

## The afterthought phenomenon in stress: impacts of retrospective appraisal on stress responses

**Authors:** Chen, Hongyu, Wang, Peishan, Wang, Xiaoyu, Zhan, Lei, Sun, Xi-anhong, Huang, Zheng, Zhang, Liang, Zhang, Liang

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### Abstract

**Background:** While psychosocial stressors trigger neuroendocrine responses and affect task performance, many studies overlook the dynamic nature of the stress appraisal process. **Goal:** This study aims to explore whether subjective appraisals at various time points can interpret individual stress responses, both behaviorally and physiologically, using controlled laboratory conditions. **Methods:** A total of 137 effective participants were recruited to induce individual stress states using the Trier Social stress Test (TSST). Subjective appraisals were measured both before (anticipatory appraisal) and after the stressor (retrospective appraisal). Concurrently, participants' cortisol responses and task performances were documented. **Results:** Findings indicate that anticipatory appraisal doesn't significantly impact task performance, whereas retrospective appraisal markedly affects performance of the corresponding tasks. Regarding cortisol levels, multivariate regression analysis revealed that only the retrospective appraisal of the speech task accounted for the observed variance in cortisol response under stress. **Discussion:** The data suggests that retrospective appraisals are more indicative of behavioral and physiological responses to psychosocial stressors than anticipatory appraisals. These findings lend empirical support to refining the biopsychosocial model and underscore the utility of retrospective appraisal in capturing individual stress response variations.

### Full Text

#### Preamble

#### The “Afterthought” Phenomenon in Stress: Impacts of Retrospective Appraisal on Stress Responses

Hongyu Chena,b,1, Peishan Wanga,b, Xiaoyu Wanga,b, Lei Zhana,b,2, Xianghong Suna,b, Zheng Huanga,b, Liang Zhanga,b,\*

aKey Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China

bDepartment of Psychology, University of Chinese Academy of Sciences, Beijing, China

1 <https://orcid.org/0009-0007-1219-0146>

2 <https://orcid.org/0000-0003-0470-3160>

**Correspondence:**

Liang Zhang, Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China.

Email: [zhangl@psych.ac.cn](mailto:zhangl@psych.ac.cn)

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**Keywords:** stress, retrospective appraisal, behavioral performance, cortisol response

## Introduction

All organisms inherently strive to maintain a state of homeodynamic balance, also known as dynamic homeostasis. This balance is vital when faced with disruptions from various factors in both their internal and external environments (Agorastos & Chrousos, 2022; Chrousos, 1995; Nicolaides et al., 2014). In order to sustain homeostasis, organisms have evolved intricate systems to respond to both physical and psychological stressors (Chrousos, 2009; von Dawans et al., 2021). Compared to the autonomic nervous system (ANS), which addresses stressors rapidly, the hypothalamus-pituitary-adrenocortical (HPA) axis offers a slower response to stress, mainly through the secretion of glucocorticoids such as cortisol in humans (Chrousos, 2009; Lin et al., 2021). A wealth of research indicates that maladaptive stress responses can be linked to an array of mental and physical disorders, including anxiety, depression, and various cardiovascular diseases (Cohen et al., 2007). Therefore, understanding the human stress response is of primary importance.

It is crucial to recognize that stress is not merely a generic blend of physiological and psychological reactions triggered by stimuli. Indeed, even when confronted with an identical stressor, different individuals can exhibit varying responses (Kirschbaum et al., 1999; Sapolsky, 2015). To elucidate the nuances of these stress responses, Lazarus and Folkman (1984) introduced the Transactional Theory of Stress. This theory posits an essential appraisal process that mediates between the stressor and the subsequent response. It is the individual's assessment of demands and resources that ultimately determines their reaction to the stressor. More precisely, this cognitive appraisal process can be broken down into two stages: primary appraisal, which assesses the potential significance or implications of the stressor, and secondary appraisal, which steers individuals toward identifying the most effective coping strategies (Bityutskaya & Korneev, n.d.; Carpenter, 2016; Folkman et al., 1986; Lazarus & Folkman, 1984).

Subjective appraisal plays a pivotal role in modulating the stress response, with its influence evident not just in behavioral outcomes but also in physiological reactions. A substantial body of research has delved into the repercussions of appraisal on task performance. Findings reveal that, whether in competitive scenarios like athletic competitions (Calmeiro et al., 2014) or in socially evaluative situations such as public speaking (Lyons & Schneider, 2005), individuals who perceive their resources to exceed task demands consistently outperform those who assess their resources as insufficient. Furthermore, the contents of subjective appraisal also shape neuroendocrine responses, as exemplified by variations in cortisol secretion in response to stressors (Olf et al., 2005; Pulpulos et al., 2020; Qusted et al., 2011).

When discussing appraisal, it is commonplace to measure the outcome at a singular time point. However, it is essential to understand that the appraisal process is dynamic, suggesting that individuals might recalibrate their appraisal outcomes throughout the stress experience (Eschleman et al., 2012). Specifically,

initial primary and secondary appraisal outcomes can shape the coping strategies individuals employ to deal with the stressor. As these strategies manifest in behavioral and physiological responses, they alter the individual's environment, which in turn influences subsequent appraisals. This dynamic nature complicates pinpointing a specific moment when appraisal accurately represents the entirety of the process and its relationship with stress responses.

Categorizing appraisals based on their timing can help clarify this complexity. One approach distinguishes between anticipatory appraisal, which precedes the stressor, and retrospective appraisal, which follows it. Anticipatory appraisal is rooted in an individual's internal schema, heavily intertwined with cognitive processes. This schema frames how individuals interpret their environment, formulating expectations of imminent stressors and thus priming them to anticipate specific outcomes (Riegler, 2001). An individual's foresight regarding a stressor and their self-assessed coping ability can guide the allocation of cognitive resources during preparatory phases, allowing for strategic adjustment of coping mechanisms (De Raedt & Hooley, 2016). Conversely, retrospective appraisal, conducted post-stressor, encapsulates an individual's reflection on past events (Pitts et al., 2018), often aligning with personal recollections of the stressor (Lomeli, 2015). However, memories can be reshaped by emotional input, making emotions a pivotal determinant in retrospective appraisal (Schmidt, 2004). A study by Folkman and Lazarus (1985) segmented appraisals into three phases surrounding a midterm examination: anticipation (pre-exam), waiting (post-exam, pre-results), and outcome (post-exam, post-results). Their findings indicated that anticipatory appraisals were problem-focused, leveraging cognitive components to evaluate upcoming stressors and informing preparatory actions. In contrast, during the waiting and outcome stages, the focus shifted to evaluating the significance of the past stressor and interpreting results. With outcomes fixed and unchangeable, problem-focused coping reduced, supplanted by emotion-focused coping strategies.

In essence, while anticipatory appraisal invokes an active, cognition-driven state, retrospective appraisal is more passive and emotion-oriented.

Currently, there is limited literature examining the distinctions between anticipatory and retrospective appraisal. One notable study in this realm was undertaken by Gaab and colleagues (2005). They enlisted 81 healthy young male participants and gauged both anticipatory and retrospective appraisal before and after administering the Trier Social Stress Test (TSST). Their findings underscored the significant role of anticipatory appraisal in determining cortisol response to stress. However, the study's exclusive focus on males and lack of task-specific appraisal for the TSST might have introduced ambiguities in the outcomes, potentially leading to misleading findings such as the attenuated importance of retrospective appraisal.

Building on these findings, our study aims to delineate the influence of subjective appraisal at different junctures on individuals' stress responses, both physiologically and behaviorally. We induced a stress state using the widely recognized

psychosocial stress task, the TSST, and captured subjective appraisal both pre-stressor (anticipatory) and post-stressor (retrospective). Our primary objective was to ascertain whether retrospective appraisal serves as a credible predictor of observed behavioral and physiological stress responses, as per our hypothesis. By addressing these inquiries, we aim to furnish more robust evidence, enriching our understanding and thereby contributing to a comprehensive biopsychosocial framework.

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## Method

### Participants

Based on existing research (Lin et al., 2022; Wang et al., 2021), the following exclusion criteria were applied during participant recruitment to minimize potential confounding factors: (1) taking any drugs within two weeks prior to the experiment; (2) a history of neuroendocrine disease or long-term use of related medications; (3) presence of severe chronic physical or mental diseases; (4) significantly disrupted circadian rhythms or chronic engagement in night shifts; (5) heavy drinking or smoking within two weeks of participating in the experiment; (6) having oral wounds or other oral diseases; (7) pregnant females or those taking hormonal contraceptives. Female participants were asked to avoid their menstrual phase on the day of the experiment.

Based on a prior sample size calculation with G\*Power 3.1, at least 68 participants were needed for a linear multiple regression analysis with  $f^2 = 0.3$  (Lin et al., 2021), six predictors, power  $(1-\beta) = 0.95$ , and  $\alpha = 0.05$ . To obtain a valid dataset, a total of 137 participants were recruited through online screening, all of whom were right-handed and had normal or corrected vision. Seventeen participants were excluded from analysis for the following reasons: seven participants withdrew from the experiment with missing data; cortisol samples from four participants did not meet quality criteria for analysis; and data recording errors occurred for six participants. Ultimately, 120 valid datasets were retained for analysis, including 62 males (51.7%). The average age of participants was 22.40 years ( $SD = 2.50$ ), with a range of 17-28 years. The mean BMI was  $21.28 \pm 2.62$ . All participants provided informed consent before participation and received monetary compensation. The study was approved by the ethics committee of the Institute of Psychology, Chinese Academy of Sciences.

### Materials

**Experimental Self-Report Measures Anticipatory Appraisal.** In this experiment, the Primary Appraisal Secondary Appraisal (PASA) scale was used to measure individuals' anticipatory cognitive appraisal before completing a stressful task. The PASA scale was developed based on the cognitive appraisal theory proposed by Lazarus and Folkman (1984) and further refined by Gaab

and colleagues (2005). The scale assesses two sub-processes of cognitive appraisal: primary appraisal (PA) and secondary appraisal (SA).

The PA scale includes the dimension of ‘threat’ (e.g., “I do not feel worried because the situation does not represent any threat for me”) and the dimension of ‘challenge’ (e.g., “This task challenges me”), while the SA scale consists of two dimensions: ‘self-concept of own abilities’ (e.g., “In this situation, I know what I can do”) and ‘control expectancy’ (e.g., “It mainly depends on me whether the experts judge me positively”). Each dimension includes four items that measure self-reported appraisal outcomes, comprising a total of 16 items in the PASA scale. Participants rated each item on a scale from 1 to 6 based on their current feelings (1 = “Strongly disagree”; 6 = “Strongly agree”).

The PASA results were computed as the difference between the mean value of SA and the mean value of PA. A higher resultant value signifies stronger conviction among individuals who believe their ability is sufficient to cope with task demands. The internal consistency of PASA, as represented by Cronbach’s  $\alpha$ , ranges from 0.63 to 0.83, indicating reasonable ( $> 0.60$ ) to good ( $> 0.80$ ) consistency (Gaab et al., 2005). Based on the data obtained in this study, Cronbach’s  $\alpha$  ranged from 0.68 to 0.78, thereby substantiating good internal consistency of the PASA assessment.

**Retrospective Appraisal.** Drawing from relevant literature, Visual Analogue Scales (VAS) were used to measure levels of threat, challenge, self-concept, and perceived control following completion of a stressful task (Crichton, 2001; Gaab et al., 2005; Kirschbaum et al., 1999). Since participants were subjected to two distinct tasks designed to induce stress, the VAS was administered twice to assess the effects of each task (i.e., speech task and calculation task) separately. The dimensions of ‘threat’ (e.g., “The stress level I felt during the speech/calculation task”) and ‘challenge’ (e.g., “The level of challenge of the former speech/calculation task”) constitute primary appraisal (PA), while secondary appraisal (SA) comprises ‘self-concept’ (e.g., “The ability I displayed in the former speech/calculation task”) and ‘perceived control’ (e.g., “The level of control of the results of the speech/calculation task I perceived”). Participants rated each item on a scale from 0 to 10 (0 = completely inconsistent, 10 = completely consistent).

Similarly, the VAS index was derived from scale results (overall appraisal = SA - PA). Cronbach’s  $\alpha$  for each sub-dimension of VAS was calculated based on the data obtained in this study. The results showed that the scale exhibits good internal consistency, with  $\alpha$  values ranging from 0.828 to 0.924.

**Experimental Biochemical Measures** Saliva samples were collected using Salivette collection tubes (Sarstedt, Rommelsdorf, Germany). During collection, participants placed a sterile cotton strip beneath their tongue for 1-2 minutes until saturated with saliva. Following collection and labeling, saliva samples were stored at  $-22^{\circ}\text{C}$  for subsequent biochemical analysis. Cortisol concentra-

tions were measured utilizing the Roche Cortisol Test Kit II (Cortisol II, Roche Diagnostics, Numbrecht, Germany). The lowest sensitivity for cortisol is 1.5 nmol/L, with an allowable inter-assay variation of less than 12.7% and intra-assay variation of less than 7.1%. The area under the response curve with respect to increase (AUC<sub>i</sub>) was calculated, serving as an indicator of integrated cortisol response. This index represents participants' physiological state during the stressful task.

**Psychosocial Stress Test** The Trier Social Stress Test (TSST) paradigm, developed by Kirschbaum et al. (1993), has been extensively utilized in laboratory studies investigating acute stress (Birkett, 2011; Kudielka et al., 2007; Reschke-Hernández et al., 2017). Meta-analyses have found that TSST can elicit significant responses in the hypothalamus-pituitary-adrenal (HPA) axis, inducing stable and relatively lasting cortisol responses (Allen et al., 2014; Dickerson & Kemeny, 2002, 2004; Kudielka et al., 2004, 2007). Existing studies also demonstrate that the TSST paradigm possesses high validity among Chinese participants (Lin et al., 2021; Lei, 2021). Consequently, TSST was chosen as the task to induce participants' stress state. TSST comprises three phases: preparation (5 min), public speech task (5 min), and mental calculation task (5 min), for a total of 15 minutes.

During the preparation phase, the experimenter introduced task requirements to participants in the preparation room. Participants were instructed to imagine being accused of shoplifting by a security guard in a supermarket and had to defend themselves in front of several supermarket managers. These managers would evaluate participants' speech performance, and the entire process would be video-recorded for subsequent expert review. Participants could use pen and paper for note-taking during preparation but had to deliver their speech without any prompts.

In the speech phase, participants were led to the speech room and delivered a 5-minute speech in front of three unfamiliar experimenters ( 'managers' ). Throughout this process, experimenters provided no task-related feedback and scored participants' performance based on 'eye contact', 'voice quality', 'speech fluency', and 'speech comfort'. The 'integral stress level' scores served as an indicator of speech performance.

Subsequently, the experimenter instructed participants to complete a 5-minute mental calculation task, requiring them to continuously subtract 13 from 1022 and verbally report each result. If participants made any error, they had to stop and restart the task. The lowest number achieved was recorded, and the difference between baseline and TSST performance served as an indicator for calculation task performance.

## Procedure

During recruitment, baseline performance on the calculation task was measured via computer without time pressure or other stressors present in the formal experiment. Demographic information was also collected during recruitment.

To minimize the effect of circadian rhythm on cortisol, all participants completed the experiment between 2:00 PM and 5:00 PM (Kirschbaum et al., 1993; Reschke-Hernández et al., 2017; Wang et al., 2021). To prevent dilution of cortisol levels in saliva, participants were not permitted to eat or drink once the experiment commenced. The experimental procedure is shown in Fig. 1 [Figure 1: see original paper].

Participants initially entered an isolated laboratory and completed a 30-minute acclimation period, during which they were provided with magazines to read and completed informed consent forms. Following acclimation, baseline salivary cortisol samples (TB) were collected. Participants then entered the preparation room to prepare for the speech task after confirming their understanding of task requirements. They also completed the PASA questionnaire to provide anticipatory appraisals for the upcoming speech task.

Upon conclusion of the preparation period, participants were led into the speech room and completed the TSST. Immediately afterward, the experimenter guided participants back to the preparation room (less than a 30-second walk) to collect salivary cortisol measurements and complete VAS at Time 0-minute (T0). Two separate VAS assessments were conducted for retrospective appraisal of the speech and calculation tasks. Participants continued to rest in the preparation room, and salivary cortisol measurements were obtained at 5, 10, 15, 20, 30, 40, 50, and 60 minutes (T5, T10, T15, T20, T30, T40, T50, and T60) (Kirschbaum et al., 1993; Lin et al., 2022; Wang et al., 2021).

## Data Analysis

Initially, a one-way repeated measures ANOVA of salivary cortisol data was performed to verify whether the stress paradigm effectively induced participants' stress response (Lin et al., 2021; Vijayan et al., 2010). Subsequently, relationships between subjective appraisal and behavioral and physiological responses were examined through a series of multivariate linear regression analyses: (1) speech and calculation task performance as outcome variables; (2) cortisol response (AUC<sub>i</sub>) as the outcome variable. Independent variables included appraisal results for different tasks at various time points. Gender and age were incorporated as control variables in the performance models, while age, BMI, and menstrual cycle phase for female participants were also controlled in the cortisol response model.

Statistical analysis was conducted using SPSS 25.0. All reported p-values were two-tailed with significance level set at 0.05.

## Results

### Verification of Paradigm Validity

A one-way repeated measures ANOVA was conducted using cortisol levels as the within-subjects variable. Results showed a significant main effect of the within-subjects factor ( $F(9, 1071) = 121.39, p < 0.001, \text{partial } \eta^2 = 0.51$ ), and the variation trend of cortisol can be observed in Fig. 2 [Figure 2: see original paper].

Post-hoc analysis revealed that cortisol concentrations significantly increased from baseline ( $5.09 \pm 2.65$  nmol/L) to immediately after TSST ( $7.89 \pm 4.27$  nmol/L), 5 minutes after TSST ( $10.44 \pm 5.73$  nmol/L), and 10 minutes after TSST ( $12.32 \pm 7.05$  nmol/L), with each time point showing significantly higher cortisol levels than the previous one. Cortisol concentration reached its peak value 10 minutes after the TSST and subsequently began to decline. Further analysis revealed no significant difference between baseline and the end of the measurement period ( $t(119) = 0.25, p = 0.80$ ).

### Regression Analysis

To explore relationships between subjective appraisal at different time points and participants' stress responses, multivariate linear regression analyses were conducted to examine potential associations between variables.

**Subjective Appraisal and Task Performance** We conducted two multivariate regression models to explore relationships between subjective appraisals and stressful task performance. Models were controlled for age and gender, with results displayed in Table 1. Anticipatory appraisals did not significantly predict performance on either the speech or calculation tasks ( $p > 0.05$ ).

In contrast, retrospective appraisals of the speech task significantly accounted for variance in speech performance ( $\beta = 0.301, t = 2.893, p = 0.005$ ), while retrospective appraisals of the calculation task significantly accounted for variance in calculation performance ( $\beta = 0.413, t = 4.438, p < 0.001$ ).

**Subjective Appraisal and Physiological Response** According to existing studies, we included age, BMI, and menstrual cycle phase of female participants as control variables in the multivariate regression model. Results showed that retrospective appraisals of the speech task significantly accounted for variance in integrated cortisol response regarding increase ( $\beta = -0.217, t = -1.988, p = 0.049$ ). Results are presented in Table 2.

## Discussion

In our study, we recruited 137 healthy college students to explore whether subjective appraisals at various time points serve as valid indicators of stress responses, both behaviorally and physiologically. Results demonstrated that the TSST, as implemented in our study, effectively elicited an acute stress response in participants, as indicated by cortisol concentration levels. The retrospective appraisal of the speech task was a significant contributor to reactive performance on the same task. Similarly, the retrospective appraisal of the calculation task substantially explained variance in performance for that task. Conversely, anticipatory appraisals did not correlate with performance on either the speech or calculation tasks.

Moreover, regression analyses revealed that the retrospective appraisal of the speech task significantly accounted for differences observed in cortisol stress responses. These results support our hypothesis that retrospective appraisal is a primary determinant of an individual's stress response.

The primary finding of our study is that retrospective appraisal, rather than anticipatory appraisal, holds central correlation with stress response. To understand this result, it is essential to delineate the distinction between these concepts. Appraisal results do not remain constant during the stress process; individuals may alter their subjective appraisals following the stress experience. Consequently, it is imperative to investigate anticipatory and retrospective appraisals distinctly.

From an emotional standpoint, experimental results from Folkman and Lazarus (1985) highlight that the emotion component is more prominent in retrospective appraisal than in anticipatory appraisal. This emotional component significantly correlates with individuals' responses to external stimuli. Supporting this, Barrett's (1998) dimensional emotion theory posits that the arousal dimension of emotion aligns closely with the concept of action readiness. This suggests that appropriate emotional responses prepare individuals more adeptly to adapt to external stimuli, optimizing attainment of their objectives (Laborde, 2016; Lench et al., 2011).

Further focusing on stress, Smith and Lazarus (1990) emphasized the intrinsic link between emotion and stress response, positing that one's emotional state offers profound insights into potential behaviors when confronted with stressors. Beyond theoretical evidence, empirical research by Ashkanasy and colleagues (2003) in workplace settings ascertained that stress-related emotions mediate the influence of workplace stressors on both individual and organizational performance, further underscoring the emotion-stress response connection.

Given that anticipatory appraisals aim for enhanced allocation of cognitive resources and retrospective appraisals seek to provide superior explanations of current outcomes, it is evident that anticipatory appraisals possess a more substantial cognitive component than retrospective appraisals. However, during

anticipatory appraisal, which demands precise information to bolster cognitive processing, individuals often lack comprehensive details about the stressor and available resources. In contrast, after directly experiencing a stressful task, individuals gain a clearer understanding, culminating in the biopsychosocial model where subjective appraisals (from a retrospective standpoint) and physiological responses harmonize. Furthermore, while cognition is anticipated to formulate superior strategies against subsequent stressors, many studies, including those by Kusev and colleagues (2017), assert that behavioral influences predominantly stem from emotions rather than cognitive evaluations.

Moreover, from a physiological perspective, compelling evidence indicates that retrospective appraisal and HPA axis activation share overlapping anatomical structures. Research across both animal models (Radley et al., 2006) and human studies (Urry et al., 2006) has demonstrated that the prefrontal cortex (PFC) plays a pivotal role in modulating the stress response of the HPA axis (Lopez et al., 2018). Concurrently, the PFC has been recognized as playing a significant role in retrospective appraisal. A meta-analysis by Buhle et al. (2014) indicated that the reappraisal process, which occurs following stressor onset, is associated with activation of both the dorsolateral prefrontal cortex (DLPFC) and ventrolateral prefrontal cortex (VLPFC). Importantly, these areas show partial overlap with brain regions involved in HPA activation. Furthermore, retrospective appraisal can influence activity in the bilateral amygdala, a critical structure given that the amygdala serves as the intermediary through which the PFC affects the HPA axis (Buhle et al., 2014; Lopez et al., 2018).

Furthermore, our results revealed that only the retrospective appraisal of the speech task accounted for variance in cortisol levels. Al' Absi et al. (1997) discovered that while both speech and calculation tasks elicited significant endocrine responses, the speech task led to more pronounced changes in cortisol concentration compared to the calculation task. This observation was corroborated in subsequent studies (Al' Absi et al., 2002). In essence, the speech task emerges as the primary stressor influencing individuals' cortisol responses.

Our findings highlight that only task-specific appraisal outcomes account for variance in targeted task performance. Broadly speaking, planning related to actions and alignment between intended and actual plan implementation hinge largely on individual task-specific appraisals (Niemi-virta, 2002). While there is limited research in this domain, an empirical study by Tanaka (2007) identified a substantial impact of task-specific appraisal on individual task performance. Extending this understanding, other studies have posited that self-reported appraisal results tied to specific tasks or challenges (e.g., self-efficacy) are more indicative of individual problem-solving performance than those based on broader domains (Bandura et al., 1999; Pajares & Miller, 1995).

Several limitations of this research warrant mention, and future experiments should address these outstanding questions. Firstly, when constructing the biopsychosocial model, cortisol was the sole physiological index we evaluated. While cortisol is a key marker, numerous physiological indicators can delin-

evaluate an individual's stress response (Blascovich et al., 2004; Vine et al., 2013). Subsequent research could incorporate a broader range of indicators to enrich the biopsychosocial model. Secondly, while the laboratory-based acute stress paradigm (TSST) effectively induces individual stress responses, it diverges from stress scenarios individuals face in real-world operational contexts. To enhance real-world applicability of our findings, experiments conducted in actual workplace settings would be valuable.

To conclude, our research provides a nuanced understanding of how subjective appraisal at varying timeframes correlates with behavioral and physiological responses in stress contexts. Unlike many studies that assess stress at a singular point in time, our innovative approach captures the dynamic evaluation process of stress both before and after the stress event. By focusing on cortisol as a physiological indicator and delving into the roles of anticipatory and retrospective appraisal, this study illuminates the complexities of stress reactions. Notably, our findings underscore the prominent role of retrospective appraisal in understanding variations in stress responses, challenging some traditional views in the biopsychosocial model. This not only enhances our comprehension of individual stress mechanisms but also reaffirms the importance of context-specific appraisals in psychological research on stress.

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## Conflict of Interest

The authors have no conflict of interest to disclose.

## Data Availability Statement

The raw data and analysis codes of this research are available from the corresponding author, Dr. Liang Zhang, upon reasonable request.

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