mood scale (VAMS) was then used to test retrospective time perception [28]. The process for inducing high state anxiety has more negative information than that for inducing low state anxiety, which leads to a larger number of emotional state changes.

In Experiment 2, we particularly explored the mechanism underlying the influence of state anxiety on time perception. Both theoretical models and empirical studies of time perception show that retrospective time perception is related to memory resources [13, 29]. In addition, some studies have found that anxious individuals have a memory bias towards negative stimuli [30]. That is, memory bias might function as the mechanism underlying the influence of state anxiety on time perception. Accordingly, we propose hypothesis 2: memory bias mediates the influence of state anxiety on retrospective time perception (H2). In this experiment, we measured participants' state anxiety, memory biases and retrospective time perceptions in recent life, and then the subjective scores were directly introduced into a bootstrap analysis as continuous variables.

In Experiment 3, the variable "Engagement" was introduced to investigate the moderated mediating effect of engagement and memory bias on the influence of state anxiety during retrospective time perception. Previous studies suggest that the higher the level of an individuals' task engagement, the higher the number of cognitive resources allocated [31, 32] which in turn leads to different retrospective time perceptions. Therefore, we propose hypothesis 3: engagement moderates the mediation effect of memory bias on the influence of state anxiety on retrospective time perception (H3).

## 2. Experiment 1

Experiment 1 aimed to preliminarily explore the relationship between state anxiety and retrospective time perception. We investigated the differences in retrospective time perception after the induction of high and low state anxiety. The hypothesis to be examined is that the retrospective time estimation of high state anxious individuals is slower than that of low state anxious individuals (H1).

### 2.1. Method

#### 2.1.1. Participants and Design

A total of 48 university students were recruited to participate in the experiment (13 males, 35 females,  $M_{\text{age}} = 23.79$  years,  $SD = 4.63$ ). The participants were randomly assigned to the high state anxiety group ( $N = 24$ ) or the low state anxiety group ( $N = 24$ ).

The independent variable is State Anxiety (high vs. low), and the dependent variable is Retrospective Time Perception.

#### 2.1.2. Procedure and Materials

State anxiety induction. The participants were asked to recall and imagine anxious or calm events to induce high or low state anxiety [33]. First, the participants were asked to

describe an event that resulted in anxiety or feeling of calm. The instruction was as follows: "Please describe a recent event that made you very anxious (calm). Please try to describe the details of the event and your feelings in no less than 100 words". Next, the participants underwent a period of mood incubation. The instruction was as follows: "Then, imagine you feel the anxious (calm) experience becoming stronger, which reminds you of other things that make you very anxious (calm)". Finally, the participants were asked to recall another anxious or calm event to reinforce their emotions. The instruction was as follows: "Please recall another event that made you very anxious (calm). Please try to describe the details of the event and your feelings in no less than 100 words".

State anxiety measurement. The VAMS was adopted to measure state anxiety [28]. The participants were asked to rate their current subjective experience of anxiety on a bar with 0 at one end and 100 at the other. The instruction was as follows: "Please choose any number between 0 and 100 to represent how anxious you feel now. Among them, 0 means very relaxed, and 100 means very anxious".

Retrospective time perception measurement. Similarly, the VAMS was adopted to measure retrospective time perception. The participants were asked to rate their time perception of the state anxiety induction on a bar with 0 at one end and 100 at the other. The instruction was as follows: "Please choose any number between 0 and 100 to represent how fast you think time passes in describing and recalling anxious (calm) events. Among them, 0 means very slow, and 100 means very fast".

Procedure. A professional platform named "Wenjuanxing" was used to program and run the experiment. The participants completed the experiment through the following process. Baseline state anxiety was examined in a pretest. Both the high and low state anxiety groups were subjected to manipulations of anxiety induction and posttest state anxiety. Then, the participants completed the retrospective time perception measurement. The participants had the right to withdraw from the experiment at any time and to contact the experimenter if they had any questions, as did the participants in the following experiments.

### 2.2. Results

#### 2.2.1. State Anxiety

An analysis of variance (ANOVA) with State Anxiety (high vs. low) as a between-subjects factor and Testing Time (pre vs. post) as a within-subject factor was conducted on the VAMS of state anxiety. No main effects emerged for State Anxiety ( $F(1, 46) = 3.060, p = 0.087, \eta^2 = 0.062$ ) or Testing Time ( $F(1, 46) = 0.162, p = 0.689, \eta^2 = 0.004$ ). However, a significant interaction of State Anxiety  $\times$  Testing Time ( $F(1, 46) = 7.358, p = 0.009, \eta^2 = 0.138$ ) was found. Independent sample  $t$ -tests revealed that the high state anxiety group scored much higher than the low state anxiety group on the posttest of state anxiety ( $t(46) = 2.870, p = 0.006, d = 0.828$ ) but not on the pretest of state anxiety ( $t(46) = -0.049, p = 0.962, d = 0.014$ ). The paired sample  $t$ -tests showed that the scores of the high state anxiety group increased significantly in the posttest ( $M_{\text{pre}} = 32.88,$

$SD_{pre} = 25.18$ ,  $M_{post} = 45.13$ ,  $SD_{post} = 27.10$ ,  $t(23) = 2.239$ ,  $p = 0.035$ ,  $d = 0.457$ ), while the scores of the low state anxiety group did not ( $M_{pre} = 33.21$ ,  $SD_{pre} = 22.32$ ,  $M_{post} = 24.13$ ,  $SD_{post} = 23.47$ ,  $t(23) = -1.608$ ,  $p = 0.121$ ,  $d = 0.328$ ). These results suggest that the state anxiety induction procedure was successful.

### 2.2.2. Retrospective Time Perception

The independent sample *t*-test revealed that for the retrospective time perception, the high state anxiety group perceived time more slowly than the low state anxiety group ( $M_{high} = 45.58$ ,  $SD_{high} = 23.21$ ,  $M_{low} = 62.46$ ,  $SD_{low} = 30.77$ ,  $t(46) = -2.145$ ,  $p = 0.037$ ,  $d = 0.619$ ).

### 2.3. Discussion

Experiment 1 preliminarily explored the influence of state anxiety on retrospective time perception and found that the high state anxiety group retrospectively perceived the duration to be slower than the low state anxiety group, and therefore, H1 is supported. Thus, the effect of state anxiety on retrospective time perception was confirmed.

## 3. Experiment 2

Experiment 2 aimed to explore the mechanism underlying the influence of state anxiety on retrospective time perception. The hypothesis to be examined is that memory bias mediates the influence of state anxiety on retrospective time perception (H2). In the experiment, the three variables related to recent life were measured directly by subjective reports and used as continuous variables for data analysis of the mediating role of memory bias on the influence of state anxiety on retrospective time perception.

### 3.1. Method

#### 3.1.1. Participants and Design

A total of 56 university students were recruited to participate in the experiment based on the available time window (35 males, 21 females,  $M_{age} = 21.66$  years,  $SD = 2.23$ ).

The independent variable is State Anxiety, the mediator is Memory Bias, and the dependent variable is Retrospective Time Perception.

#### 3.1.2. Procedure and Materials

The VAMS was adopted to measure state anxiety, memory bias and retrospective time perception.

*State anxiety measurement.* The participants were asked to rate their current subjective experience of anxiety in recent life on a bar with 0 at one end and 100 at the other. The instruction was as follows: "Please choose any number between 0 and 100 to represent the anxiety level in your recent life. Among them, 0 means very relaxed and 100 means very anxious".

*Memory bias measurement.* The participants were asked to rate their current subjective memory of recent life on a bar with 0 at one end and 100 at the other. The instruction was as follows: "Please choose any number between 0 and 100 to represent the positive / negative level of your memory of your

recent life. Among them, 0 means very negative, and 100 means very positive".

*Retrospective time perception measurement.* The participants were asked to rate their time perception for recent life on a bar with 0 at one end and 100 at the other. The instruction was as follows: "Please choose any number between 0 and 100 to represent how fast you think time has passed in your recent life. Among them, 0 means very slow, and 100 means very fast".

*Procedure.* The participants completed the subjective reports on state anxiety, memory bias and retrospective time perception in turn.

### 3.2. Results

We analyzed the mediating effect of memory bias on the relationship between state anxiety and retrospective time perception. We conducted a mediation analysis (Model 4, based on 5000 bootstrap samples) with State Anxiety (the scores of the VAMS, continuous variable) as the independent variable *X*, Retrospective Time Perception (the scores of the VAMS, continuous variable) as the dependent variable *Y*, and Memory Bias (the scores of the VAMS, continuous variable) as the mediator *M* [34].

The analyses and bootstrap results indicated that the indirect effect of State Anxiety on Retrospective Time Perception through Memory Bias was significant, with a 95% CI that excluded zero ( $Effect = -0.0727$ ,  $SE = 0.0473$ , 95% CI =  $[-0.2156, -0.0069]$ ). Furthermore, the direct effect of State Anxiety on Retrospective Time Perception was also significant when Memory Bias was included in the model ( $Effect = 0.3973$ ,  $SE = 0.1174$ ,  $p = 0.0013$ , 95% CI =  $[0.1619, 0.6327]$ ). This pattern of results indicates a competitive mediation, as per Zhao, Lynch and Chen [35]. Thus, memory bias mediates the influence of state anxiety on retrospective time perception.

### 3.3. Discussion

In Experiment 2, state anxiety, memory bias and retrospective time perception regarding recent life were measured directly by subjective reports and used as continuous variables for data analysis. The results show that memory bias mediated the influence of state anxiety on retrospective time perception, and therefore, H2 is supported.

## 4. Experiment 3

On the basis of Experiment 2, the variable of "Engagement" was introduced in Experiment 3 to investigate the moderated mediating effect. The hypothesis to be examined is that engagement moderates the mediation effect of memory bias on the influence of state anxiety on retrospective time perception (H3).

### 4.1. Method

#### 4.1.1. Participants and Design

A total of 74 university students were recruited to participate in the experiment based on the available time

window (18 males, 56 females,  $M_{\text{age}} = 23.12$  years,  $SD = 2.60$ ). The participants were randomly assigned to the high state anxiety group ( $N = 37$ ) or the low state anxiety group ( $N = 37$ ).

The independent variable is State Anxiety (high vs. low), the moderator is Engagement, the mediator is Memory Bias, and the dependent variable is Retrospective Time Perception.

#### 4.1.2. Procedure and Materials

State anxiety induction and measurement. The method was the same as in Experiment 1.

*Engagement measurement.* The VAMS was adopted to measure engagement. The participants were asked to rate their engagement in the experiment on a bar with 0 at one end and 100 at the other. The instruction was as follows: "Please choose any number between 0 and 100 to represent your engagement when describing recent or recalling past anxious (calm) experiences in this experiment. Among them, 0 means a very low level of engagement, and 100 means a very high level of engagement".

*Memory bias measurement.* Similar to Experiment 2, the participants were asked to rate their memory of the experiment on a bar with 0 at one end and 100 at the other. The instruction was as follows: "Please choose any number between 0 and 100 to represent the positive / negative level of your memory of the experiment. Among them, 0 means very negative, and 100 means very positive".

*Retrospective time perception measurement.* The verbal estimation task, a classical paradigm for retrospective time perception measurement [36], was used to prompt the participants estimate the entire duration of the experiment. The instruction was as follows: "Please estimate the time duration from the beginning of the experiment to the present in minutes, accurate to 0.1 minutes".

*Procedure.* First, baseline state anxiety was examined in a pretest. Then, both the high and low state anxiety groups were subjected to manipulations of anxiety induction and posttest state anxiety. Next, the participants completed the engagement measurement and the memory bias measurement successively. Finally, all participants were asked to estimate time retrospectively using the verbal estimation task.

## 4.2. Results

### 4.2.1. State Anxiety

Experiment 3 replicated the findings of Experiment 1. The anxiety induction procedure was also successful. Specifically, an ANOVA with State Anxiety (high vs. low) as a between-subjects factor and Testing Time (pre vs. post) as a within-subject factor was conducted on the VAMS of state anxiety. A main effect for State Anxiety ( $F(1, 72) = 8.879$ ,  $p = 0.004$ ,  $\eta^2 = 0.110$ ) but not for Testing Time ( $F(1, 72) = 0.056$ ,  $p = 0.813$ ,  $\eta^2 = 0.001$ ) was observed. Moreover, a significant interaction of State Anxiety  $\times$  Testing Time ( $F(1, 72) = 32.707$ ,  $p < 0.001$ ,  $\eta^2 = 0.312$ ) was found. Independent sample  $t$ -tests revealed that the high state anxiety group scored much higher than the low state anxiety group on the posttest of state anxiety ( $t(72) = 5.931$ ,  $p < 0.001$ ,  $d = 1.379$ ) but not on the pretest of state anxiety ( $t(72) = -0.156$ ,  $p = 0.877$ ,  $d = 0.036$ ). The paired

sample  $t$ -tests showed that the state anxiety of the high state anxiety group increased significantly in the posttest ( $M_{\text{pre}} = 32.65$ ,  $SD_{\text{pre}} = 24.90$ ,  $M_{\text{post}} = 47.89$ ,  $SD_{\text{post}} = 23.77$ ,  $t(36) = 4.249$ ,  $p < 0.001$ ,  $d = 0.699$ ), while the scores of the low state anxiety group declined significantly ( $M_{\text{pre}} = 33.54$ ,  $SD_{\text{pre}} = 24.32$ ,  $M_{\text{post}} = 19.51$ ,  $SD_{\text{post}} = 16.79$ ,  $t(36) = -3.843$ ,  $p < 0.001$ ,  $d = 0.632$ ).

### 4.2.2. Mediating Effect of Memory Bias

A mediation analysis was conducted (Model 4, based on 5000 bootstrap samples) with State Anxiety (high vs. low) as the independent variable  $X$  (the high state anxiety group was coded  $X = 0$ , and the low state anxiety group was coded  $X = 1$ ), Retrospective Time Perception (the duration estimation, continuous variable) as the dependent variable  $Y$ , and Memory Bias (the scores of the VAMS, continuous variable) as the mediator  $M$ . To exclude the effect of the real duration required for a participant to complete the experiment, the real duration was added to the model as the Covariant [34].

The bootstrap results indicated that the indirect effect of State Anxiety on Retrospective Time Perception through Memory Bias was significant, with a 95% CI that excluded zero ( $Effect = -0.9254$ ,  $SE = 0.5194$ , 95% CI =  $[-2.1980, -0.0699]$ ). Meanwhile, the direct effect of State Anxiety on Retrospective Time Perception was not significant when Memory Bias was included in the model ( $Effect = 0.9959$ ,  $SE = 0.8038$ ,  $p = 0.2195$ , 95% CI =  $[-0.6072, 2.5990]$ ). This pattern of results indicated an indirect-only mediation, as per Zhao et al. [35]. Thus, the memory bias mediated the influence of state anxiety on retrospective time perception, which was consistent with the results of Experiment 2.

### 4.2.3. Moderating Effect of Engagement

A moderation analysis was conducted (Model 1, based on 5000 bootstrap samples) with Memory Bias (the scores of the VAMS, continuous variable) as the independent variable  $X$ , Retrospective Time Perception (the duration estimation, continuous variable) as the dependent variable  $Y$ , and Engagement (the scores of the VAMS, continuous variable) as the moderator  $W$ . Similarly, the real duration was added to the model as the Covariant [34].

The bootstrap results indicated that engagement moderated the effect of memory bias on retrospective time perception ( $coeff = -0.0010$ ,  $SE = 0.0004$ ,  $p = 0.0258$ , 95% CI =  $[-0.0019, -0.0001]$ , see Figure 1). Specifically, when the scores of the VAMS for engagement were high ( $M+1SD = 88.21$ ), the effect of Memory Bias on Retrospective Time Perception was significant, with a 95% CI that excluded zero ( $Effect = -0.0427$ ,  $SE = 0.0162$ ,  $p = 0.0103$ , 95% CI =  $[-0.0749, -0.0104]$ ). When the scores of the VAMS for engagement were low ( $M-1SD = 37.28$ ), the effect of Memory Bias on Retrospective Time Perception was not significant, with a 95% CI that included zero ( $Effect = 0.0084$ ,  $SE = 0.0172$ ,  $p = 0.6260$ , 95% CI =  $[-0.0259, 0.0427]$ ). Therefore, for individuals with higher levels of engagement, those with negative memory bias ( $M-1SD = 29.29$ ) showed a slower retrospective time perception than individuals without negative memory bias ( $M+1SD = 83.68$ ); for individuals with lower levels of engagement, there was no

difference in retrospective time perception between those with and those without a negative memory bias.

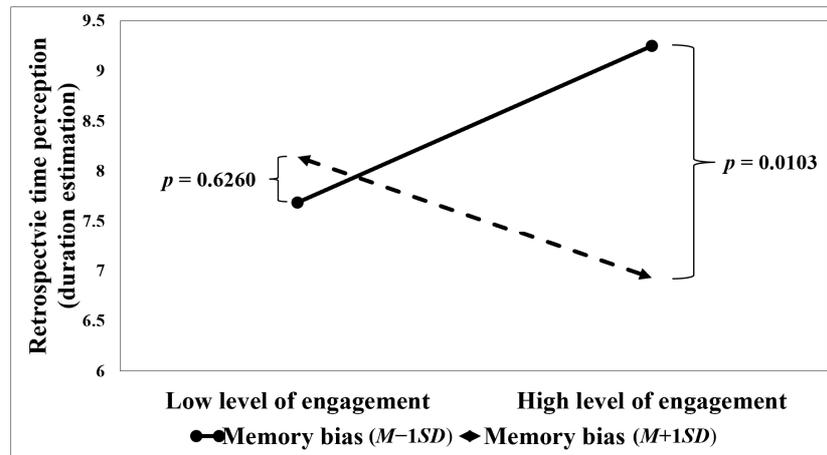


Figure 1. Moderating effect of engagement on the relationship between memory bias and retrospective time perception.

#### 4.2.4. Moderated Mediating Effect of Engagement and Memory Bias

A moderated mediation analysis was conducted (Model 14, based on 5000 bootstrap samples) with State Anxiety (high vs. low) as the independent variable  $X$  (the high state anxiety group was coded  $X = 0$ , and the low state anxiety group was coded  $X = 1$ ), Retrospective Time Perception (the duration estimation, continuous variable) as the dependent variable  $Y$ , Memory Bias (the scores of the VAMS, continuous variable) as the mediator  $M$ , and Engagement (the scores of the VAMS, continuous variable) as the moderator  $V$ . Similarly, the real duration was added to the model as the Covariant [34].

The bootstrap results indicated that engagement moderated the mediation effect of memory bias on the influence of state anxiety on retrospective time perception. Specifically, the index of moderated mediation was significant, with a 95% CI that excluded zero ( $Index = -0.0364$ ,  $SE = 0.0162$ , 95% CI =  $[-0.0707, -0.0077]$ ). The direct effect of State Anxiety on Retrospective Time Perception was not significant when Memory Bias was included in the model ( $Effect = 1.2368$ ,  $SE = 0.7855$ ,  $p = 0.1200$ , 95% CI =  $[-0.3307, 2.8043]$ ). Meanwhile, engagement moderated the effect of memory bias on retrospective time perception ( $coeff = -0.0011$ ,  $SE = 0.0004$ ,  $p = 0.0170$ , 95% CI =  $[-0.0019, -0.0002]$ ). When the scores of the VAMS for engagement were high ( $M+1SD = 88.21$ ), the indirect effect of State Anxiety on Retrospective Time Perception through Memory Bias was significant, with a 95% CI that excluded zero ( $Effect = -2.0137$ ,  $SE = 0.8174$ , 95% CI =  $[-3.8932, -0.6610]$ ). When the scores of the VAMS for engagement were low ( $M-1SD = 37.28$ ), the indirect effect of State Anxiety on Retrospective Time Perception through Memory Bias was not significant, with a 95% CI that included zero ( $Effect = -0.1610$ ,  $SE = 0.4892$ , 95% CI =  $[-1.1120, 0.8614]$ ). Therefore, for individuals with higher levels of engagement, memory bias had an indirect-only mediating role in the effect of state anxiety on retrospective time perception; for individuals with lower levels of

engagement, memory bias did not mediate the effect of state anxiety on retrospective time perception.

#### 4.3. Discussion

Experiment 3 systematically explored the relationship between state anxiety, retrospective time perception, memory bias and engagement. Experiment 3 further confirmed the mediating role of memory bias on the influence of state anxiety on retrospective time perception found in Experiment 2. More importantly, Experiment 3 found that engagement moderated the mediation effect of memory bias on the influence of state anxiety on retrospective time perception, which supports H3.

## 5. General Discussion

### 5.1. Main Findings

The central aim of the present study was to investigate the role of memory bias and engagement in how individuals retrospectively perceive time when they are in an anxious state. In Experiment 1, high and low state anxiety was successfully induced, and we then found that the high state anxious individuals retrospectively perceived time more slowly than the low state anxious individuals, and H1 is supported. In Experiment 2, state anxiety, memory bias and retrospective time perception regarding recent life were measured by subjective reports and used as continuous variables for the data analysis of the mediating role of memory bias. We found that memory bias mediates the influence of state anxiety on retrospective time perception, and therefore, H2 is supported. In Experiment 3, the relationship between state anxiety, retrospective time perception, memory bias and engagement was explored. Experiment 3 further confirmed the mediating role of memory bias in the influence of state anxiety on retrospective time perception found in Experiment 2. More importantly, the results show that engagement moderates the mediation effect of memory bias on the influence of state

anxiety on retrospective time perception, and thus, H3 is supported.

Overall, we found that high state anxious individuals subjectively experience a retrospective duration as proceeding more slowly than low state anxious individuals. In addition, we found that memory bias mediates the influence of state anxiety on retrospective time perception. More importantly, we further found that engagement moderates the mediation effect of memory bias.

### **5.2. Influence of State Anxiety on Retrospective Time Perception**

We found that high state anxious individuals retrospectively perceive time more slowly than low state anxious individuals, which is consistent with the findings of previous research on anxiety and prospective time perception [11, 12, 23, 24, 37]. Our study is the first to systematically explore how state anxiety affects retrospective time perception, which fills the gap in the literature on the consequences of anxiety, especially state anxiety, in retrospective timing. Hopefully, our findings will provide a reference for future related research.

### **5.3. The Mediating Role of Memory Bias**

We demonstrated that memory bias mediates the influence of state anxiety on retrospective time perception, which reveals the mechanism underlying the effect of state anxiety on retrospective timing. In particular, high state anxiety is more likely to activate individuals' negative memory bias, which in turn leads to slower retrospective time perceptions.

In addition, this finding provides direct empirical support for the contextual-change model [26, 27]. As mentioned above, the contextual-change model states that changes in the environment and cognitive strategies or emotional states are codable background changes in memory, which may in turn lead to changes in retrospective timing. Although the contextual-change model was adopted by some previous researchers to interpret their own research findings, others have even attempted to validate the model using indirect methods, such as varied difficulty or familiarity of experimental tasks [13]. In fact, research on memory and retrospective timing faces a critical challenge. That is, how to test the role of memory directly allocated to timing [38]. Our study attempted to solve this difficult problem by measuring the memory bias of anxious individuals directly. We found that high state anxious individuals show more negative memory bias (i.e., perceived more contextual changes), which in turn leads them to perceive time more slowly than low state anxious individuals.

### **5.4. The Moderated Mediating Role of Engagement**

We found that engagement moderates the mediation effect of memory bias on the influence of state anxiety on retrospective time perception. The levels of individuals' engagement have an important impact on the allocation of cognitive resources [31, 32]. The more cognitive resources

were allocated to experimental tasks, the more memory resources were allocated to the process through which state anxiety affects retrospective timing. In the present study, individuals with higher levels of engagement allocated more memory resources to the experiment, which is probably the reason for the complete mediating effect of memory bias. In this sense, state anxiety affects retrospective time perception only through memory bias and only for high engagement individuals. For individuals with lower levels of engagement, fewer memory resources were allocated to the experiment; therefore, memory bias does not mediate the relationship between state anxiety and retrospective time perception. Indeed, there is a lack of research on how engagement plays a role in the influence of anxiety on retrospective timing in the relevant literature. Hopefully, our study provides new insight in this field by introducing engagement to moderate the mediation of memory bias in the relationship between state anxiety and retrospective timing.

### **5.5. Implications and Future Research Trends**

We reported the internal process of retrospective time perception of individuals in an anxious state and demonstrated the critical role of engagement and memory bias in the process. In terms of theoretical implications, our study introduces a new paradigm for research on memory in time perception, namely, the direct measurement of memory bias. This method comes from the study of cognitive characteristics of anxious patients or depressed patients [30]. By introducing this innovative method, our study provides direct empirical support for the contextual-change model [26, 27].

Regarding practical implications, our study is the first to describe and interpret retrospective timing when individuals are in an anxious state in real life. Time distortion is a very common phenomenon in our daily life; sometimes, individuals need to estimate time prospectively, and other times, they need to estimate time retrospectively. However, previous studies have focused on only prospective timing [11, 12, 23, 24], and almost no studies have been conducted on retrospective timing. In this regard, our study serves as a step forward in understanding how individuals retrospectively perceive time when they are anxious.

Regarding clinical implications, our study provides a reference for the treatment of anxious individuals' time distortions. Our study interpreted the internal mechanism by which anxiety affects retrospective time perception distortion, which we think can be helpful for understanding the causes of the time perception distortions of anxious individuals. Furthermore, the mediating role of memory bias may suggest some new treatments for improving the accurate time perception of anxious individuals via correcting memory bias.

Future research can be carried out in the following areas. First, although several paradigms and designs were used in the present study to explore the relationship between state anxiety and retrospective time perception, as well as the moderated mediating effect of engagement and memory bias, more divergent methods can be adopted to verify the stability of the results in future studies. Second, our study focused on

the effect of state anxiety on retrospective time perception and the role of engagement and memory bias underlying the effect. Although state anxiety is more common than anxiety disorders in our daily life, future studies may further examine the moderated mediating model found in the present study from the perspectives of different anxiety samples with trait anxiety and other anxiety disorders.

## 6. Conclusion

The results suggested that (1) high state anxious individuals subjectively experienced a retrospective duration as proceeding more slowly than low state anxious individuals, (2) memory bias mediated the influence of state anxiety on retrospective time perception, and (3) engagement moderated the mediation effect of memory bias. The present study provides evidence suggesting that high state anxious individuals subjectively experience a retrospective duration as proceeding more slowly than low state anxious individuals, memory bias mediates the influence of state anxiety on retrospective time perception, and engagement moderates the mediation effect of memory bias. Our research contributes to the understanding of the roles that engagement and memory bias play in how individuals retrospectively perceive time when they are in an anxious state.

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