ABSTRACT

The present study examined how different types of stress influenced students' reading comprehension by manipulating time pressure and appraisal framing. Time pressure was manipulated by varying the amount of time available to complete reading tasks, while appraisal framing altered how participants interpreted stress (reappraisal, neutral, evaluation threat). The study also compared native (L1) and non-native (L2) English readers.

Participants completed reading comprehension tasks based on the Nelson-Denny Reading Test while their eye movements were recorded to assess reading efficiency.

Results showed that native participants demonstrated higher reading accuracy than non-native participants, and time pressure significantly reduced accuracy. Importantly, an interaction between time pressure and appraisal framing revealed that time pressure impaired accuracy in the neutral and threat conditions but not in the reappraisal condition, suggesting a buffering effect of reappraisal.

For reading efficiency, non-native participants exhibited longer fixation durations, gaze durations, and total reading times than native participants. Time pressure reduced total reading time for both groups, with a stronger effect for non-native participants. Notably, appraisal framing influenced processing efficiency, such that reappraisal reduced processing time and the difference between native and non-native participants.

Overall, these findings suggest that stress can be either harmful or beneficial, depending on how it is interpreted, and highlight the potential of reappraisal to mitigate the negative effects of stress on reading performance.

Eustress or Distress? The Interactive Effects of Time Pressure and Appraisal Framing on Reading Comprehension Among L1 and L2 Readers

by

Ran Jing

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INTRODUCTION

When your heart rate speeds up, your blood pressure rises, and your body prepares for a fight-or-flight response —do not worry, this is a normal reaction under stress. In a strict sense, stress is not an illness but a natural physiological and psychological mechanism. However, in recent years, negative reports about stress have become increasingly prominent, as it has become more common in daily life. For example, Gallup News (2021) reported that approximately 40% of adults around the world have experienced severe stress or worry. Furthermore, the American Psychological Association (Bethune, 2022) also noted that more than three-quarters of adults in the United States reported symptoms related to stress, with nearly half stating that stress had a negative impact on their daily behavior.

Among students, health and academic performance are also affected by stress. For example, in an observational study of 456 German undergraduate medical students, higher perceived academic-related stress was found to predict poorer academic performance (Kötter et al. 2017). These results are consistent with the findings of Khan et al. (2013), who found that, particularly among younger and less experienced students, higher levels of perceived stress were reported, which in turn negatively affected their performance. Similarly, Hudd et al. (2000) found that students with higher levels of stress are more prone to engage in poorer health habits, such as poor diet, unstable sleep patterns, and have increased levels of stress-related illness, like a heart attack. Taken together, these reports indicate that stress has become a global public health challenge that cannot be ignored.

However, not all stress is harmful. In a study of health profession students, Monk (2004) found that although many students reported severe psychological distress, some of them nevertheless achieved outstanding academic results. In fact, several students with high levels of psychiatric symptoms performed exceptionally well in their final examinations. Monk suggested that this paradoxical finding could be explained by theories of activation and arousal (Duffy, 1962; Yerkes & Dodson, 1908), which propose that a certain level of stress may act as a positive motivator, enhancing performance under pressure.

While too much stress often leads to distraction and lower overall performance, a moderate level can increase motivation and focus on difficult tasks (Wunsch et al., 2019). This difference between eustress and distress shows that the effect of stress depends not only on its intensity but also on how people think about it (Jamieson et al., 2012). Importantly, research on foreign language (L2) reading suggests that stress can impair comprehension by consuming limited working memory resources. This effect may be especially pronounced for L2 readers due to their higher cognitive processing demands (Rai et al., 2011).

Therefore, building on these ideas, this study explores how time pressure and appraisal framing jointly influence reading comprehension in both L1 and L2 readers. By comparing these two groups, the study aims to examine whether stress responses differentially affect reading performance depending on language background.

LITERATURE REVIEW

Activation Theory

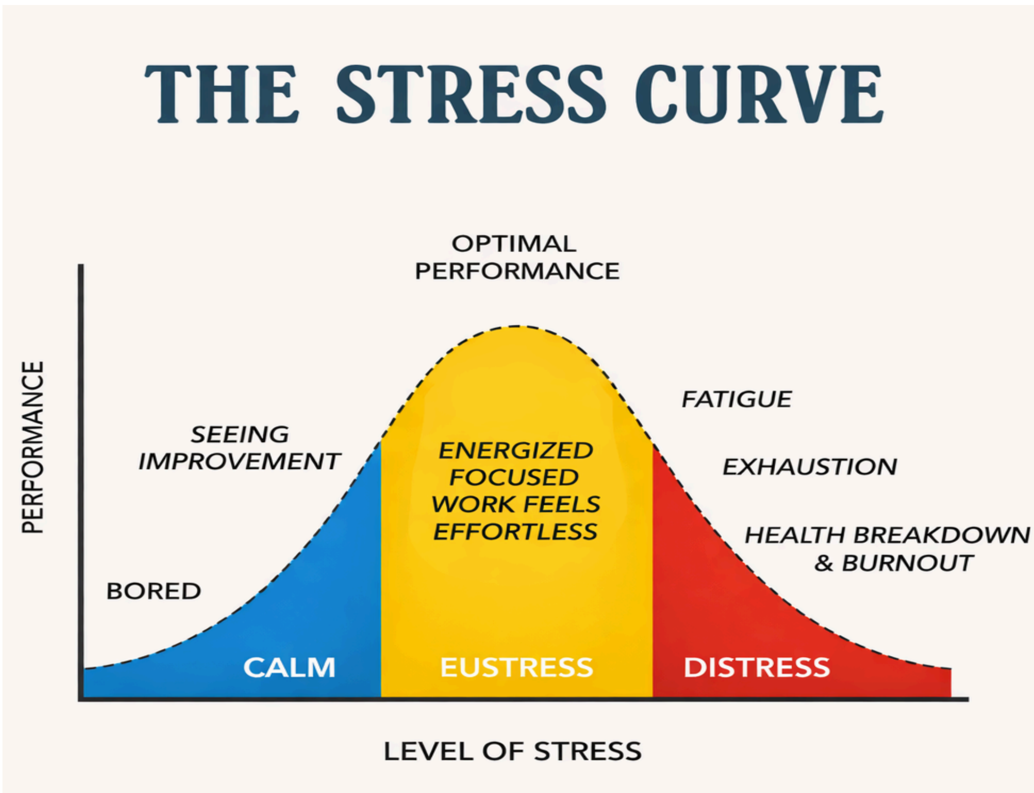
According to the Yerkes–Dodson law (1908), stress level has a curvilinear, inverted U-shaped relationship with performance. When an individual experiences either low arousal or excessive arousal, performance tends to decrease. In contrast, when arousal reaches a moderate and optimal level that corresponds to the peak of the inverted U, performance is maximized.

Selye (1956) further distinguished between eustress, a motivating and adaptive form of stress, and distress, a harmful and maladaptive form. Within this framework, the optimal level of arousal described by Yerkes and Dodson can be understood as eustress, which may enhance efficiency and concentration, thereby promoting better performance. In contrast, excessive arousal can be conceptualized as distress, which may impair attention and cognitive functioning, ultimately reducing performance (Yerkes et al., 1908). As illustrated in Figure 1, performance increases with moderate levels of arousal but declines when arousal is either too low or excessively high.

Building on this idea, Duffy's (1962) activation theory further suggests that the effect of stress on performance depends on the level of physiological arousal. Moderate stress can help people focus and stay engaged. However, an excess of stress can overload the mind, impairing attention and working memory (Eysenck et al., 2007). Studies have shown that stress can disrupt working memory and explicit memory, especially when the task is complex (Luethi et al., 2009). Reviews also indicate that stress, especially excessive and chronic stress, can impact academic performance by biologically altering the brain systems that support working memory and executive function and by causing cognitive overload by increasing negative thoughts, impairing sleep, and harming emotional regulation (Almarzouki, 2024).

Figure 1

Activation Theory and the Inverted U-Shaped Relationship Between Stress and Performance.



Cognitive Reappraisal

Beyond physiological arousal, recent models emphasize the role of cognitive appraisal in determining whether stress is experienced as motivating or overwhelming. The Biopsychosocial (BPS) Model of Challenge and Threat (Blascovich et al., 2010) provides a framework for understanding why moderate stress sometimes enhances performance and why excessive stress can be harmful. When individuals interpret the situation as manageable and believe they have sufficient resources to meet task demands, they enter a challenge state, a form of adaptive arousal associated with efficient cardiovascular activation and approach motivation. Conversely, when the same situation is viewed as overwhelming or uncontrollable, individuals experience a threat state, accompanied by physiological patterns that hinder focus and performance.

In stressful contexts, individuals often interpret physiological signals such as a racing heart or sweaty palms as signs of anxiety or fear (Mendes et al., 2007). These negative interpretations can amplify the sense that situational demands exceed personal coping resources, leading to a maladaptive threat response (Bouton et al., 2001). But teaching people to view arousal as a functional and adaptive state can improve both emotional and physiological outcomes. In fact, the literature suggests such an approach might be efficacious. For example, Jamieson et al. (2010) demonstrated that when GRE test-takers were instructed to reappraise their arousal as a helpful challenge response, they exhibited stronger physiological activation and significantly improved math performance, both in practice and on the actual exam. This finding suggests that the way individuals interpret arousal can shift it from a distress response to a eustress response, thereby enhancing cognitive performance under pressure.

Consistent with these findings, Jamieson et al. (2012) further demonstrated that reappraising arousal can produce both physiological and cognitive benefits under acute stress. In their study, participants who were instructed to reinterpret their physiological arousal as functional and adaptive showed a more favorable cardiovascular profile, characterized by higher cardiac output and lower total peripheral resistance, indicating a challenge rather than a threat state. In addition, these participants reported greater perceived coping resources and displayed reduced attentional bias toward emotionally negative information, suggesting enhanced cognitive control under stress.

However, most previous studies mainly focused on stress reappraisal and its effects on physiological responses and performance in tasks such as mathematics or public speaking. Fewer studies have examined whether these findings extend to more complex, real-world academic tasks, such as reading comprehension, which requires sustained attention, integration of information, and efficient cognitive processing under pressure. Therefore, the present study employs cognitive reappraisal as the main intervention to examine how reframing stress as a functional and motivating state influences reading processes and outcomes.

Reading Comprehension

English proficiency test scores such as the IELTS Academic, TOEFL iBT, and PTE Academic are crucial for university admission in English-speaking countries (e.g., Australia, Canada, the United Kingdom, the United States, and New Zealand) as well as in non-English-speaking countries (e.g., Switzerland, Germany, France, Spain, and Japan). As a result, these assessments are among the most widely administered language proficiency tests worldwide. Most of these examinations evaluate four core skills: speaking, writing, listening, and reading (Applyindex Growth Team, 2025).

Among these four skills, reading comprehension plays a particularly central role in higher education contexts because academic learning is predominantly text-based (Grabe, 2010; Snow, 2002). University students are required to process large volumes of written materials, such as textbooks, research articles, and examination passages (Grabe, 2010). Therefore, reading comprehension is often considered a central indicator of academic language proficiency (Alderson, 2000). Koda and Zehler (2008) further affirmed that reading is a crucial component of academic learning that enables individuals to participate meaningfully in broader scholarly communities.

Reading comprehension refers to the process of constructing meaning from written texts rather than merely extracting isolated words or sentences (Woolley, 2011). According to Leipzig (2001), reading is a multifaceted process involving word recognition, comprehension, fluency, and motivation. Because reading integrates multiple linguistic and cognitive processes, insufficient proficiency in reading may hinder students' access to academic knowledge across disciplines (Charity et al., 2004). Thus, reading ability is fundamental to academic success.

Nelson-Denny Reading Test as a Comprehension Measure

The standard English proficiency tests such as TOEFL and IELTS were designed as large-scale, high-stakes assessment tools for academic admission and migration purposes (ETS, 2023; IELTS, 2023; Green, 2007). These assessment tests are aimed at evaluating overall language proficiency in standardized testing environments rather than at serving as flexible instruments for controlled experimental research (Bachman & Palmer, 1996). Therefore, even though they are widely recognized as an indicator of language ability, their structure and administration constraints may limit their suitability for laboratory-based experiment manipulation.

Due to this reason, our study used the Nelson-Denny Reading Test as reading materials to evaluate participants' reading comprehension ability. The Nelson-Denny Reading Test is a standardized test of reading comprehension (Ready et al., 2012). It provides a trustworthy assessment of student ability in three areas: vocabulary, reading comprehension, and reading rate. These important skills are related and interdependent (Brown et al., 1993). The Nelson-Denny (ND) Reading Test (Form H) contains two sections, a vocabulary section and a reading comprehension section. Because this study focuses on reading comprehension performance, only the reading comprehension section of the ND test is relevant. For the reading comprehension section, each participant needs to read seven passages and answer 35 factual and inferential questions. The comprehension performance was determined by summing the number of correct answers; incorrect responses did not result in score penalties (Binder et al., 2016).

The Nelson-Denny Reading Test (Form H) was standardized on a national sample of approximately 7300 students across secondary and postsecondary levels. Item analyses showed appropriate increases in difficulty across grade levels and satisfactory item discrimination. The equivalent-form reliability coefficients for the Vocabulary and Comprehension subtests were approximately 0.72-0.73, indicating acceptable reliability for research purposes. Differential item functioning analyses were also conducted to reduce potential bias across gender and ethnic groups. Although these reliability coefficients are not at the level typically required for high-stakes individual assessment, they are generally considered adequate for experimental research. Overall, the evidence suggests that the test provides sufficiently reliable and appropriate measurement of reading comprehension and reading rate in college populations (Brown et al., 1993).

Using Eye-Tracking to Evaluate Reading Comprehension

While the Nelson-Danny Reading Test provides measures of vocabulary, reading comprehension, and reading rate based on its test score and reading time, it is not able to indicate the cognitive processes and abilities underlying the reading. Eye-tracking techniques, however, could offer a powerful complement to traditional reading comprehension assessments. These techniques record individuals' continuous and natural real-time reading behavioral traces without disruption (Moss, 2023). Therefore, the eye-movement data allows researchers to analyze and observe underlying cognitive processes and individual differences in them.

Eye-movement data could record various natural reading behaviors, including reading time and fixation on certain vocabulary or sentences, and the number of re-readings on certain sentences or the passage. Specifically, eye-movement measures are often categorized into early-stage and late-stage processing indices. Early processing measures include first fixation duration, which refers to the length of the initial fixation on a target word, and gaze duration, defined as the total time spent on a word or region before the eyes move to another location. These measures are typically associated with early lexical processing and initial word recognition.

In contrast, late-stage processing measures include regression patterns and total reading time. Regressions occur when readers move their eyes back to previously read text, often reflecting difficulties in comprehension or the need for reanalysis. Total reading time refers to the cumulative time spent on a word or passage, including all fixations and re-reading, and is considered an index of overall processing effort.

Previous research has shown that these eye-movement measures not only reflect distinct aspects of reading but also provide richer insights when examined in relation to other variables, test formats, passage difficulties, readers' working memory, and so on. Those eye-movement data have provided important insight into readers' cognitive processes and strategies in response to or in association with different conditions (Mézière, 2023).

Overall, eye-tracking is a non-invasive methodology that provides direct and online measures of cognitive processing during reading comprehension (de-la-Peña, 2024). However, few studies have simultaneously examined how multiple eye-movement measures, such as first fixation duration, gaze duration, and total reading time, relate to reading performance, particularly under different stress conditions. Therefore, the present study used eye-movement data to examine how time pressure and appraisal framing influence reading efficiency, as reflected in first fixation duration, gaze duration, and total reading time.

Time limits with Reading Comprehension

Time pressure is one of the most common methods used to induce stress in reading research, as it directly challenges readers' ability to balance speed and comprehension. Vibert et al. (2025) examined how reading time constraints affect reading comprehension and eye movements. They found that as the time limit became stricter, the reading comprehension score decreased. Interestingly, this study found that the relationship between comprehension and reading time showed a nonlinear decline, meaning that comprehension did not decrease in direct proportion to the reduction in available reading time. For example, when reading time was reduced to one-sixth of the original, from 38 seconds to 6.3 seconds, comprehension dropped by only about half, from 87% to 49% accuracy, indicating that readers were able to partially adapt their reading behavior to the time pressure. In other words, participants demonstrated a certain level of resilience, adjusting their reading strategy rather than simply reading faster at the cost of understanding.

However, almost all eye movement measures, except for saccade rate, were affected by the time restriction. Shorter reading times led to shorter fixations, larger saccade amplitudes, and faster left-to-right gaze velocity, showing that readers adapted by scanning the text more efficiently. But these adaptations did not fundamentally change their reading behavior; participants still made regressive saccades and directly fixated on more than three-quarters of the content words even under the shortest time limit. This suggests that while readers adjust their eye movements under pressure, their core reading strategies remain largely intact, helping them preserve comprehension as much as possible despite time constraints (Vibert et al., 2025).

Notably, Vibert et al.'s (2025) findings partially contrast with Walczyk et al.'s (1999) previous research, which found that moderate time limitations may enhance reading comprehension by encouraging students to be more mindful and to put in greater effort. Specifically, Walczyk et al. tested college students' reading under three conditions —no time pressure, moderate time pressure, and severe time pressure— and found that the comprehension score under moderate time pressure was significantly higher than under no time pressure and severe time pressure, which did not differ significantly from each other. This study indicates how under moderate levels of stress, performance might actually be enhanced.

Overall, prior studies provide mixed evidence. Some studies, such as Vibert et al. (2025), suggest that time limits tend to impair comprehension and influence readers' eye movement patterns when they are under stress, but some readers can also adapt to this situation to maintain partial understanding. Whereas other studies, like Walczyk et al. (1999), indicate that moderate time pressure may increase comprehension. These findings imply that time pressure is an important factor that can function as either distress or eustress depending on its intensity and the reader's ability to adapt. Therefore, given its theoretical and practical significance for reading comprehension, the present study will include time pressure as a key experimental factor.

Comprehension within Native versus Nonnative Language Readers

Previous literature has also explored how stress may differentially influence reading comprehension performance between native language readers (L1) and nonnative language readers (L2). Rai et al. (2014) found that stress increased reaction time only for L2 readers, particularly those with higher reading anxiety or lower working memory, while L1 readers with a stronger working memory had shortened reaction times and faster performance under stress. Increasing inferential difficulty of reading materials also led to significantly slower reaction time or lower reading accuracy for L2 readers than L1 readers. Overall, this study demonstrated how under equivalent stress conditions and given the same text materials, L2 readers are more vulnerable to the negative effects of stress on performance, reflecting greater cognitive load during reading compared to L1 readers.

Taken together, these findings highlight the importance of distinguishing between eustress and distress. They demonstrate that stress does not have a uniform effect, but rather interacts with factors such as task demands and individual differences in native language. In fact, stress has been shown to significantly affect core cognitive processes such as working memory and attention (Eysenck et al., 2007), which are precisely the mechanisms that support reading comprehension. Therefore, understanding how different types of stress influence these processes, especially among L1 readers and L2 readers who may be differently influenced, is essential. This framework provides the basis for the current research, which investigates how eustress and distress impact reading comprehension performance among first- and second-language readers, utilizing eye-tracking measures to capture differences in cognitive processing.

Overview of the Present Study

This thesis seeks to contribute to the literature on how stress shapes reading comprehension by focusing on eustress-like and distress-like processing during reading. Although recent research has investigated many findings on the relationship between stress, health, and performance, much less is known about how these factors affect students' reading comprehension, particularly when comparing first-language (L1) and second-language (L2) readers. To address these gaps, the present study examines reading accuracy and efficiency in L1 and L2 readers using eye-tracking measures and investigates whether time pressure and appraisal framing can shape stress responses into eustress-like or distress-like experiences that subsequently influence reading comprehension performance.

Purpose Statement and Research Questions

Stress can manifest as either eustress, a motivating and adaptive state, or distress, a harmful and maladaptive state, depending on how individuals appraise a situation. In this study, appraisal framing will serve as the key manipulation to induce these states: participants in the reappraisal condition will be encouraged to view their physiological arousal as functional and performance-enhancing (eustress-like), whereas those in the evaluation threat condition will be led to perceive the task as being judgmental and high-stakes (distress-like). A neutral condition will also be included as a baseline.

Given these manipulations, this study aims to examine how different stress conditions, such as eustress (induced through reappraisal), distress (via evaluation threat), and neutral, affect reading comprehension accuracy and efficiency among first- and second-language English readers. In addition, this study will investigate how time pressure, operationalized by providing one group with enough time and another group with limited time to complete the reading task, interacts with these outcomes.

Based on these ideas, the main research question for this study is: Do time pressure (no time pressure vs. mild time pressure) and appraisal framing (reappraisal, neutral, and evaluation threat) induce eustress-like or distress-like states that influence reading accuracy and efficiency, and do these effects differ between L1 and L2 readers?

To answer this overarching research question, the study will also examine the following hypotheses:

H1: Participants who receive reappraisal instructions will show higher reading comprehension accuracy and greater reading efficiency (shorter first fixation and gaze duration and total reading time) compared to those in the neutral and evaluation threat conditions, indicating a eustress-like effect.

H2: Participants in the evaluation threat condition will show lower reading comprehension accuracy and reduced reading efficiency (longer first fixation and gaze duration and total reading time) compared to those in the neutral and reappraisal conditions, indicating a distress-like effect.

H3: Under mild time pressure, the beneficial effects of reappraisal will become more pronounced, whereas the negative effects of evaluation threat will increase.

H4: Appraisal framing effects will differ between L1 and L2 readers. (e.g., L1 readers will show greater reading efficiency under reappraisal compared to L2 readers.)

H5: Working memory capacity will moderate the effect of appraisal framing on reading efficiency.

METHOD

Participant Characteristics

This study recruited quantitative data from 74 participants at Mount Holyoke College. They were split into English L1 (native) or L2 (non-native) readers through self-report. In total, 32 participants were classified as L1 speakers and 42 as L2 speakers.

Participants formed a diverse first languages pool with English (n = 32), Mandarin (n = 22), Spanish (n = 4), and several other languages such as Haitian Creole, Hausa, Korean, Kinyarwanda, Marathi, Mongolian, Russian, and Urdu (each n = 1). Two participants reported multiple first languages, and four did not report their first language. Racial identities included White, Asian, Black or African American, and American Indian or Alaska Native. Participants ranged in age from 18 to 44 years (M = 20.01, SE = 0.39).

In terms of gender, the majority of participants identified as female (n = 64), with a small number identifying as gender non-conforming (n = 5), one participant preferring not to disclose, and four participants who did not report their gender.

This study initially recruited 74 participants. However, due to technical issues with the eye-tracker, incomplete data recording and heavy workload, only 49 data were used to analyze reading efficiency, while 66 participants had usable data and were included in the final analyses for reading accuracy. This final sample size we recruited still exceeded the originally proposed target of 60 participants.

The proposed sample size of 60 participants is based on both the feasibility of our study design, given the time constraints of an academic year, and previous scholarly work. For example, Jamieson et al. (2010) used 60 participants (31 males and 29 females) to examine how reappraising arousal as a challenge affected GRE performance. Their study used a between-subjects design with two appraisal conditions and found significant effects of reappraisal on both physiological responses and performance. Their study also showed that a sample size of 60 is large enough to observe clear differences between experimental conditions. Since the current study also includes multiple appraisal conditions and measures of reading performance, 60 participants were chosen as a reference.

Participants had to be 18 years or older and have normal or corrected-to-normal vision. Participants who reported diagnosed reading disabilities such as dyslexia, uncorrected vision problems, or a recent concussion were not recruited. This study also excluded people who feel uncomfortable doing timed academic tasks. These criteria are to ensure the data are accurate and that the task did not cause unnecessary stress for participants.

Sampling Procedures

Participants were recruited through Mount Holyoke College's SONA research participation system, campus-wide flyers, and email announcements. The SONA system is an online platform used by the Psychology Department to connect students with approved research studies and help them earn course credit for participation. Students registered in SONA were able to sign up for this study and received two research credits for participation. To ensure sample diversity, the study was also recruited from the general student body through voluntary sign-ups. Those who were not eligible for SONA credit received $10 as compensation for their time.

This study used a convenience sampling method, since participants were recruited from the Mount Holyoke College student population who could voluntarily sign up through SONA or other campus announcements. The study took place in the Psychology Department's eye-tracking lab. Each participant completed the experiment individually in a quiet testing room equipped with an eye-tracking device.

Materials & Data Collection

Reading Materials

The Nelson-Denny Reading Test (Form H) was used to assess participants' reading comprehension ability. In this study, six of the seven passages from the comprehension section were selected due to their similar length, ranging from 15 to 21 lines. The remaining passage was used as a practice trial. Each passage was followed by five comprehension questions. See Appendix A for a sample passage.

Time Pressure Condition

Time pressure was manipulated by varying the amount of time participants were given to complete each reading passage. One group was given sufficient time to complete the task, whereas the other was required to complete each passage under a limited time constraint. This manipulation was designed to induce differences in perceived stress levels, with time pressure expected to increase task-related stress.

Previous research using the Nelson-Denny Reading Test (Kwabi, 2014) has shown that participants typically spend approximately 2 minutes and 30 seconds reading each passage. Based on this benchmark, a time limit of 2 minutes per passage was implemented in the present study. This duration was chosen to introduce a moderate level of time pressure, increasing participants' sense of urgency while still allowing them sufficient time to attempt all questions.

Self-report Materials

This study used the Stress Mindset Measure (SMM) and the State Trait Anxiety Inventory (STAI) to assess participants' self-reported stress levels before and after the experiment. The SMM (see Appendix B) is a questionnaire developed by Crum, Salovey, and Achor (2013) that uses an 8-item Likert scale to assess participants' general beliefs about the effects of stress. This questionnaire not only evaluates a participant's general stress mindset, but it also includes statements reflecting both enhancing and debilitating views of stress across domains such as health, learning, and performance. Participants indicated their level of agreement on a five-point Likert scale ranging from 0 (*strongly disagree*) to 4 (*strongly agree*). Four items (indicated by an *) were reverse-scored, and an average score was computed, with higher values indicating a stronger belief that stress can have positive, enhancing effects. The SMM has demonstrated good internal reliability (Cronbach's α = .87).

The STAI (see Appendix C) was originally developed by Spielberger, Gorsuch, and Lushene (1964). It is a well-established self-report instrument designed to measure two distinct aspects of anxiety: state anxiety (temporary feelings of anxiety experienced in the moment) and trait anxiety (a person's general tendency to experience anxiety across situations). The inventory consists of 20 items, each rated on a 4-point Likert scale that reflects the intensity or frequency of anxiety-related feelings. Several items were reverse-scored (Items 1, 2, 5, 8, 11, 15, 16, 19, and 20), and higher scores indicate higher levels of anxiety. The STAI has been translated into over 30 languages and has demonstrated strong reliability and validity across diverse populations (Sesti, 2000). Reported reliability coefficients range from .65 to .86 for the Trait-Anxiety scale and .16 to .62 for the State-Anxiety scale, consistent with expectations given the transient nature of state anxiety.

Working Memory Materials

This study used the Woodcock-Johnson Backward Digit Span to test each participant's working memory capacity. The Woodcock-Johnson Backward Digit Span is also known as the Numbers Reversed subtest, to measure participants' working memory capacity. It is a test that asks participants to listen to a sequence of numbers and then repeat them in the reverse order. For example, if the numbers 5, 8, and 2 are read aloud, the correct response would be 2, 8, 5.

In this task, participants first hear short sequences of digits presented one at a time. If they respond correctly, the next sequence becomes longer and more difficult. The task continues until the participant can no longer recall the sequence accurately. The final score is based on the longest sequence the participant can correctly repeat backward. A higher score on the backward digit span indicates greater working memory capacity.

Eye-tracker

A high-precision SR Research EyeLink 1000 system was used to collect eye-movement data at a sampling rate of 1000 Hz. The system can detect movements as small as 0.01 degrees of visual angle and has a tracking range of about 32 degrees horizontally and 25 degrees vertically. The average calibration error across participants is expected to be around 0.3 degrees of visual angle. Eye movements is recorded from the right eye by default.

Before the experiment, the eye-tracker and chinrest were set up on a stable desk to keep the participants' head position fixed. The eye-tracking camera was placed about 65 cm from the chinrest, and a 24-inch monitor was positioned about 93 cm away. This setup ensured participants could read the passages comfortably while maintaining stable and accurate recordings.

Procedures

Each session lasted about 45 to 60 minutes, including consent, reading tasks, answering questions, and debriefing. After participants signed the consent form, they were asked to provide basic demographic information, including their age, gender, native language, and nationality. Then, the researcher guided the participant to sit in front of a computer and adjusted their position to ensure comfort while using the eye-tracking equipment.

At the start of the experiment, each participant was asked to finish the Stress Mindset Measure (SMM) and the State Trait Anxiety Inventory (STAI) questionnaires. Then each participant was randomly assigned to one of the three appraisal framings (reappraisal, neutral, or evaluation threat), and one of two time pressure conditions (no pressure or mild time pressure). Participants in all conditions first heard or read the following general instructions:

> "The goal of this research is to examine how emotional and cognitive arousal during a reading task relates to performance. Because it is normal for people to feel some anxiety or alertness during academic activities, the data collected will help us understand how these feelings influence reading comprehension."

For participants in the control condition (the neutral condition), the cover story ended here. Participants assigned to the reappraisal condition then heard or read:

> "People often think that feeling anxious while taking a test will lead to poor performance. However, recent research suggests that arousal does not harm performance and can even enhance it. In fact, people who feel anxious during a test may actually perform better. This means that you should not be concerned if you feel anxious while taking today's reading test. If you notice yourself feeling anxious, remind yourself that your arousal may be helping you perform well."

In addition, participants assigned to the evaluation threat condition heard or read:

"This task is designed to measure your academic reading ability. Your performance will be compared to that of other college students. Try your best to demonstrate your reading and analytical skills, as your results may reflect your academic potential."

After receiving the instructions, participants completed six reading comprehension passages on a computer while their eye movements were recorded by an eye-tracker. After finishing the reading tasks, participants completed a working memory test as well as two self-report questionnaires: the Stress Mindset Measure (SMM) and the State-Trait Anxiety Inventory (STAI).

Following the questionnaires, the researcher conducted a brief interview with the participant to assess whether they noticed any feelings of stress during the experiment. If stress was reported, the participant was asked to describe its sources. Finally, the researcher conducted a debriefing session to explain the true purpose of the study and answered any questions participants had about the experiment.

Analytic Strategy

The independent variables in this study were time pressure conditions (no pressure vs. mild time pressure), appraisal framing (reappraisal, neutral, evaluation threat), and language group (L1 vs. L2). The dependent variables were reading accuracy, reading efficiency, and self-reported affect and anxiety. Reading accuracy was measured by participants' scores on reading comprehension questions. Reading efficiency was measured by the first fixation duration, gaze duration, and total reading time collected by the eye-tracking technology. Self-reported affect and anxiety were measured using the SMM and the STAI before and after the reading task.

To analyze the data, this study used linear mixed effects models to examine reading accuracy and reading efficiency. A linear mixed effects model allows researchers to analyze data where observations are grouped. By including both fixed and random effects, this model captures general patterns across conditions while also accounting for individual differences and item-level variability. For response accuracy, a generalized linear mixed-effects model with a Poisson distribution was used, as this dependent variable represented count data.

In all models, the following effects were entered as fixed effects: appraisal framing (reappraisal, neutral, evaluation threat), time pressure conditions (no pressure vs. mild time pressure), and language group (L1 vs. L2). Working memory is a continuous predictor and has been centered. The following interactions are: appraisal framing* time pressure conditions, appraisal framing* language group, appraisal framing* working memory, time pressure conditions* language group, time pressure conditions* working memory, language group* working memory, appraisal framing* time pressure conditions* language group, appraisal framing* time pressure conditions* working memory, appraisal framing* language group* working memory, time pressure conditions* language group* working memory, and appraisal framing* time pressure conditions* language group* working memory. The intercepts for participants and passages were included as random effects in each linear-mixed effects and generalized linear mixed-effects model. All analyses were conducted using SPSS version 28, with the Restricted Maximum Likelihood (REML) estimation method applied for linear models. The equation for the full model is expressed as:

$$Y_{ijk} = \beta_0 + \beta_1 X_{1ijk} + \beta_2 X_{2ijk} + \beta_3 X_{3ijk} + \beta_4 X_{4ijk} + \beta_5 X_1 X_{2ijk} + \beta_6 X_1 X_{3ijk} + \beta_7 X_1 X_{4ijk} + \beta_8 X_2 X_{3ijk} + \\ + \beta_9 X_2 X_{4ijk} + \beta_{10} X_3 X_{4ijk} + \beta_{11} X_1 X_2 X_{3ijk} + \beta_{12} X_1 X_2 X_{4ijk} + \beta_{13} X_1 X_3 X_{4ijk} + \beta_{14} X_2 X_3 X_{4ijk} + \beta_{15} X_1 X_2 X_3 X_{4ijk} + u_i \\ + v_j + \varepsilon_{ijk}$$

Where Y_{ijk} = the dependent variable, X_1 = appraisal framing (reappraisal, neutral, evaluation threat), X_2 = time pressure conditions (no pressure vs. mild time pressure), X_3 = language group (L1 vs. L2), X_4 = working memory, u = intercept for participants, v = intercept for passages, ε= residual error.

In addition to the linear mixed-effects analyses, self-reported stress scores collected from the Stress Mindset Measure and State-Trait Anxiety Inventory were analyzed to verify the effectiveness of the experimental manipulations. Specifically, a three-way ANOVA was conducted with the stress score as the dependent variable and appraisal framing, time pressure, and language group as the independent variables. This analysis determined whether participants experienced different levels of stress across experimental conditions as expected.

RESULTS

Reading Accuracy

For the analysis of reading accuracy, 66 participants' multiple-choice reading comprehension accuracy scores were entered as dependent variables. Language group, time pressure, and appraisal framing were entered as fixed effects, while participants and passages were treated as random effects to account for individual and item-level variability.

The LME model for reading accuracy revealed a significant main effect of language, $F(1, 374) = 13.10$, $p < .001$, representing that native speakers ($M = 4.32$, $SE = 0.07$) demonstrated higher accuracy than non-native speakers ($M = 3.97$, $SE = 0.07$). There was also a significant main effect of time pressure, $F(1, 374) = 20.75$, $p < .001$, with participants in the no time pressure condition ($M = 4.37$, $SE = 0.07$) outperforming those in the time pressure condition ($M = 3.92$, $SE = 0.07$). No significant main effect was found for appraisal framing, $F(2, 374) = 0.66$, $p = .519$. Notably, working memory was a significant covariate, $F(1, 374) = 6.64$, $p = .010$, indicating that higher working memory capacity was associated with overall better performance.

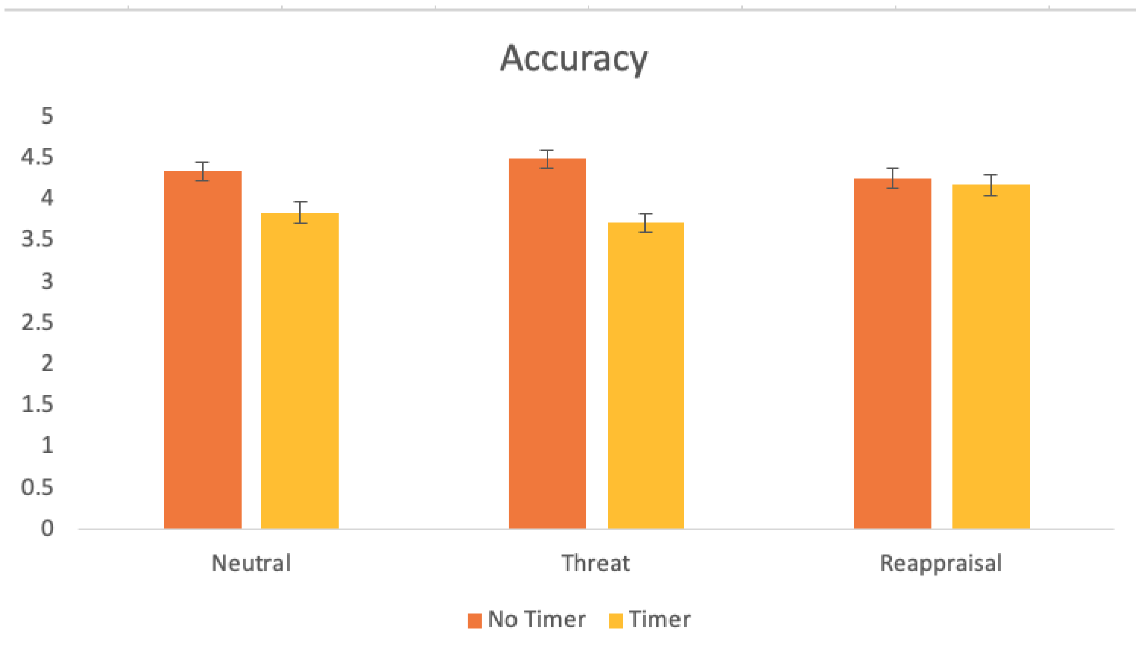
However, as illustrated in Figure 2, there was a significant interaction between time pressure condition and appraisal framing, $F(2, 374) = 4.21$, $p = .016$, indicating that the effect of time pressure was different across framing conditions. Specifically, simple effects analysis revealed that time pressure significantly reduced accuracy in both the neutral condition, $F(1, 374) = 8.88$, $p = .003$, and the threat condition, $F(1, 374) = 22.81$, $p < .001$. In contrast, time pressure had no significant impact on accuracy within the reappraisal condition, $F(1, 374) =$

0.17, $p = .685$. This pattern suggests that reappraisal may buffer the negative effects of time pressure on reading comprehension.

Furthermore, the interaction between language and time pressure was not significant, $F(1, 374) = 3.05$, $p = .082$, nor was the interaction between language and appraisal framing, $F(2, 374) = 0.26$, $p = .772$. Finally, the three-way interaction among language, time pressure, and appraisal framing was also nonsignificant, $F(2, 374) = 0.93$, $p = .394$.

Figure 2

Mean reading comprehension accuracy across appraisal framing conditions as a function of time pressure



Reading Efficiency

First Fixation Duration

For the analysis of reading efficiency, we analyzed 49 participants' eye-tracking data, using the first fixation duration as a dependent variable. The results revealed a significant main effect of language, $F(1, 275) = 45.368$, $p < .001$. Specifically, non-native participants showed a longer first fixation duration (*M* = 245.45, *SE* = 2.62) than native participants (*M* = 222.42, *SE* = 2.17).

A marginal main effect of time pressure was also observed, $F(1, 275) = 3.10$, $p = .080$. Participants in the time pressure condition showed numerically shorter first fixation duration (*M* = 230.97, *SE* = 2.51) than those under no time pressure condition (*M* = 236.90, *SE* = 2.26), although this difference did not reach statistical significance. In addition, the main effect of appraisal framing was significant, $F(2, 275) = 6.10$, $p = .003$. Pairwise comparisons indicated that first fixation durations were significantly longer in the threat condition (*M* = 241.42, *SE* = 3.15) compared to the reappraisal condition (*M* = 226.64, *SE* = 2.82), $p < .001$. However, the difference between the threat and neutral conditions (*M* = 233.74, *SE* = 2.79) did not reach statistical significance ($p = .068$). There was also no significant difference found between the neutral and reappraisal conditions ($p = .075$).

Moreover, as shown in Figure 3, a significant interaction between language and time pressure emerged, $F(1, 275) = 10.97$, $p = .001$. Results showed that time pressure significantly reduced first fixation durations for non-native participants $F(1, 275) = 10.94$, $p = .001$. In contrast, no significant effect of time pressure was observed for native participants, $F(1, 275) = 1.45$, $p = .229$. These results suggest that the effect of time pressure differed across language groups, with non-native readers showing greater sensitivity during early lexical processing.

Furthermore, as shown in Figure 4, a marginal two-way interaction was found between language and appraisal framing, $F(2, 275) = 2.35$, $p = .097$. Simple effects analysis showed that non-native participants had significantly longer first fixation durations than native participants in the neutral condition, $F(1, 275) = 14.72$, $p < .001$, the reappraisal condition, $F(1, 275) = 6.17$, *p* =

.014, and the threat condition, $F(1, 275) = 26.45$, $p < .001$. Moreover, there was no significant two-way interaction between time and appraisal framing, $p = .149$.

Overall, these findings indicate that non-native readers consistently exhibited longer first fixation durations than native readers. This language difference became more pronounced under time pressure, but remained similar across appraisal framing conditions. Suggesting that time pressure, rather than framing, influenced the extent of this difference.

Figure 3

Mean first fixation duration for native and non-native readers under no time pressure and time pressure conditions

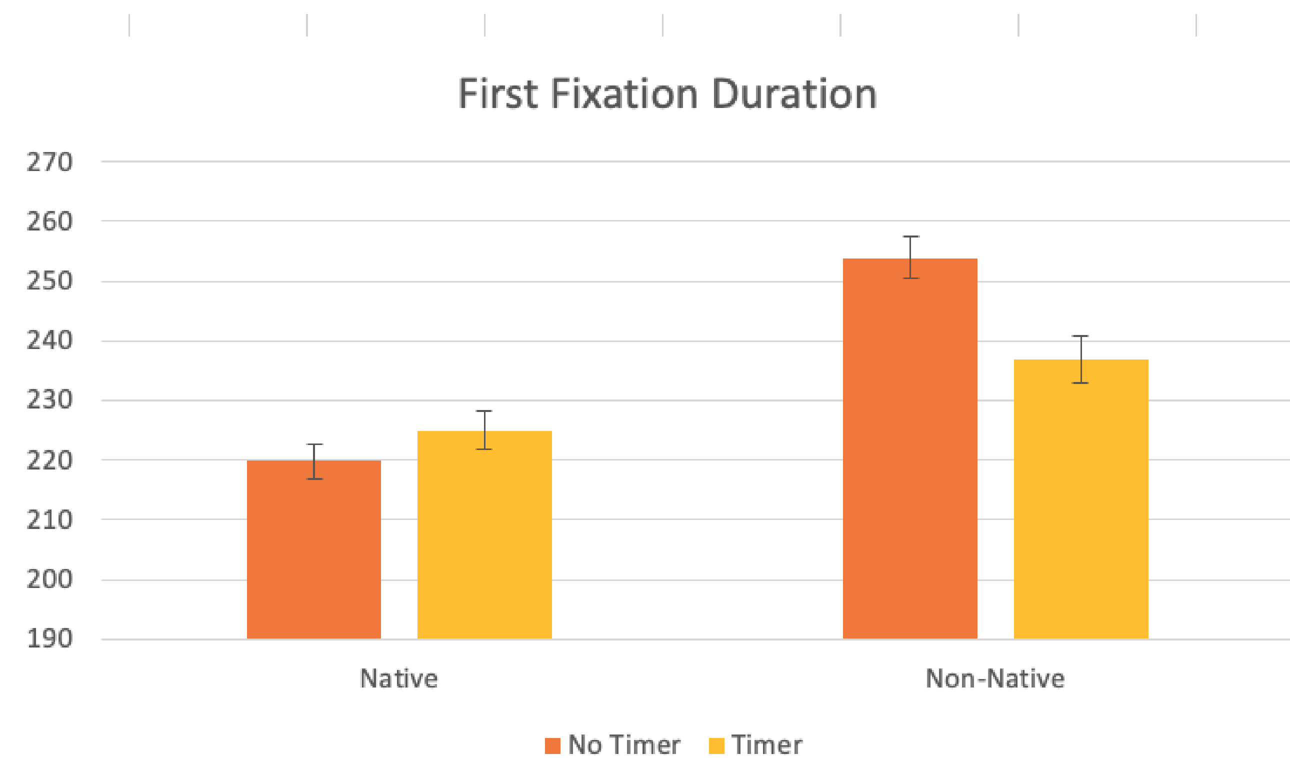
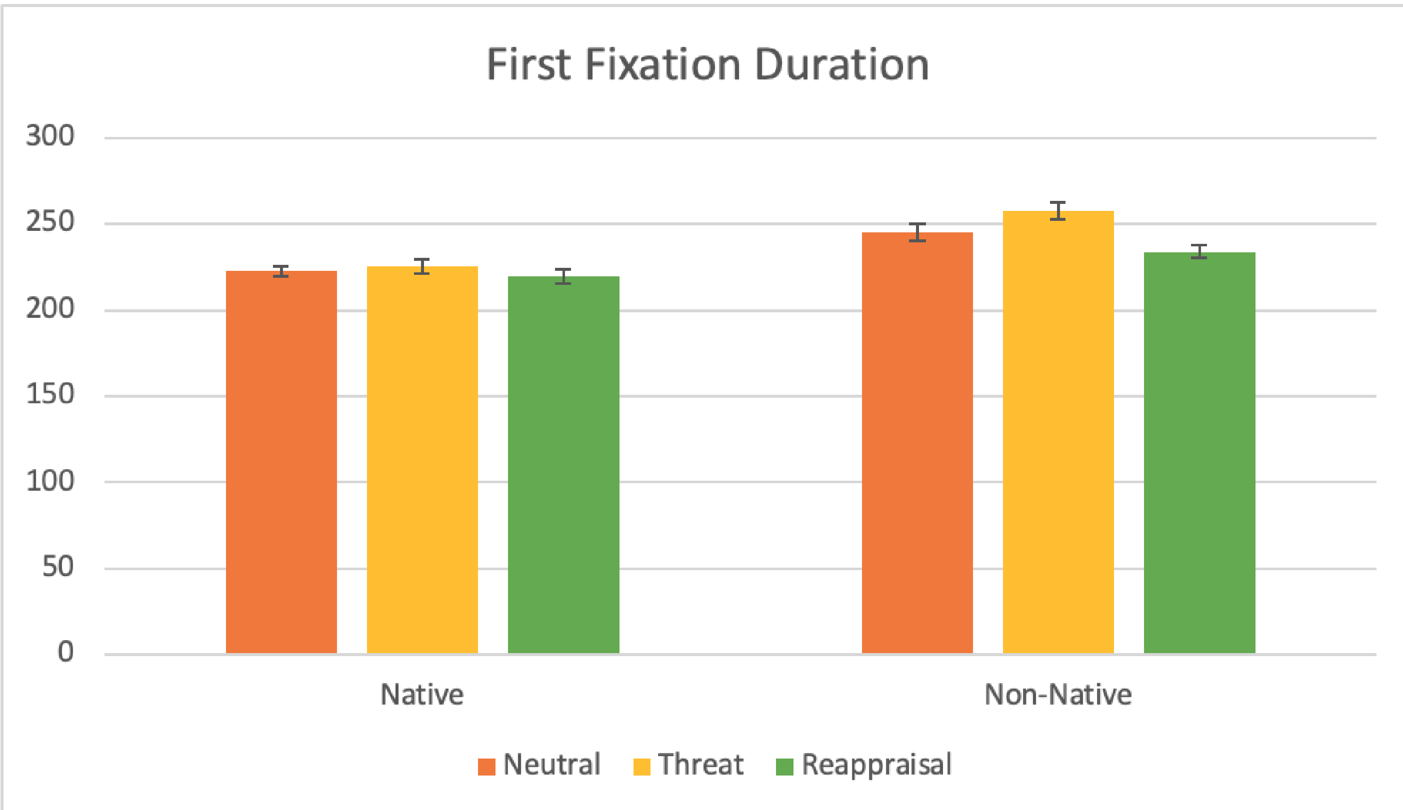


Figure 4

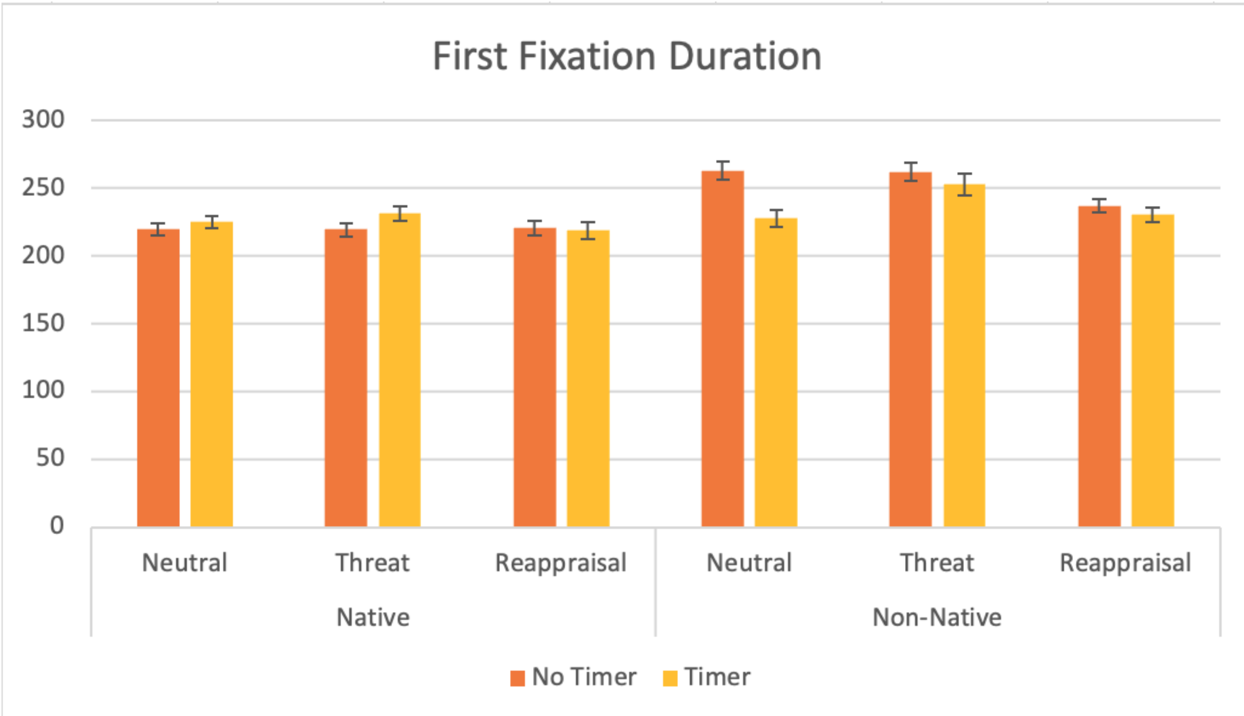
Mean first fixation duration across appraisal framing conditions (neutral, threat, reappraisal) for native and non-native readers



However, as Figure 5 showed, the three-way interaction among language, time pressure, and appraisal framing was marginally significant, $F(2, 275) = 2.53$, $p = .082$. Follow-up analyses showed that time pressure only significantly affected non-native participants in the neutral condition, $F(2, 275) = 7.18$, $p < .001$. No significant effects were observed in other conditions.

Figure 5

Mean first fixation duration across appraisal framing conditions for native and non-native readers under no time pressure and time pressure



Gaze Duration

For the analysis of reading efficiency, we analyzed 49 participants' eye-tracking data, using the gaze duration as a dependent variable. The results revealed a significant main effect of language, $F(1, 275) = 76.22$, $p < .001$. Specifically, non-native participants showed a longer gaze duration ($M = 288.67$, $SE = 3.55$) than native participants ($M = 248.22$, $SE = 2.94$).

Additionally, a significant main effect of appraisal framing emerged, $F(2, 275) = 7.41$, $p < .001$, as Figure 6 showed. Pairwise comparisons indicated that gaze durations were significantly longer in both the neutral condition ($M = 272.69$, $SE = 3.78$, $p = .002$) and the threat condition ($M = 276.42$, $SE = 4.27$, $p < .001$) compared to the reappraisal condition ($M = 256.23$, $SE = 3.82$). In contrast, no significant difference was observed between the neutral and threat conditions (p = .512), suggesting that reappraisal reduced overall processing time relative to the other conditions. However, there was no significant main effect for time pressure, $F(1, 275)$ = .864, p = .353. Gaze duration did not differ significantly between the time pressure and no time pressure conditions. Notably, working memory was a significant covariate, $F(1, 275)$ = 10.05, p = .002, indicating that higher working memory was associated with shorter gaze duration.

Furthermore, as shown in Figure 7, the interaction between language and time pressure did not reach statistical significance, $F(1, 275)$ = 3.08, p = .080, although a marginal trend was observed. Follow-up analyses indicated that time pressure did not significantly affect gaze durations for either native participants, $F(1, 275)$ = .411, p = .522, or non-native participants, $F(1, 275)$ = 3.07, p = .081. However, a marginal trend suggested that non-native readers may be more sensitive to time pressure.

Figure 6

Mean gaze duration across appraisal framing conditions (neutral, reappraisal, threat)

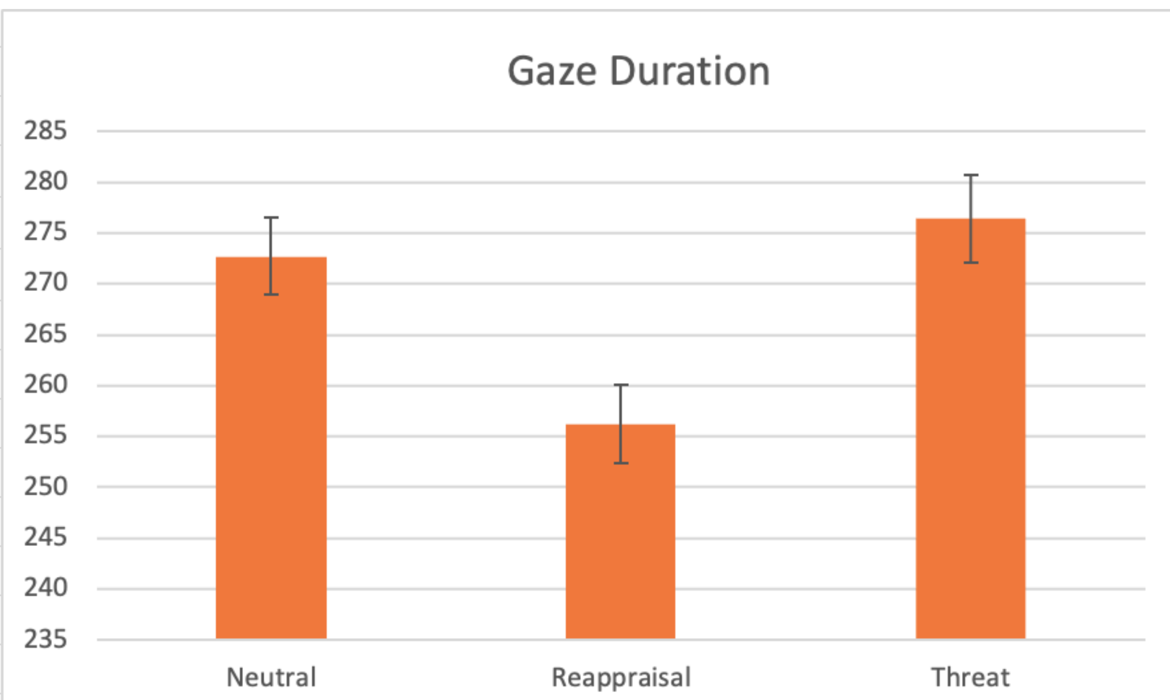
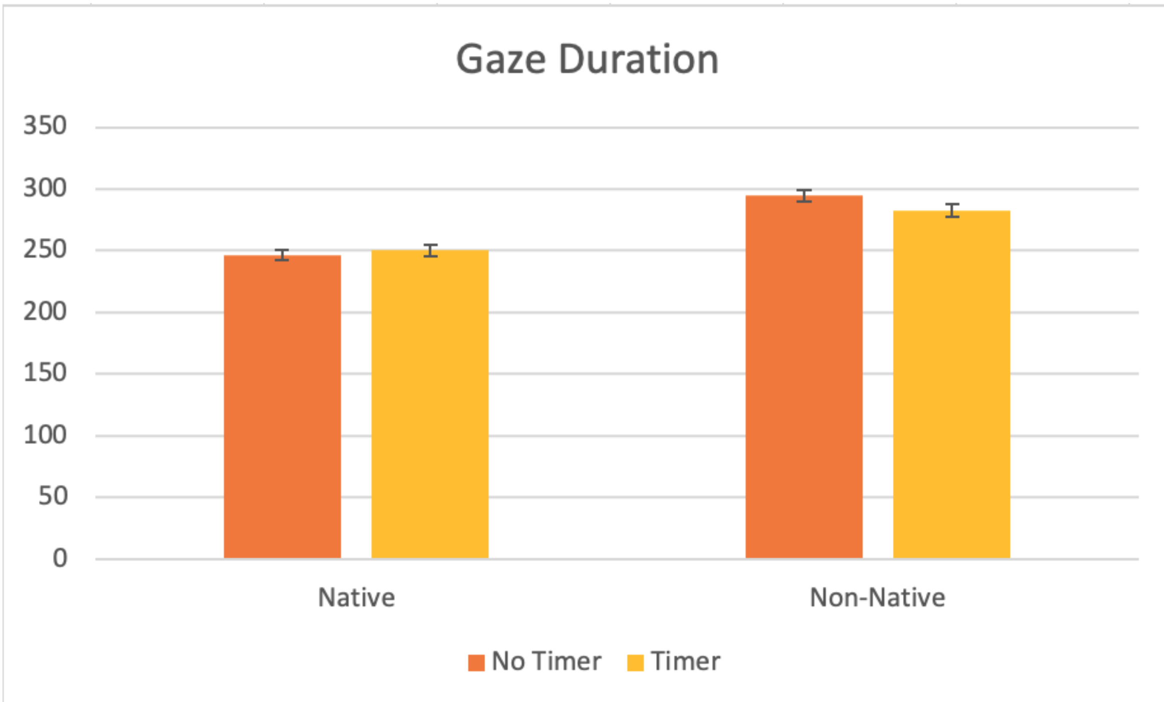


Figure 7

Mean gaze duration for native and non-native readers under no time pressure and time pressure conditions



Furthermore, a significant two-way interaction was found between language and appraisal framing (Figure 8), $F(2, 275) = 3.74$, $p = .025$. Simple effects analysis indicated that native participants had significantly shorter gaze durations than non-native participants in the neutral condition, $F(1, 275) = 37.01$, $p < .001$, the reappraisal condition, $F(1, 275) = 8.89$, $p = .003$, and the threat condition, $F(1, 275) = 34.01$, $p < .001$. Notably, the magnitude of this difference was reduced in the reappraisal condition compared to the neutral and threat conditions, suggesting that reappraisal attenuated the language-related processing difference.

A significant two-way interaction was also found between time pressure and appraisal framing, F(2, 275) = 7.99, p < .001. Follow-up analyses, as shown in Figure 9, indicated time pressure significantly reduced gaze durations in the neutral condition, $F(1, 275) = 10.11$, $p =$

.002. Interestingly, the analysis found that in threat condition, participants under time limit (*M* = 287.32, *SE* = 6.60), showed significantly longer gaze duration, *p* = .012, than those in the no time limit condition (*M* = 265.52, *SE* = 5.51). However, no significant difference was observed in the reappraisal condition, *p* = .177.

Figure 8

Mean gaze duration across appraisal framing conditions (neutral, threat, reappraisal) for native and non-native readers

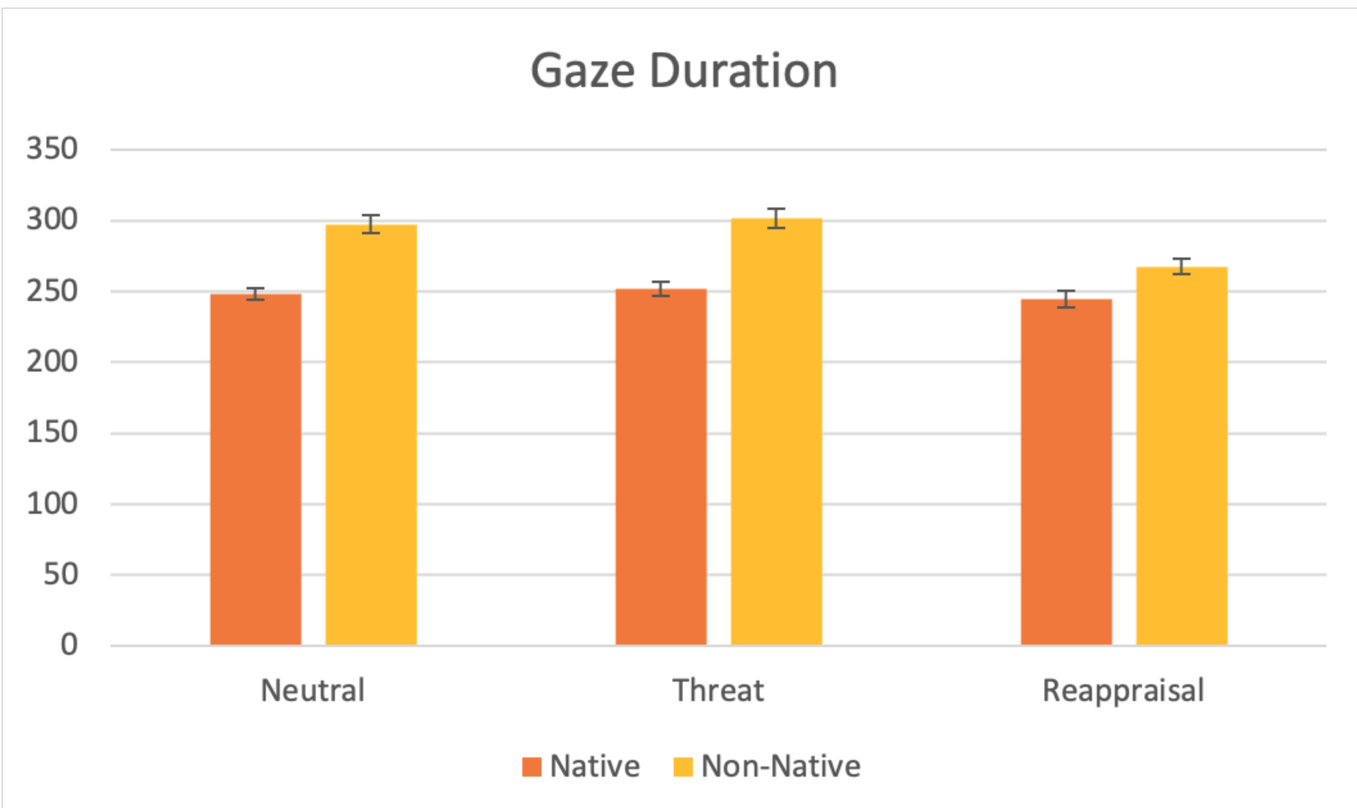
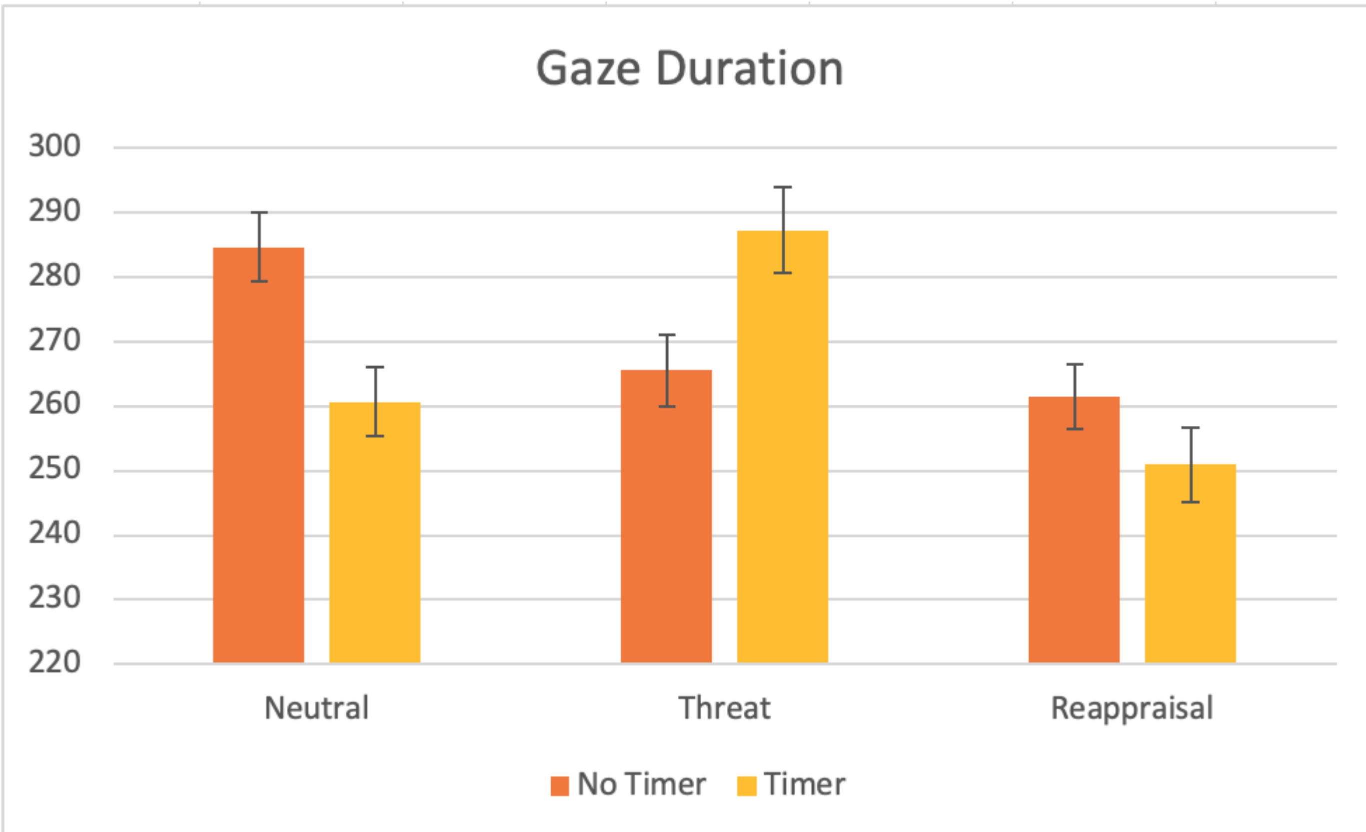


Figure 9

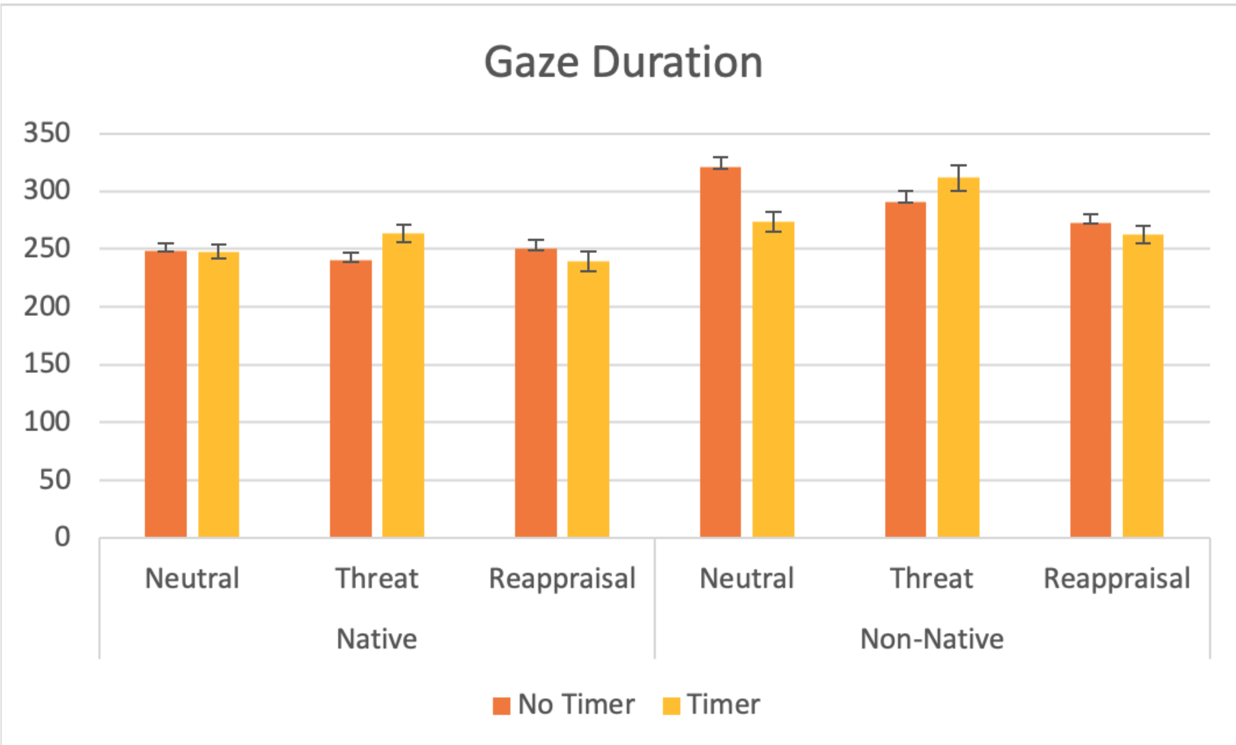
Mean gaze duration across appraisal framing conditions under no time pressure and time pressure



Notably, the three-way interaction among language, time pressure, and appraisal framing was marginally significant, $F(2, 275) = 2.79$, $p = .063$, as Figure 10 showed. However, follow-up analyses suggested distinct patterns across groups. For non-native participants, time pressure significantly reduced gaze durations only in the neutral condition, $F(1, 275) = 14.43$, $p < .001$, whereas no effects were observed in the reappraisal or threat conditions. In contrast, for native participants, time pressure showed a significant effect only in the threat condition, $F(1, 275) = 5.32$, $p = .022$, but not in the neutral or reappraisal conditions.

Figure 10

Mean gaze duration across appraisal framing conditions for native and non-native readers under no time pressure and time pressure



Total reading time

For the analysis of reading efficiency, we analyzed 49 participants' eye-tracking data, using the total reading time as a dependent variable. The results revealed a significant main effect of language, $F(1, 275) = 184.40$, $p < .001$. Specifically, non-native participants showed a longer total reading time ($M = 152046.92$, $SE = 3184.94$) than native participants ($M = 95545.53$, $SE = 2637.90$).

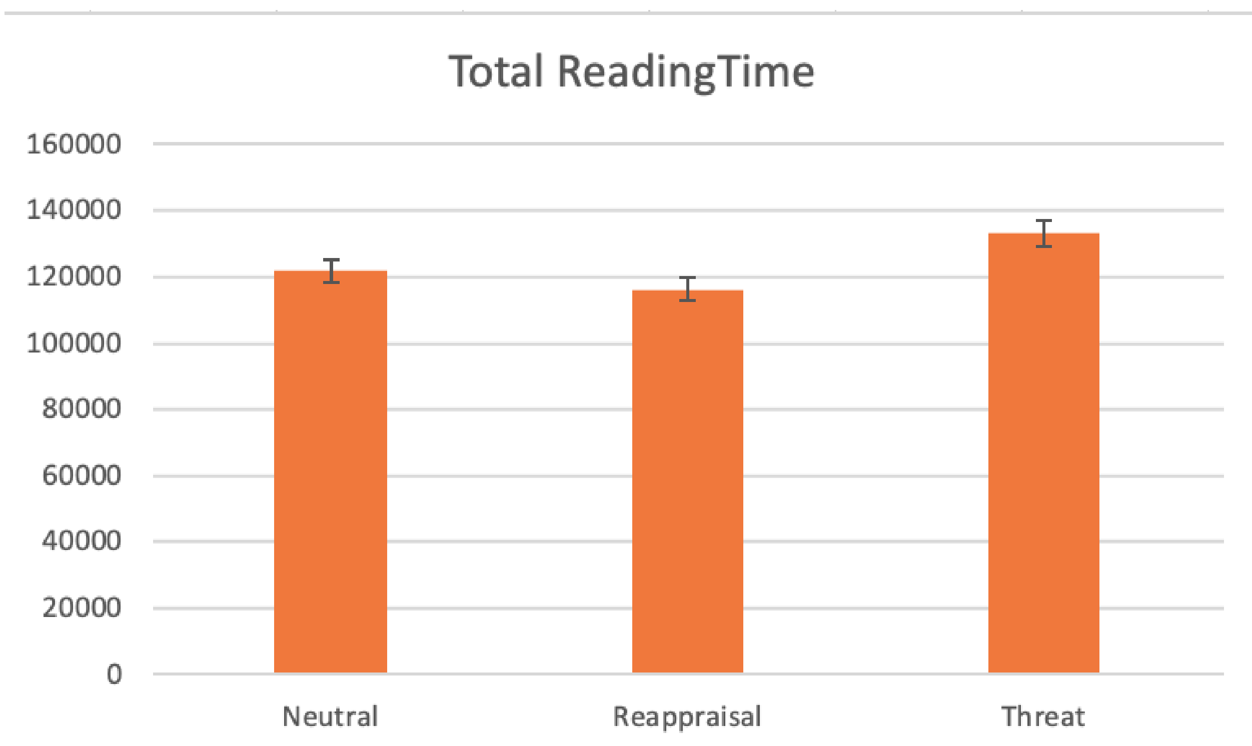
A significant main effect of time pressure was observed, $F(1, 275) = 120.58$, $p < .001$. Participants in the time pressure condition showed significantly shorter total reading time ($M =$

101271.64, *SE* = 3046.95) than those under no time pressure condition (*M* = 146320.80, *SE* = 2752.73). Additionally, as shown in Figure 11, the main effect of appraisal framing was also significant, $F(2, 275) = 5.51$, $p = .004$. Pairwise comparisons indicated that total reading time was significantly longer in the threat condition (*M* = 133206.04, *SE* = 3833.68) when compared to the neutral condition (*M* = 121917.87, *SE* = 3389.90) and the reappraisal condition (*M* =116264.76, *SE* = 3432.75).

However, the difference between the reappraisal and neutral conditions did not reach statistical significance ($p = .243$). Interestingly, working memory was a significant covariate, $F(1, 275) = 23.13$, $p < .001$, indicating that higher working memory was associated with shorter total reading time.

Figure 11

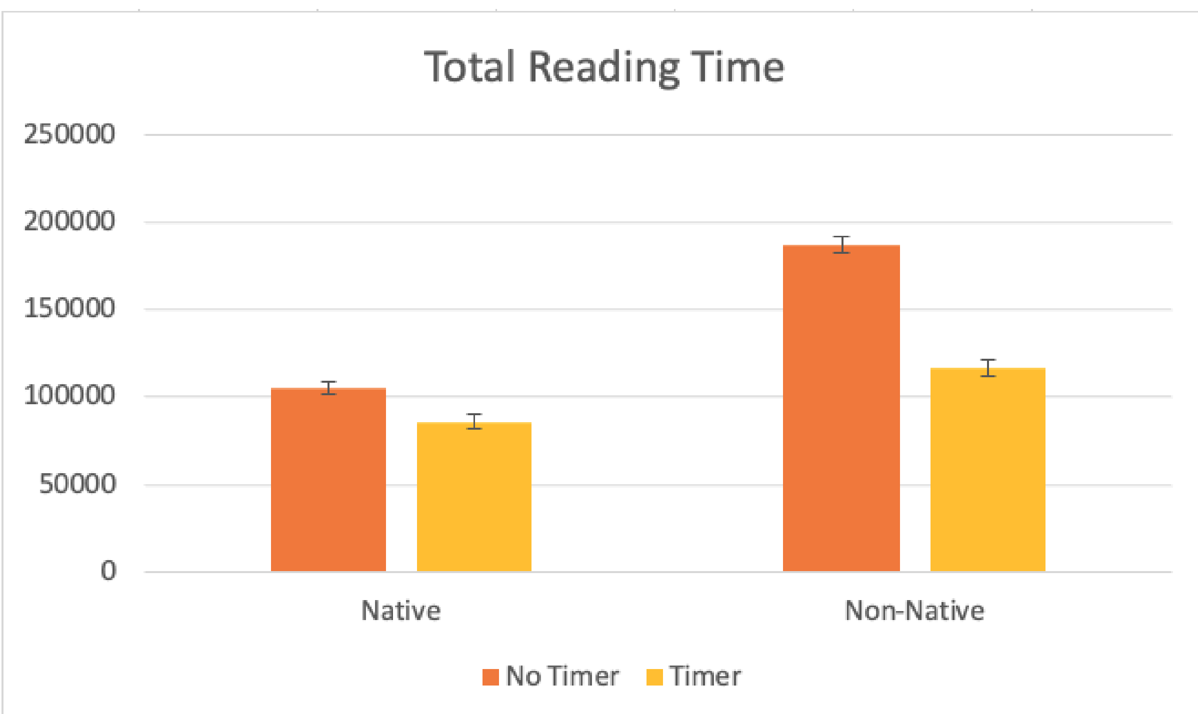
Mean Total Reading Time across appraisal framing conditions (neutral, reappraisal, threat)



Moreover, a significant interaction between language and time pressure emerged, $F(1, 275) = 39.53$, $p < .001$, shown as Figure 12. Follow-up analyses indicated that time pressure significantly reduced total reading time for both native participants, $F(1, 275) = 13.40$, $p < .001$, and non-native participants, $F(1, 275) = 126.94$, $p < .001$. Specifically, native participants showed shorter total reading times under time pressure ($M = 85904.61$, $SE = 3911.98$) compared to no time pressure ($M = 105186.45$, $SE = 3534.10$). A similar pattern was observed for non-native participants; the total reading times were also reduced under time pressure ($M = 116638.67$, $SE = 4706.16$) compared to no time pressure ($M = 187045.61$, $SE = 4229.57$). These results suggest that time pressure affected both groups, but the reduction in total reading time was more pronounced for non-native readers.

Figure 12

Mean Total Reading Time for native and non-native readers under no time pressure and time pressure conditions



Furthermore, a significant two-way interaction was also found between language and appraisal framing, $F(2, 275) = 20.03$, $p < .001$, shown as Figure 13. Simple effects analyses indicated that non-native participants exhibited significantly longer total reading times than native participants across all conditions, including the neutral condition, $F(1, 275) = 72.37$, $p < .001$, the reappraisal condition, $F(1, 275) = 10.35$, $p = .001$, and the threat condition, $F(1, 275) = 126.55$, $p < .001$. Specifically, the magnitude of this difference varied across conditions. For example, the gap between non-native and native participants was substantially reduced in the reappraisal condition compared to the neutral and threat conditions. However, there was no significant two-way interaction between time and appraisal framing, $p = .299$.

Moreover, as shown in Figure 14, the significant effect of three-way interaction was observed, $F(2, 275) = 7.193$, $p < .001$. Follow-up analyses revealed that when there is no time limit, native participants are spending more time in the reappraisal condition ($M = 122308.41$, $SE = 6757.24$) compared to the neutral ($M = 98177.03$, $SE = 5571.11$) and threat conditions ($M = 95073.90$, $SE = 6045.54$), yet there is no significant difference between the neutral and threat conditions.

For the non-native participants, students under no time limit spent the least amount of time in the reappraisal condition ($M = 149868.62$, $SE = 6093.85$), followed by the neutral condition ($M = 186435.04$, $SE = 8051.61$), and the longest reading time in the threat condition ($M = 226061.83$, $SE = 7870.99$). For the timed condition, similar to the native participants, there were no differences across the conditions, $p = .166$.

Figure 13

Mean Total Reading TIme across appraisal framing conditions (neutral, threat, reappraisal) for native and non-native readers

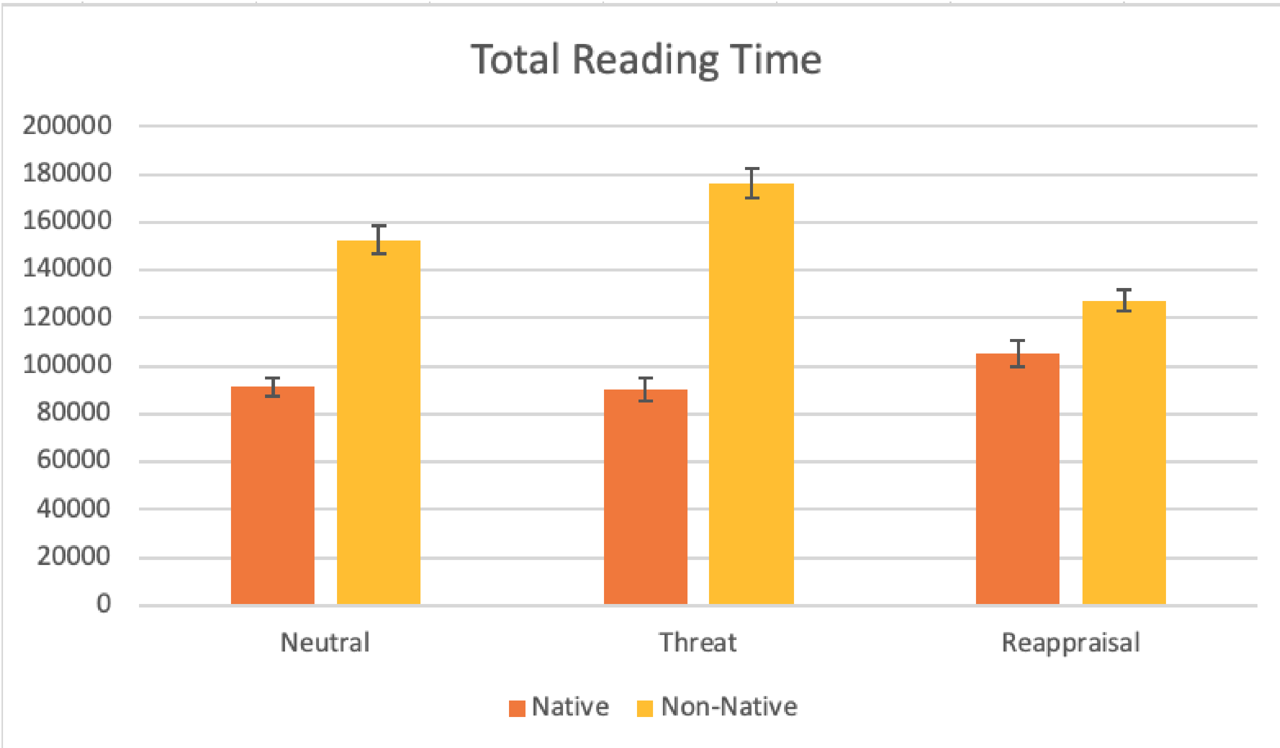
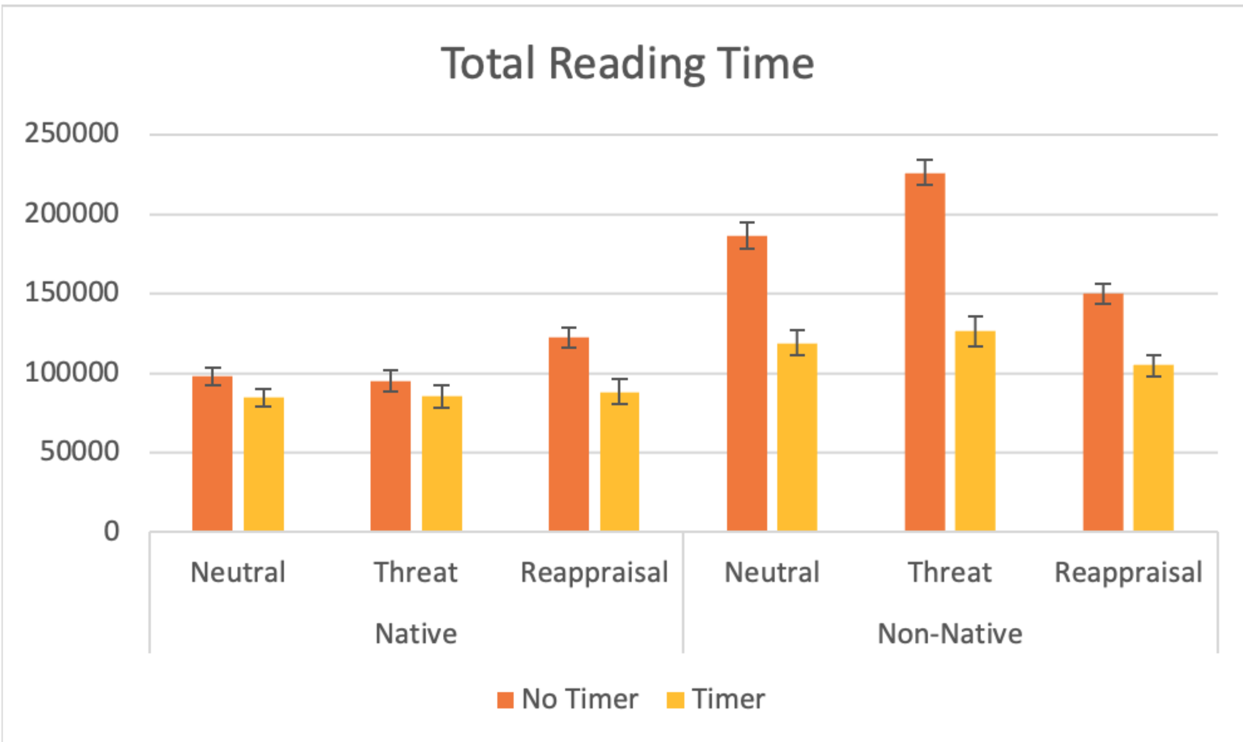


Figure 14

Mean Total Reading Time across appraisal framing conditions for native and non-native readers under no time pressure and time pressure



Two Self-report Questionnaires

For the Stress Mindset Measure (SMM), there was a significant interaction between prepost test (pre-test vs. post-test) and appraisal framing, $F(2, 55) = 4.63$, $p = .014$. Pairwise comparisons indicated that, at post-test, participants in the reappraisal condition reported significantly higher SMM scores than those in the neutral condition ($p < .001$), suggesting a more positive stress mindset following reappraisal framing. No other pairwise comparisons at post-test reached significance.

Moreover, results also showed a marginal three-way interaction between time pressure, prepost test, and appraisal framing, *p* = .078. However, follow-up analyses did not reveal a consistent pattern of significant effects, with only a marginal effect observed in the reappraisal condition at pre-test *p* = .069.

For the State Trait Anxiety Inventory (STAI), a significant main effect of the prepost test was observed for STAI scores, $F(1, 55) = 7.95$, $p = .007$. Specifically, participants reported significantly higher state anxiety after completing the reading task ($M = 2.10$, $SE = 0.08$) compared to before the task ($M = 1.93$, $SE = 0.06$), indicating an increase in momentary anxiety following the experiment. This suggests that the reading task increased participants' subjective anxiety levels, regardless of experimental condition.

However, no other significant main effects or interactions were observed, including interactions between time and language, time pressure, or appraisal framing.

DISCUSSION

In this study, we investigated how time pressure and appraisal framing jointly influence reading comprehension performance among native (L1) and non-native (L2) readers. By integrating behavioral accuracy with eye-tracking measures, we sought to determine whether psychological reappraisal could foster an eustress state that leads to superior performance compared to the distress induced by evaluative threat, particularly when readers are under time pressure.

The Relationship between Reappraisal Framing and Reading Performance

The first hypothesis (H1) predicted that reappraisal would lead to higher accuracy and efficiency compared to neutral and threat conditions, while the third hypothesis (H3) further specified that these benefits would be more pronounced under time pressure. Our findings provide compelling support for the integration of these two hypotheses.

Regarding accuracy, there was no significant main effect for appraisal framing. Meaning that overall accuracy scores did not differ across the three conditions, and did not support our H1. However, a significant interaction between time pressure and appraisal framing emerged, which supports H3. Specifically, results revealed that while time pressure reduced accuracy in the neutral and threat conditions, it had no such negative effect in the reappraisal condition.

These findings are consistent with previous research showing that the interpretation of physiological arousal plays a critical role in shaping performance. For example, Jamieson et al. (2010) found that participants who reinterpreted arousal as a challenge response performed better on math tasks under stress. Similarly, Jamieson et al. (2012) demonstrated that reappraisal leads to more adaptive physiological responses and improved cognitive control.

Together, prior research suggests that reappraisal can shift individuals from a threat state to a challenge state, thereby enhancing performance under stress. Building on this framework, our study's findings further demonstrate that in the presence of external stressors, such as time pressure, reappraisal can effectively buffer against the negative impact of stress, allowing individuals to maintain stable reading comprehension performance.

For reading efficiency, the results partially supported H1 and H3. Across efficiency measures, a general pattern emerged that the threat condition tended to show longer processing times. However, this pattern was not entirely consistent across all metrics. While total reading time was significantly longer in the threat condition, gaze duration did not differ between the neutral and threat conditions. Furthermore, the differences in first fixation duration between these two conditions were only marginal. Notably, the reappraisal condition consistently showed shorter processing times across measures.

However, it is crucial to consider these efficiency measures in the context of accuracy performance. While the main effect of framing was not significant in accuracy performance, the interaction effect points toward a more complex relationship between time pressure and appraisal framing. Specifically, although both the reappraisal and neutral conditions showed shorter first fixation duration, gaze duration, and total reading time than the threat condition under time pressure, their accuracy patterns differed. Under time pressure, accuracy remained stable in the reappraisal condition, whereas it decreased in both the neutral and threat conditions. Although participants in the neutral condition also read faster, their speed-accuracy trade-off was disrupted, meaning that faster reading was not accompanied by adequate comprehension. This pattern is partly consistent with previous findings showing that time pressure often leads to faster reading and shorter fixation durations, while its effect on comprehension depends on readers' ability to adapt (Vibert et al., 2025).

However, the present findings further suggest that such adaptation is not uniform across conditions. In the reappraisal condition, shorter durations were observed with stable accuracy. This indicates that time pressure facilitated more efficient processing without compromising comprehension. In other words, participants were able to process the text more quickly while maintaining performance.

Therefore, these findings not only support H3, but also suggest, much like the prior finding, that while reappraisal may not provide a general advantage in low stress contexts, it functions as a buffer that helps maintain stable performance under external pressure. These results also indicate that the effectiveness of adaptation depends on how stress is interpreted.

The Relationship between Threat Framing and Reading Performance

The second hypothesis (H2) predicted that the evaluation threat would impair performance and efficiency, reflecting distress, was also partially supported. While there was no overall main effect of appraisal framing on accuracy, participants in the threat condition showed lower accuracy under time pressure. This suggests that the negative effects of threat are context-dependent and become more pronounced under external stress.

This pattern aligns with the past research indicating that individuals often interpret physiological arousal as anxiety or threat in stressful contexts, which can lead to maladaptive responses (Mendes et al., 2007; Bouton et al., 2001). As a result, such interpretations may amplify perceived task demands and reduce effective cognitive functioning.

Moreover, the eye-tracking measures revealed a general pattern where the threat condition tended to have longer processing times. The eye-tracking results showed a consistent pattern across all three measures, where processing times were longer in the threat condition compared to the reappraisal condition. This was observed for first fixation duration, gaze duration, and total reading time. However, this pattern was not identical across all comparisons. In particular, the difference in first fixation duration between the neutral and threat conditions was only marginal. In addition, the gaze duration did not differ between the threat and neutral conditions. This suggests that the effect is driven more by the facilitative role of reappraisal rather than a uniform slowing effect of threat.

Notably, longer first fixation duration, gaze duration, and total reading time are generally associated with slower processing, increased cognitive load, and less efficient reading. Given that all participants read identical texts across conditions, the longer first fixation, gaze duration, and total reading time observed in the threat condition cannot be attributed to differences in textual complexity; instead, they reflect the influence of appraisal framing. Specifically, threat framing appears to disrupt reading fluency by requiring greater attentional resources during processing.

Interestingly, gaze duration showed a pattern that partly supported our second hypothesis under the interaction between threat framing and time pressure. Consistent with this prediction, participants in the evaluation threat condition showed longer gaze durations under time pressure compared to the no time pressure condition. This suggests that threat framing impaired reading efficiency when combined with time pressure.

In contrast, participants in the reappraisal and neutral conditions showed a pattern consistent with previous research (Vibert et al., 2025), with shorter gaze durations under time pressure. A prior study has shown that time constraints lead to shorter fixations and faster eye movements, reflecting more efficient scanning of the text. However, these adjustments do not necessarily preserve comprehension. In the present study, accuracy decreased under time pressure in both the neutral and threat conditions, suggesting that faster eye movements may come at the cost of reduced comprehension.

Overall, these findings suggest that appraisal framing and time pressure may interact to increase cognitive load, depending on how people interpret it. For example, when participants felt evaluated and had limited time, they required more attentional resources to process the text. As a result, their reading became less efficient.

The Relationship between Language Group and Reading Performance

The fourth hypothesis predicted that appraisal framing would have different effects on L1 and L2 readers. Overall, the results provide partial support for this hypothesis and suggest that language background plays a critical role in how individuals respond to stress during reading. Consistent with prior findings, L2 participants showed overall lower accuracy and longer processing times compared to L1 participants, indicating greater cognitive demands during reading. This finding aligns with Rai et al. (2014), who found that stress increased reaction times primarily for L2 readers, particularly those with lower working memory or higher reading anxiety, while L1 readers showed greater resilience under stress.

Notably, this study revealed that the effects of time pressure differ across stages of processing for L1 and L2 readers. At the early stage, as reflected by first fixation duration, time pressure significantly reduced processing time for non-native participants, but not for native participants. This suggests that L2 readers are more sensitive to time pressure during early lexical processing.

At a slightly later stage of processing, as reflected by gaze duration, time pressure did not significantly affect either group. Although a marginal trend suggested that non-native participants may still be somewhat more sensitive. This pattern suggests that the effects of time pressure may emerge most strongly during early lexical processing and become less pronounced during later integrative stages of reading.

At the overall processing level, time pressure significantly reduced total reading time for both native and non-native participants. However, this reduction was much larger for non-native readers. Specifically, non-native participants showed a substantially greater decrease in total reading time under time pressure, indicating that non-native participants compressed their processing time to a greater extent in response to time constraints. However, combined with previous findings in this study for reading accuracy between L1 and L2 participants, such a pattern may reflect a compensatory strategy. Even L2 participants showed shorter total reading time in the time limit condition, but compared with L1 participants, their reading accuracy was also lower in the time limit condition, where they speed up their reading more aggressively, potentially at the cost of comprehension.

Furthermore, the interaction between language and appraisal framing showed no significant effects on accuracy. However, clear differences emerged in reading efficiency. Across all three measures, non-native participants showed significantly longer first fixation durations, gaze durations, and total reading times than native participants in the neutral, reappraisal, and threat conditions.

Importantly, the magnitude of this language difference varied across framing conditions. Specifically, the gap between native and non-native participants was reduced in the reappraisal condition compared to the neutral and threat conditions. This suggests that reappraisal may help attenuate the processing disadvantage typically observed in L2 readers.

These findings are consistent with previous research showing that stress affects attention and working memory (Eysenck et al., 2007). In the present study, L2 participants consistently required more processing time across conditions, indicating greater cognitive demands during reading. However, the reduced gap in the reappraisal condition suggests that adaptive stress interpretation may help free up cognitive resources. In contrast, under neutral and threat conditions, L2 participants may have fewer available resources to manage both comprehension and stress, making their reading performance more vulnerable under pressure.

How Working Memory Affects Reading Performance

The fifth hypothesis (H5) predicted that working memory capacity would moderate the effect of appraisal framing on reading efficiency. However, the present results provided only limited support for this. Although working memory was a significant predictor of reading performance, a finding consistent with previous scholarship (Eysenck et al., 2007), there was no clear evidence that it significantly interacted with appraisal framing or time pressure.

Aligned with previous findings, working memory played an important role in reading comprehension. Higher working memory capacity was associated with better performance and more efficient processing, supporting findings that stress can impair working memory and attention, particularly under demanding conditions (Eysenck et al., 2007; Luethi et al., 2009). In addition, prior research using eye-tracking has shown that working memory is closely related to how readers allocate attention during reading, with higher working memory capacity associated with shorter fixation durations and more efficient processing of textual information (Ardoin, 2019; Yeari, 2021).

However, contrary to our prediction, working memory did not significantly moderate the effects of appraisal framing. One possible explanation is that the influence of working memory appeared to exert a general facilitative effect on reading performance, rather than showing condition-specific modulation in the present study. In other words, individuals with higher working memory tended to perform better overall, but did not necessarily respond differently to specific stress manipulations such as reappraisal or threat.

Another possibility is that the effects of working memory may be more pronounced under higher levels of stress or more demanding tasks. In the present study, the level of time pressure may not have been strong enough to produce differential effects across working memory levels. Future research could further examine this possibility by manipulating stress intensity or including more sensitive measures of individual differences.

Implications

This study contributes to a better understanding of how different types of stress influence cognitive processing during reading. By examining the interaction between time pressure and appraisal framing, the findings identify specific conditions under which stress can either enhance or impair reading performance. Importantly, the results demonstrate that stress is not uniformly detrimental. Instead, its effects depend on how individuals interpret the situation, highlighting the role of cognitive appraisal in shaping performance outcomes.

From a theoretical perspective, these findings extend existing models of stress and performance, such as the Yerkes–Dodson framework (1908), by showing that the impact of stress is not only determined by its intensity but also by how it is perceived. Our results further provide empirical support for the distinction between eustress and distress, suggesting that reappraisal can shift individuals toward a more adaptive state even under external pressure.

In addition, the findings have contributed to the literature on reading and cognitive processing by showing that stress affects not only overall performance, such as accuracy, but also how readers process text in real time. Using eye-tracking measures, this study provides evidence that stress changes how long readers fixate on words and how they move through the text. These momentary changes provide insight into how readers adjust their reading behavior under different stress conditions. Therefore, it is important to consider not only final performance outcomes, but also the underlying reading processes when studying reading comprehension.

From a practical perspective, these findings have provided important implications for educational settings. A clearer understanding of how reappraisal and time limits shape reading accuracy and efficiency can help teachers, test designers, and reading specialists create more effective learning and testing environments. For example, moderate levels of time pressure, when paired with supportive framing, may help students stay focused and engaged without compromising comprehension. In contrast, high-pressure or threat-based environments may increase cognitive load and reduce performance, especially for stress sensitive learners.

Furthermore, by comparing L1 and L2 readers, this study highlights how language background interacts with stress to influence reading performance. The results suggest that L2 readers are more sensitive to stress and may require additional support under demanding conditions. This has important implications for designing more inclusive assessments and instructional practices. For instance, educators may consider adjusting time constraints, providing clearer instructions, or incorporating stress-reduction strategies to better support L2 learners. Overall, these findings emphasize the importance of considering both psychological factors and individual differences when evaluating reading performance. By showing that stress can either support or hinder learning depending on how it is experienced, this study offers valuable insights for both theory and practice.

Limitations and Future Research

Despite this study offering several meaningful findings, some limitations should be acknowledged. First, the data in this study was collected from a women's college, resulting in a predominantly female participant pool. While this context provided a relatively controlled and consistent sample, it may limit the generalizability of the findings. Therefore, future research should include more diverse samples in terms of gender, educational background, and cultural context to determine whether the present findings can be extended to broader populations.

Furthermore, eye-tracking data also presents some limitations. While eye-tracking measures provided valuable insight into real-time reading processes, only 49 participants contributed usable eye-tracking data. This relatively smaller data size may limit the reliability and generalizability of the findings related to reading efficiency. In addition, some effects observed in this study, particularly those involving the interaction between threat framing and time pressure, were primarily reflected in specific measures such as gaze duration and were not consistently observed across all eye-tracking measures. This suggests that certain findings may be measure-specific and should be interpreted with caution. Future research could aim to analyze larger eye-tracking datasets and explore additional measures, such as regression patterns or re-reading behavior, to provide a more comprehensive understanding of how stress influences reading.

Second, this study found that working memory did not significantly moderate the effects of appraisal framing or time pressure. One possible explanation is that the influence of working memory may be more general rather than condition-specific. Another possible explanation is that the present study may not have been sensitive enough to detect these interaction effects. For example, the level of time pressure may not have been strong enough to produce differential effects across individuals with varying working memory capacity. Therefore, future research could address this limitation by manipulating stress intensity more systematically or by including more fine-grained measures of working memory and related cognitive processes.

Finally, the present study focused on a specific type of reading task under controlled experimental conditions. While this design strengthens internal validity, it may not fully capture the complexity of real-world reading situations. Interestingly, informal post-experiment interviews revealed that some participants reported experiencing stress due to the laboratory setting itself, which created a sense of pressure. Others indicated that the combination of the reading materials and testing environment reminded them of prior high pressure testing situations, such as the SAT or TOEFL, which may have further influenced their stress responses. These factors suggest that participants' stress levels may not have been driven solely by the experimental manipulations, but also by contextual and experiential influences.

As a result, caution is warranted when generalizing these findings to real-world settings. Future research could extend this work by examining different types of texts (e.g., more complex or domain-specific materials), varying task demands, or employing more naturalistic reading environments to better understand how stress and appraisal operate in everyday learning contexts.

Despite these limitations, the present study provides important insights into how stress, appraisal, and individual differences interact to influence reading performance. By identifying both the boundaries and strengths of these findings, future research can build on this work to further clarify the role of stress in cognitive processing and learning.

Compelling Conclusion

Overall, the present study demonstrates that the effects of stress on reading performance are not uniform; they depend critically on how stress is interpreted. While time pressure alone can impair comprehension, reappraisal allows individuals to maintain both efficiency and accuracy, highlighting its role as a protective mechanism under stress. In contrast, threat framing increases cognitive load and limits readers' ability to adapt, particularly under demanding conditions.

Importantly, these effects are not the same for all readers. Non-native readers were more sensitive to stress, suggesting that individual differences in language background shape how stress influences cognition. Although working memory contributed to overall performance, it did not determine how individuals responded to stress in this study.

Taken together, these findings show that stress does not have a single effect on reading. Its impact depends on how it is interpreted and on individual differences such as language background. In some cases, stress can support performance, while in others it can harm it. This highlights the importance of considering both cognitive and emotional factors when studying reading.

APPENDIX A

Sample of NELSON-DENNY Reading Test Passage

Many insects community through sound, Male crickets use sound to attract females and to warn other males away from their territories. They tub a scraper on one forewing against a vein on the other forewing to procedure chirping sounds. Each cricket species produces several calls that differ from those of other cricket species. In fact, because many species look similar, entomologists often use the class to identify the species. Mosquitoes depend on sound, too. Males that are ready to make home in on the buzzing sounds produced by females. The male senses this buzzing by means of tiny hairs on his antennae, which vibrate only to the frequency emitted by a female of the same species.

Insects may also communicate by tapping, rubbing, or signaling. Fireflies use flashes of light to find a mate. Each species of firefly has its own pattern of flashes. Males emit flashes in flight, and females flash back in response. This behavior allows male fireflies to locate a mate of the proper species. However, they must beware of female fireflies of the genus *Photuris*, which can mimic the flashes of other species. If a male of a different species responds to the flash of a *Photuris* female and attempts to mate, the female devours him. This is surely one of the more unusual behavioral adaptations in the enormously successful world of insects.

APPENDIX B

Description of Stress Mindset Measure (SMM)

Participants rated items on a five-point scale ranging from 0=strongly disagree to 4=strongly agree. SMM scores are obtained by reverse scoring the four negative items (indicated by an *) and then taking the mean of all 8 items. Higher scores on the SMM represent the mindset that stress is enhancing.

Stress Mindset Questions

Rate the extent to which you agree or disagree with the following questions:

(scoring: use this scale for all 8)

0 = Strongly Disagree

1 = Disagree

2 = Neither Agree nor Disagree

3 = Agree

4 = Strongly Agree

1. The effects of stress are negative and should be avoided.*
2. Experiencing stress facilitates my learning and growth.
3. Experiencing stress depletes my health and vitality.*
4. Experiencing stress enhances my performance and productivity.
5. Experiencing stress inhibits my learning and growth.*
6. Experiencing stress improves my health and vitality.
7. Experiencing stress debilitates my performance and productivity.*
8. The effects of stress are positive and should be utilized.

APPENDIX C

Description of State Trait Anxiety Inventory

Read each statement and select the appropriate response to indicate how you feel right now, that is, at this very moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

1	2	3	4
Not at all	A little	Somewhat	Very Much So

1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I feel tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel uncomfortable	1	2	3	4
11. I feel self confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I feel jittery	1	2	3	4

14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

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