2023

# The Relationship Between Task-Induced Stress and Time Perception

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# THE RELATIONSHIP BETWEEN TASK-INDUCED STRESS AND TIME PERCEPTION

by

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A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Psychology
in the College of Sciences
at the University of Central Florida
Orlando, Florida

Spring Term, 2023

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# Abstract

A distortion of time is often reported under the presence of stress or threatening stimuli, for instance motor vehicle accidents or near-death experiences. There is a lack of research on the complexity of time distortion under stress; thus, the present study aimed to explore the relationship between stress and time perception. Given the challenges associated with producing a stress response in a laboratory setting, difficult tasks have been previously used to produce a stress response, such as anagram tasks. However, it remains unknown whether experiencing time pressure while completing a stressful task can also influence time distortion. To investigate this, participants completed either an easy or difficult anagram task and received either an unspecified time limit or no time limit to complete the task. It was hypothesized that participants would experience the greatest distortion of time when the task was difficult, and they were provided an unspecified time limit. Contrary to the hypothesis, we failed to find differences in task performance or time perception across the various conditions, which may be explained by the inability to produce a stress state. While stress manipulation was unsuccessful, the findings suggest utilizing multiple tasks may be more effective at replicating a physiological or psychological stress state. Thus, the results of this study warrant further investigation to examine the relationship between stress, time pressure, and time distortion.

## Acknowledgements

I would first like to thank my thesis chair, Dr. Peter Hancock, and Dr. Isabell Winkler for their continued support and guidance throughout my research. I would also like to thank doctoral student Mira Gruber for being my mentor and role model in academic research. I am truly grateful for this opportunity and the assistance I was provided during this process.

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# Introduction

A distortion of time perception is often reported under the presence of extreme stress or threatening stimuli (Hancock & Weaver, 2005), for instance motor vehicle accidents or near-death experiences. Such distortions are generally experienced as time appearing to drastically speed up or slow down, altering one's perception of the time-based events. Whether someone perceives a slowing down or speeding up of time depends on the direction of attention during the event. When attention is directed toward the threatening stimulus, events are registered at an increased rate. The increased registration of external events results in time appearing to slow down and be overestimated (Hancock & Weaver, 2005). When attention is directed toward the experienced stress symptoms, rather than toward the threatening stimulus itself, time appears to speed up and be underestimated (Hancock & Weaver, 2005). Such distortions may result in the inability to effectively process incoming stimuli, thus debilitating one's performance.

Given that authentic high-stress conditions are generally experienced suddenly and unexpectedly (Hancock & Weaver, 2005), it is difficult to study the relationship between stress and time distortion in a laboratory setting. Thus, researchers often resort to stress-inducing tasks to manipulate such states. Task-induced stress is commonly accomplished by utilizing varying levels of task difficulty or by introducing a multi-task environment, resulting in stress symptoms, such as task disengagement, distress, and worry (Matthews et al., 2002). While past researchers have successfully replicated stress conditions using such techniques, there is a lack of research on how time pressure to complete a task may impact one's stress response, and how time is perceived under such conditions. Thus, the goal of the present study is to explore the relationship between task-induced stress, time-limit-induced stress, and time perception. Specifically, it is of interest to know whether time pressure can be used along with varying task difficulties to manipulate one's stress state, and if such states produce a distortion of time. The contributions of the present study may provide alternative means to replicate a stress state ethically within a laboratory setting and provide further information on the association between stress and time distortion. The given study may also provide important implications for settings that involve time limits, for instance in testing environments.

# Literature Review

## Time Perception and Distortion

Although not physically observed, the passage of time is experienced and referenced daily. For instance, utilizing phrases such as “time flying by” or “time crawled on” are common expressions in the English language. Rather than experiencing time directly, events are perceived in time and in relation to temporal passing (Le Poidevin, 2019). Pöppel (1978) describes the fundamental aspects of temporal experience. These fundamental aspects are known as ‘elementary time experiences,’ and include change, past and present, and the experience of duration. Within the experience of duration, time distortion may occur. Defined by the American Psychological Association (APA) (2022), time distortion is a perceptual transformation in which time appears to pass either with great rapidity or extreme slowness. Essentially, the experience of time appears to pass at an increased or decreased speed when compared to the actual duration of time that has passed. While there has been minimal research on this phenomenon, prior psychological research suggests that alterations to temporal judgements may be associated with one’s moods and emotions (Droit-Volet & Meck, 2007). For example, the well-known term “time flies when you are having fun” suggests that temporal durations are experienced at a faster rate when paired with positive emotions. Conversely negative emotions, such as boredom or stress, may be associated with the apparent slowing of one’s temporal perception (Hancock & Weaver, 2005). Thus, one’s psychological state can influence their temporal judgement. Although the underlying neural mechanisms that allow for accurate time perception remain unknown, multiple theoretical models attempt to describe this process by means of a metaphorical internal clock.

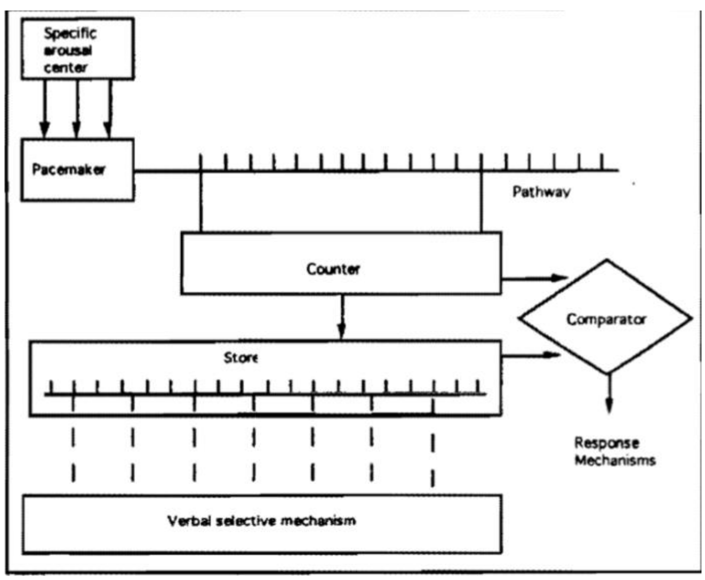
## Theories of Time Perception

### *Treisman's Internal Clock Model*

Initially proposed by Treisman (1963), the Internal Clock Model (see Figure 1) interprets the passing of time as it is experienced. The internal clock, a temporal processing unit that aids in accounting for the passing of time, is divided into three parts: a pacemaker, a counter, and a comparator. These individual compartments simultaneously work together to allow for accurate time perception (Treisman, 1963). The pacemaker continuously generates pulses at a constant frequency, where the number of pulses accounts for a physical time duration. The pacemaker is similar to the hands on a mechanical clock, which move at a consistent frequency to account for the passing of time. These pulses are sent into a calibration unit, in which their frequency is altered pending information received by sensory inputs (Treisman et al., 1990; Treisman, 1993). Essentially, when a sensory organ is stimulated, nerve impulses are transmitted to the calibration unit. The frequency at which pules are emitted from the pacemaker is then altered based on arousal levels. The calibration unit responds to the increased stimulation of sensory organs by increasing the frequency of the pulses to account for a more accurately recorded time duration. Following the alteration of the pulse frequency by the calibration unit, said pulses travel to the counter, where the numerical value of pulses is recorded and sent to the store. The store is a short-term holder for the recorded pulses, which represents a passage of time (Treisman, 1963). These values are readily available to be retrieved by the comparator, which can compare the recorded pulses to a new set of pulses from the counter. These values may be compared in a situation in which a reaction of some sort is necessary. For example, when in a batting cage, an auditory external signal (i.e., buzzer) or visual signal (i.e., a flashing light) is presented before the ball is released from the pitching machine. The first time the ball is released, the numerical value of pulses it takes for the ball to reach the bat is temporarily recorded into the store. When the next ball is released from the pitching machine, the comparator references the previous number of pulses within the store to determine the appropriate time to swing the bat and hit the ball. A verbal selective mechanism, also a part of the internal clock model and connected to the store, is a long-term storage unit which acts as a retrieval mechanism when given verbal cues (e.g., one minute, five minutes, ten minutes) (Treisman, 1963). This is how duration of time can be roughly estimated without continuously viewing a physical clock.

**Figure 1**

*A Model of Treisman's Internal Clock*



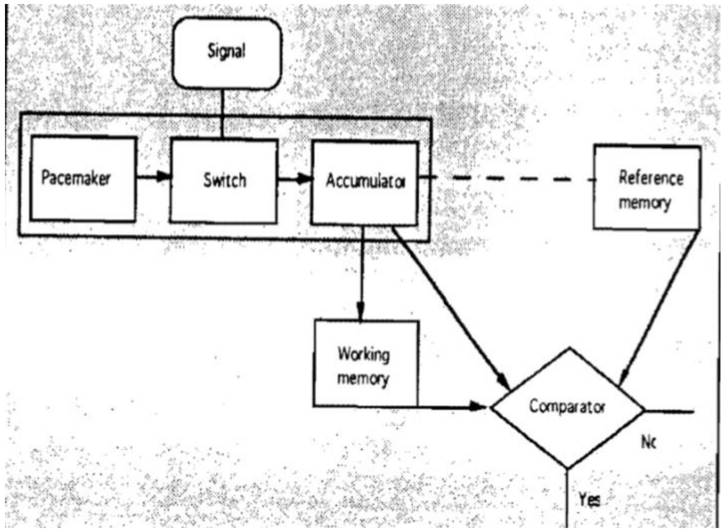

Although evidence supporting the Internal Clock Model was limited, Treisman believed collecting evidence in support of the individual parts of the model and the frequency, or speed at which it functions, would strengthen the hypothesis. Treisman and colleagues (1990) conducted a study in which participants were presented with specific time durations and were asked to estimate the length of said duration in seconds. This method assumes that the estimated time duration made by the participants is a direct representation of the frequency at which the pacemaker releases pulses within their internal clock (Treisman et al., 1990). During the time durations, participants were also exposed to a sequence of auditory clicks at a fixed frequency. These clicks were intended to act as auditory stimulation, which has been suggested to increase the speed of the internal clock (Treisman, 1963; Treisman et al., 1990). Thus, increasing the frequency of the auditory clicks should consequently increase the speed of the internal clock, resulting in participants overestimating the temporal duration experienced. The results provided evidence that for many participants, the auditory clicks interfered with time estimations, suggesting that the functioning of the internal clock was affected. However, only about 65% of the estimated time values increased as auditory clicks increased, while other time estimations made by participants decreased (Treisman et al., 1990). These results do not fully support the hypothesis that auditory stimulation would increase the speed of the internal clock, thus increasing the estimated time duration. Although Treisman and colleagues (1990) provided evidence of an internal clock which aids in temporal processing, a more complex model was required to account for the results.

### ***Scalar Timing Model***

The Scalar Expectancy Theory (SET), otherwise known as the Scalar Timing Model (Gibbon, 1977) was proposed following the publication of Treisman's (1963) Internal Clock Model. Similar to the Internal Clock Model, the SET (see Figure 2) seeks to describe the intricate and innate process of understanding time perception and time-based behavior in animals (Church, 2003; Gibbon, 1977). The SET suggests an internal temporal processing unit that aids in the processing of time. The unit is composed of three components: a perceptual timing mechanism, memory, and the decision process (Church, 2003; Meck, 1996). The perceptual timing mechanism includes a pacemaker, a switch, and an accumulator. The pacemaker, similar to Treisman's internal clock, releases pulses following movement of the switch, which is triggered by an external signal that suggests the beginning of a time period. The pulses are then sent to the accumulator, where they are categorized and counted to describe a passage of time, mimicking a stopwatch. For example, when an external signal or stimuli is experienced that represents the beginning of a time period, the switch opens, allowing for pulses to be emitted and counted by the accumulator until the end of the external signal or stimulation. The numerical pulse value is then transferred into a working memory component, in which it is stored and can be compared to other timed durations within a reference memory store. The reference memory store contains a long-term memory component that holds estimated numerical pulse values from past experiences. The decision process utilizes the number of pulses from the working memory component (i.e., the current value), the number of previously counted pulses within the reference memory store (i.e., the past value), and a threshold (i.e., whether a fixed amount of time before or after the current pulse and the reference pulse are the same) to make a behavioral decision (Church, 2003; Meck, 1996). For example, in a batting cage an auditory external signal (i.e., a buzzer) or visual signal (i.e., a flashing light) is presented before the ball is released from the pitching machine. This signal suggests the beginning of a time period, triggering the switch to open and allowing the pacemaker to emit pulses. Once the ball reaches the bat, the pulses are counted by the accumulator and stored in the reference memory store. The next time a ball is released from the pitching machine, the previously counted pulses are compared to a new set of pulses to determine the appropriate time to swing the bat and hit the ball.

**Figure 2**

*A Model of the Scalar Expectancy Theory (Gibbon, 1977)*




Church and Deluty (1977) aimed to describe and provide evidence for the functional parts of the internal clock within animals utilizing a time interval bisection task. Rat subjects were exposed to two stimuli prior to the experimental trials, one that was classified as 'short' and one that was classified as 'long.' At the start of each trial, the subject was presented with either the 'short' or 'long' stimulus, each of which corresponded to a lever. Both levers were inserted into the cage following the presentation of the stimulus, and the animal subject was required to respond to the lever that matched the duration of the stimulus. If the response made matched the temporal duration of the stimulus presented, food was delivered. In a different condition, subjects were presented with stimuli that were classified as either 'short' or 'long' but were not the same temporal duration as the stimuli initially taught. Again, subjects were given a food reward when they responded to the appropriate lever. If the internal clock model is correct, the animal subjects should be able to time the presented stimuli and respond accordingly to the appropriate lever (Church & Deluty, 1977). Results showed that the subjects were able to accurately respond to the lever that correlated to the temporal duration of the stimulus presented (Church & Deluty, 1977). Thus, the internal clock as described by the SET was supported. It can also be noted that the bisection point (i.e., the duration of the stimulus which was classified by subjects as 'long' 50% of the time) was calculated. Church & Deluty (1977) found that the bisection point was located at the geometric mean of the initially learned 'short' and 'long' durations.

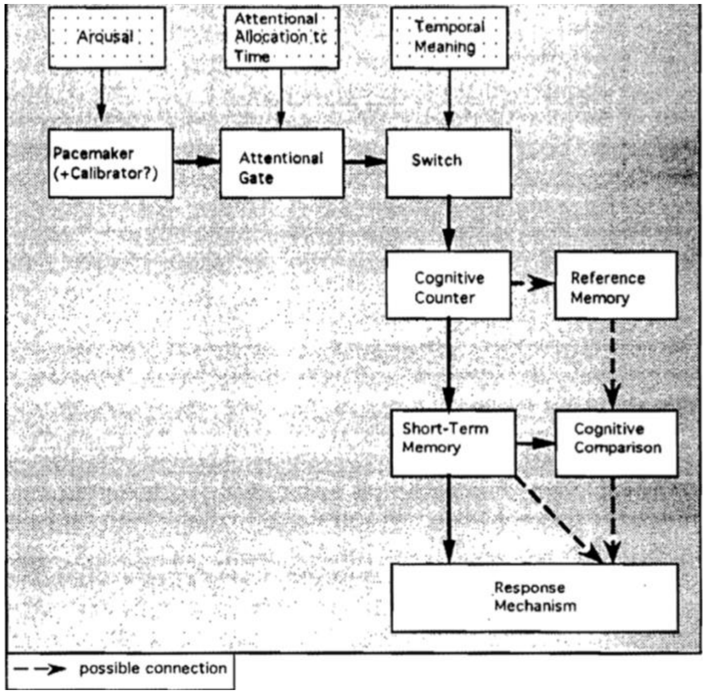
Wearden (1991) conducted a similar interval bisection task on human subjects to test the validity of the SET. As in the previous experiment, subjects were exposed to two sets of stimuli, two of which were classified as 'short' and two classified as 'long'. Following the initial exposure, participants were presented with a stimulus and asked to determine if the duration of said stimulus was more similar to the already classified 'short' or 'long' stimulus. Subjects were highly accurate in their classification of the short and long stimulus presented (Wearden, 1991). These results suggest an extreme understanding and ability to discriminate between differing temporal durations, supporting the SET and an internal clock. Unlike the bisection experiment results conducted with animal subjects (Church & Deluty, 1977), the bisection point (i.e., the duration of the stimulus which was classified by subjects as 'long' 50% of the time) in Wearden's (1991) study was closer to the arithmetic mean rather than the geometric mean (these two types of means utilize different equations to find the central tendency, or average of all calculated values). Thus, the numerical findings within these two studies were not consistent. These results may be due to the differing time durations used to represent the long and short stimuli within each experiment. Despite the inconsistency noted with the bisection point, both experiments provide evidence supporting the SET.

### ***The Attentional-Gate Model***

Derived from both Treisman's Internal Clock Model (Treisman, 1963) and the Scalar Expectancy Theory (Gibbon, 1977), the Attentional-Gate Model (AGM) suggests an internal temporal processing unit, or a unit that aids in accurately processing time (Zakay & Block, 1994, 1996). Containing all the previously discussed components within the SET (i.e., the pacemaker, counter, store, and comparator), the AGM differs only by the inclusion of a cognitive temporal component, the attentional gate (see Figure 3). Placed between the pacemaker and the switch, the gate is utilized in correspondence to the amount of attention issued towards temporal passing. When attention to time is increased, the gate opens wider allowing for more pulses to pass through and be sent to the counter. Consequently, when attentional components are not focused on time, the gate closes, and pulses are not emitted to the counter. Essentially, when the passing of time becomes relevant and important, more pulses are able to be emitted through to the counter where more time (in the form of pulses) can be accounted for (Zakay & Block, 1994, 1996). Thus, when attentional resources are directed specifically to the passing of time, the temporal qualities of events can be more accurately considered.

**Figure 3**

*A Model of the Attentional Gate Model (Zakay & Block, 1994, 1996)*




Zakay and Diamant (2011) conducted a study to examine the relationship between time duration and attention. Participants were tested individually in two separate sessions one week apart. The first meeting included creating an attentional profile of the subject via assessments found to be reliable and valid in identifying individual attentional functions (Zakay & Diamant, 2011). In the second meeting, participants were tested on time-based tasks, such as identifying short and long-time durations with and without attentional distractions. Participants who scored high in sustained attention (i.e., the ability to divide one's attention and ignore distractors) were the most accurate in differentiating between short and long durations (Zakay & Diamant, 2011). These findings demonstrate that the ability to direct attentional resources to temporal passing while ignoring surrounding distractors is crucial for accurate time perception, thus supporting the addition of the attentional gate within the Attentional-Gate Model.

**Stress**

Stress is the physiological or psychological response to internal or external stressors (APA, 2022). Stress can be a stimulus, a response to a stimulus, or a physiological consequence of one's response (Kemeny, 2003). Stressors are subjective, meaning that there are no definite stressors experienced by all of the human population. What may be a stressor for one individual, may not be for another. Physiologically, it is believed that stress is interpreted by an organism as a threat, initiating a fight or flight response (Kemeny, 2003). When such threat is identified, the sympathetic nervous system, which responds to threatening stimuli, releases adrenaline into the blood stream, resulting in an increase of involuntary processes such as heart rate (Kemeny, 2003). Many describe this internal process as an "adrenaline rush." It is also understood that internal or external stressors have a negative effect on attentional resources. One study, which examined the relationship between acute stress and attentional mechanisms found that those who were exposed to a stress-inducing task displayed enhanced activity of the sympathetic nervous system and had an increased error rate on the task compared to the control group (Sänger et al., 2014). Essentially, when participants were experiencing the threatening stimuli, their attentional resources were mobilized to allow for the sympathetic nervous system to properly respond to the interpreted threat, rather than directing attentional resources to the task.

### *Task-Induced Stress*

Recreating authentic stress responses within the constraints of the laboratory is challenging. Thus, researchers often utilize stress-based tasks in an attempt to replicate the feeling of stress easily and ethically. Such tasks may be highly difficult or require the completion of multiple tasks at once (see Matthews & Desmond, 2002). Task disengagement, distress, and worry have been shown to be common responses to tasks aiming to cause a stress response and generally result in poor task performance (Matthews et al., 2002). When exposed to a difficult task, participants may become disengaged in a task and reluctant to apply effort towards said task, resulting in a negative performance. Stress responses are positively correlated to task-demands, as increasing tasks may result in an increase of distress. Such experiences often overwhelm individuals, potentially making them feel inadequate and lack confidence. Thus, one's performance decreases while stress increases. Worry is generally associated with the unknown, such as a task one has not been previously exposed to. Thus, worry seems to be the highest before the start of the task, and gradually decreases during task performance as participants become familiar with said procedure (Matthews et al., 2002). These three responses are commonly seen in relation to task-induced stress, potentially causing a decline in performance. One's choice of coping has also been associated with the level of stress experienced and the symptoms of stress (Matthews & Campbell, 1998). For example, those who use emotion-based coping are more likely to experience intrusive, worry-related thoughts that cause distress (Matthews & Campell, 1998).

**Knowledge of Time Limit as Stress**

Time limitations have been known to be present within varying environments, such as the workforce and education. Manipulating time pressure while viewing task performance has been shown to have a strong effect of the stress-factor within the given task (Huber & Kunz, 2007; Young et al., 2012). Sudden time limitations associated with decision making causes a stress response, impairing the effectiveness of one's judgement in making such decision and hindering performance (see Ahituv et al., 1998). Thus, an association has been made between time pressure, stress, and task performance, where the manipulation of a time limit can increase one's stress state associated with a presented task, altering the quality of performance.

**Time Distortion Under Stress**

While not completely understood, time distortion, or when time is perceived to speed up or slow down, has been shown to be experienced in stressful or threatening situations. There have been real-life accounts of this phenomenon taking place, such as an aviator who was required to make a sudden ejection decision from their aircraft (Carson, 1999). Directly quoted from the aviator, "… Time had expanded greatly, so it felt like several minutes before it was time to get out… The canopy leaving, the seat going up the rail, and the aircraft disappearing below me seemed to take several minutes" (Carson, 1999). Despite the ejection process taking roughly thirty seconds, it was recalled as taking several minutes, suggesting that the passage of time slowed down immensely. Those who have experienced life-threatening danger or a "near-death experience" have also reported a temporal distortion (Noyes & Kletti, 1976). Experiences of 85 individuals were collected via questionnaire, where 75% experienced an apparent slowing of time. Events taking place around participants while experiencing such life-threatening danger were also noted to be perceived in slow motion, although internal thoughts appeared to speed up (68%). These two experiences were described by participants as happening simultaneously and were closely related, suggesting a connection between such temporal distortions (Noyes & Kletti, 1976). The slowing down of time has also been experienced and recorded by individuals who suffer from a phobia when asked to observe the object or organism associated with said phobia (Watts & Sharrock, 1984). Individuals in occupations such as a police officers or paramedics face external stressors daily, which have been found to alter temporal experiences. Seventy-one police officers participated in a shooting exercise in the evening as part of their regular training (Stafford et al., 2004). Of the participants, 60% underestimated the time duration of the shooting task. Paramedics monitored during emergency calls also recalled perceptions of elapsed time to differ significantly from the actual time of the calls, the greatest errors being the time spent in the scene and transportation time estimates (Jurkovich et al., 1987).

Real-life events associated with high stress have been attempted to be replicated experimentally but have been extremely difficult to recreate within a laboratory setting. Such experiences happen suddenly and cannot properly be re-created effectively. From a legal and ethical standpoint, participants are not to be presented life-threatening conditions that could potentially cause harm (Hancock & Weaver, 2005). However, a few experimental procedures have been able to stimulate a stress response within participants that leads to temporal distortion. Prior to the Belmont Report (National Commission of the Protection of Human Subjects of Biomedical and Behavioral Research, 1979) being put in place, which provides ethical guidelines and principles to follow within research, Langer and colleagues (1961) experimentally observed the relationship between level of danger and perceived temporal durations. Participants stood on a platform with wheels and handrails while being moved toward the edge of a stairwell at two miles per-hour. Said platform was steered manually by a member of the research team and driven by an electric motor. The individuals were blindfolded prior to the trial, but it was to be removed once the trial began. Results demonstrated that when danger increased, the time duration judged by participants decreased (Langer et al., 1961). Thus, time appeared to speed up as the level of perceived danger increased. Similarly, Caird and Hancock (1994) simulated a traffic-intersection collision. Participants tended to underestimate the arrival time of the approaching vehicle, meaning that time appeared to slow down. In another study, participants were exposed to an aversive or threating stimulus that was either expected or unexpected (Droit-Volet et al., 2010). Those who were aware of said stimulus reported to experience a distortion of the time leading up to the presentation of said stimulus. When the threatening stimulus was expected, the duration of time before experiencing said stimulus seemed to slow down. Thus, time distortion has been associated with both authentic and manipulated stress states. While documented research has demonstrated a relationship between stress and time limits, there is a lack of research surrounding how the knowledge of such a time limit can lead to time distortion.

***Time Distortion Theories Under Stress***

Time distortion has been theorized to be a result of physiological and psychological responses to internal and external stressors. As previously discussed, time distortion under stress is generally experienced in one of two ways: temporal duration being overestimated, and temporal distortion being underestimated. When overestimated, time and surrounding events are reported to appear in slow motion and specific circumstances can be recalled in great detail. When time is underestimated, events are sped up and appear to blend or 'blur' together. To effectively understand time distortion, it is crucial to first discuss how events are experienced in time. Suggested by accumulation models, an individual produces their own time perception by experiencing events and 'mapping' them out cognitively (Hancock & Weaver, 2005). Essentially, time perception depends on how a sequence of events is experienced. 'Normal' sequences of events are primarily 'mapped out' in reference to an internal 'clock' time (refer to the SET and AGM sections) in which time duration can be accurately estimated. Experiencing events in this manner can be referred to as 'time-in-passing' due to the direct perception of surrounding incidents. When stressful or threatening stimuli are introduced to one's 'normal' sequence of events, attention may be drawn and fixated to said stimuli at a more intense rate. Since attention is not generally directed, various surrounding events are increasingly registered. This increase in event registration results in a distortion of time, specifically time slowing down and becoming overestimated (Hancock & Weaver, 2005). This response is referred to as a fight response to threatening events, during which stimuli are registered in detail to identify a solution. Contrastingly, if attention is focused on 'internal' events, or the physiological response to threatening stimuli, few events are being registered. Thus, resulting in a distortion of time where events become 'blurred,' sped up, and unaccounted for (Hancock & Weaver, 2005). This response is generally referred to as a flight response to threatening stimuli, intentionally 'blocking out' stressful events. Essentially, the presentation of an abnormal, stressful event or stimulus increases one's physiological 'fight or flight' response, altering the direction and registration of attention, thus resulting in a distortion of time.

Another similar theory that provides evidence for temporal distortion is the Attentional-Gate Model. As previously discussed, this theory suggests an internal clock that accurately accounts for the passing of time, and includes an attentional gate (Zakay & Block, 1994, 1996). The gate is related to how much attention is designated to temporal passing. Thus, when time is important, the gate allows for an increase in temporal registration. For example, when one is waiting for something specific, attention becomes directed to the passing of time. As a result of this, the duration spent waiting seems to pass increasingly slowly and drawn out. Conversely, when watching a movie, attention is not directed towards temporal passing, thus time seems to pass at a more rapid rate (Zakay & Block, 1997). While these two major theories of time distortion differ, the alteration of attentional resources due to a stress response appears to be a major variable in experiencing said phenomenon.

**Present Study**

The present study aims to explore the relationship between stress and time distortion. Given the challenges associated with producing a stress response in a laboratory setting, difficult tasks are often used to produce a stress response. However, it remains unknown whether the stressful experience of having a limit to complete a task can also influence time distortion. It also remains unknown whether task difficulty moderates the potential relationship between having a time limit and time distortion. That is, perhaps having a time limit is only a source of stress when the task is also inherently difficult. Thus, the present study attempts to address these limitations in the existing research. Task disengagement, distress, and worry have been shown to be common responses to stress-inducing tasks (Matthews et al., 2002). As proposed by Hancock and Weaver (2005), attentional resources should be directed toward these symptoms rather than to the task itself or the passing of time, resulting in time appearing to speed up. However, what if the source of stress is related to time? If attention is directed toward the time limit *in addition* to any other task-induced stress symptoms, it is plausible that time perception is impacted differently. Thus, the goal of the present study is to investigate how knowledge of a time limit impacts time perception across varying levels of task difficulty. Given this goal, the following hypotheses were advanced:

**$H_1$**: Task difficulty will affect time distortion. When the task is easy, participants will accurately perceive time spent on task. When the task is difficult, participants will underestimate time spent on task.

**$H_2$**: Knowledge of a time limit will affect time distortion. When provided no time limit, participants will accurately perceive time spent on task. However, when provided an unspecified time limit, participants will underestimate time spent on task.

**$H_3$**: There will be an interaction between task difficulty and knowledge of a time limit on time estimation. Participants will experience the greatest distortion of time when the task is difficult, and they are provided an unspecified time limit, compared to when the task is easy, and they are provided an unspecified time limit or compared to when provided no time limit.

**$H_4$**: Knowledge of an unspecified time limit and task difficulty will affect task performance. When the task is hard, participants will have worse performance compared to when the task is easy. When provided an unspecified time limit, participants will have worse performance compared to when given no time limit. When the task is hard *and* they are given an unspecified time limit, participants will have the worst task performance.

# Method

## Participants

To determine the necessary sample size, a power analysis was conducted using G*Power (Faul et al., 2007). Given the lack of previous studies to draw upon, the present study adopted a moderately small effect size ($d$ = .25) according to Cohen's (1988) criteria. Alpha was set at .05 and power was set at .80. Thus, the necessary sample size was 128. Because participants may have needed to be excluded, 140 participants were recruited through the research participation system, SONA, at the University of Central Florida (UCF). Their participation was in exchange for course credit. Participants were excluded from analysis if they failed to follow study procedures or if there were issues with recording their actual time spent completing the task. Prior to recruitment, the study was reviewed and approved of by UCF's Institutional Review Board (IRB).

After applying the exclusion criteria, there was a final total sample size of 130 participants, with a mean age of 19.53 years ($SD$ = 3.416). Of such participants, 43.8% were White/Caucasian, 12.3% Black/African American, 16.9% Hispanic, Latino, or of Spanish origin, 0.8% American Indian or Alaska Native, 11.5% Asian, and 3.8% other. The majority of participants were female (58.2%), with 36.9% being male, 3.1% non-binary/third gender, and 0.8% preferring not to disclose.

The present study employed a 2x2 between-subjects experimental design. The independent variables were task-induced stress (easy vs. difficult) and time-induced stress (no time information vs. unspecified time limit). Thus, participants were randomly assigned to one of these four conditions: (1) easy task, no time information ($n$ = 32); (2) easy task, unspecified time limit (*n* = 33); (3) difficult task, no time information (*n* = 34); and (4) difficult task, unspecified time limit (*n* = 31).

## Materials

### *Short Stress State Questionnaire*

Stress was measured with the Short Stress State Questionnaire (SSSQ) (Appendix A; Helton, 2004). Derived from the Dundee Stress State Questionnaire (DSSQ) (Matthews et al., 1999) the SSSQ was used as a means of checking whether the stress manipulations were successful. The SSSQ was created to provide a shorter version of the DSSQ that can still be used as a multi-dimensional assessment for temporary states associated with stress, fatigue, and arousal. The scale differentiates between seven secondary state factors which fall under three general states: task engagement, distress, and worry. The questionnaire uses a 5-point Likert Scale ("Definitely false"- "Definitely true") and has 24 items. Various items within the SSSQ are reverse scored, meaning the item is recoded to its opposite number (i.e., a score of 1 would be recoded to a 5). Such items include: "I felt tired"; "I felt bored"; "I felt relaxed"; and "I felt confident about my performance." The scale was administered prior to the induced stress state (pre-SSSQ) and directly following the event (post-SSSQ). The effects of exposure to the task on stress was determined by standardizing change between post and pre scores using the following formula (Helton, 2004):

$$z_{change} = (\mu_{post} - \mu_{pre})/\sigma_{pre}$$

### *Time Distortion Survey*

Participants completed a Time Distortion Survey derived and modified from Ibarguren and colleagues (2022) (see Appendix B). There was one fixed-choice item in which participants reported their time distortion during the event, as well as a sliding scale question in which they reported how fast time seemed to pass on a scale from 1 (very slow) to 100 (very fast) with a midpoint of 50 (no change). Additionally, participants were asked to report how long they believed they spent on the task, in minutes and seconds.

### *Anagram Task*

An anagram is a task which requires the unscrambling of various letters to form a word. Such tasks have been utilized in experimental procedures to produce a stress response within participants (see Mogg et al., 1990 and Matthews et al., 2006). If given a high difficulty level, participants will generally struggle to complete the given anagram task, producing a stress response. Other researchers have used insolvable anagrams, further inducing a stress response since the task is unable to be completed (see Mogg et al., 1990). Participants will exhibit more stress according to the difficulty of the given anagram task. Validated solvable anagrams were derived from Tresselt and Mayzner (1966) based on the median times it took for participants to complete each anagram. The easy anagram condition consisted of words that are lightly scrambled and take between 37-65 seconds to complete (i.e., tanog [tango]), and the difficult anagram condition consisted of words that are drastically scrambled and take 91-132.5 seconds to complete (i.e., reckl [clerk]) (Tresselt & Mayzner, 1966). Given the validated median times provided by Tresselt and Mayzner (1966), participants were expected to complete the easy condition in 517.5 seconds and the difficult condition in 519 seconds. Thus, the time limit in each condition remained constant at ten minutes. A total of ten anagrams were presented within the easy condition (see Appendix D and E), and five anagrams were presented within the difficult condition (see Appendix F and G), assuming participants would complete the easy anagrams at a faster rate when compared to the difficult anagrams. Performance on the anagram task was calculated as the percentage of anagrams correctly unscrambled. Partially unscrambled anagrams were not considered correct.

**Procedure**

Participants enrolled in the study through SONA, UCF's online research participation system. The study took place in a research laboratory on UCF's campus. The room included a table and chair for participants but otherwise was empty. Research assistants were trained to aid in presenting testing materials and recording time.

When participants arrived, they were instructed to remove or turn off any visible time-keeping devices, such as a watch. To begin, participants were administered a digital version of the pre-SSSQ on Qualtrics to assess their stress state prior to beginning. Following this, participants were presented with the anagram task instructions, a pencil, and scratch paper. They were instructed on how to complete the task. They were either given no time information, or they were told there is an unspecified time limit to complete the task. In the unspecified time limit conditions, participants had 10 minutes to complete the task, although they were not informed of the exact time limit. They were also told that they will receive 1 bonus credit for accurately unscrambling all anagrams (in actuality, all participants received the bonus credit upon study completion). The research assistant recorded the actual time spent on the task using a stopwatch. After giving the instructions, the assistant gave the participant the anagram task face down. The assistant then informed the participant when they could begin the task. Once the participant flipped over their paper to begin, the research assistant began the stopwatch. If given unspecified time limit, participants were informed when 50% of the time limit was remaining. Participants were instructed to flip their paper over once they finished the task and tell the assistant when they were done. Participants given no time limit and an unspecified time limit were stopped by the assistant after 10 minutes.

After the participant finished the task, the research assistant stopped the stopwatch and verbally asked the participant how long they thought the task took, in minutes and seconds. The assistant recorded their answer. Participants then completed the post-SSSQ followed by demographic questions. Finally, participants were debriefed and thanked for their time.

## Results

The data were analyzed using SPSS (IBM Corp, 2023). Between-subjects two-way ANOVAs were used to determine whether there are any significant main effects or interactions between independent variables across the various dependent variables (time estimation, task performance, and SSSQ). The ANOVA assumptions of homogeneity and normality were checked and met. There was no significant interaction between task difficulty and time limit on stress. $F(1, 130) = 0.41$, $p = .524$, $\eta_p^2 = .00$. There was also no significant main effect of task difficulty on stress, $F(1, 130) = 0.09$ $p = .768$, $\eta_p^2 = .00$. There was also no significant main effect of time limit on stress $F(1, 130) = 0.34$ $p = .579$, $\eta_p^2 = .00$. Thus, stress manipulation was unsuccessful. Surprisingly, reported stress was higher in the easy condition ($M = 0.20$, $SD = 1.02$) compared to the hard condition ($M = 0.15$, $SD = 1.29$), although this difference was not significant, $t(128) = 0.30$, $p = .381$, $d = .05$. This trend in the data is considered in the discussion section.

### ***Time Perception***

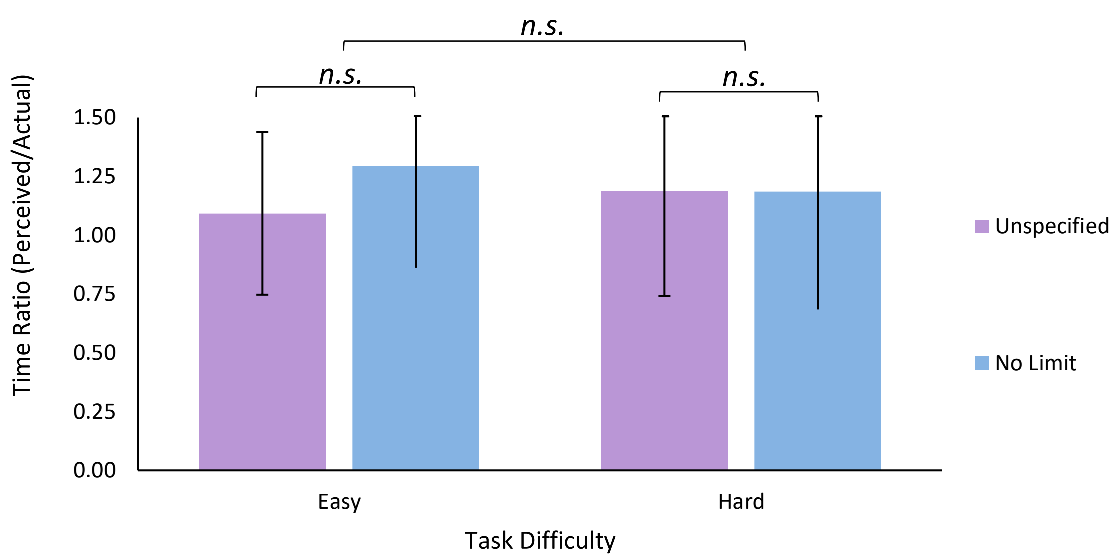
The average time spent on the task was 8.41 minutes ($SD = 2.44$) and the average perceived time on task was 9.88 minutes ($SD = 4.75$). Time perception was calculated by dividing the participant’s perceived time on task by the actual time spent on the task. Thus, a value greater than one indicates that time appeared to slow down, and a value less than one indicates that time appeared to speed up. On average, participants experienced a slowing down of time ($M = 1.19$, $SD = 0.44$).

A two-way ANOVA was conducted to examine the effects of task difficulty and time manipulation on time perception. There was no significant interaction, $F(1,130) = 1.72$, $p =$

0.192, $\eta_p^2 = .01$. There was also no significant main effect of time limit $F(1, 130) = 1.67$, $p = 0.199$, $\eta_p^2 = .01$ or task difficulty $F(1, 130) = 0.00$, $p = 0.937$, $\eta_p^2 = .00$. Thus, the manipulations did not significantly affect participant's perception of time.

**Figure 4**

*Effect of Task Difficulty and Time Limit on Time Perception*




*Note. values greater than 1 indicate time appearing to slow down. Values less than 1 indicate time appearing to speed up*

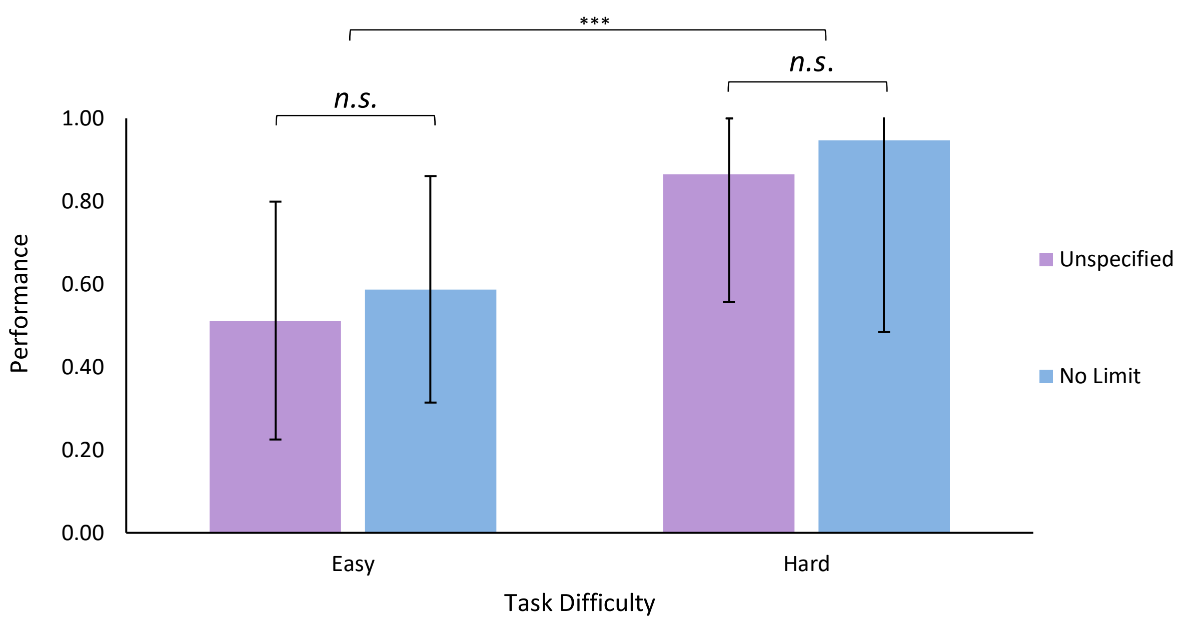
**** p < .001; n.s. is not significant; error bars are SD*

### *Task Performance*

Anagram task performance was calculated based on the number of anagrams correctly unscrambled, with partially unscrambled anagrams considered incorrect. A two-way ANOVA was run to examine the effects of task difficulty and time limit on performance. There was no significant interaction, $F(1,130) = 0.00$, $p = 0.953$, $\eta_p^2 = .00$. There was a significant main effect of task difficulty $F(1,130) = 34.91$, $p = <.001$, $\eta_p^2 = .22$. Surprisingly, participants performed better in the hard condition (*M* = 0.91, *SD* = 0.40) than the easy condition (*M* = 0.55, *SD* = 0.28). However, there was no main effect of time limit, $F(1,130) = 1.72$, $p = 0.192$, $\eta_p^2 = .01$.

**Figure 5**

*Effects of Task Difficulty and Time Limit on Performance*




*** $p < .001$; *n.s.* is not significant; error bars are SD

## Additional Time Distortion Analysis

The Time Distortion Survey included two additional questions to measure time distortion. First, participants were asked whether they felt that time had sped up, slowed down, both occurred, they were unsure, or neither occurred. A Chi-square test of independence suggested no difference in participant response to this question across the condition, $\chi^2 = (15, N = 130) = 15.56$, $p = .412$. Interestingly, the majority of participants reported that "time seemed to speed up" (34.6%) followed by "both seemed to occur" (25.4%), "time seemed to slow down" (19.2%), "I am unsure" (11.5%), "neither" (8.5%), and "other" (0.8%).

Participants were also asked “Overall, how fast did time pass for you during the task?” and used a sliding scale from 1 (“time passed very slow”) to 100 (“time past really fast”) to indicate their response. On average, participants reported a slight speeding up of time ($M$ = 59.03, $SD$ = 19.34). Once again, participants experienced a speeding up of time when they subjectively reported their time pereption. A two-way ANOVA indicated that there was no significant interaction or main effects with task difficulty and time limit on these responses (for all F tests, $p > .05$).

## Discussion

The goal of the present study was to investigate how knowledge of a time limit impacts time perception across varying levels of task difficulty. Participants were placed into one of four conditions, in which knowledge of a time limit and task difficulty were manipulated.

The first hypothesis was that task difficulty would affect time distortion. More specifically, when the task was difficult, time would appear to speed up and become underestimated. This hypothesis was not supported since there was no main effect of task difficulty on time perception. The second hypothesis was that knowledge of a time limit would affect time distortion and cause participants to underestimate time spent on the task. This hypothesis was also not supported, as there were no main effects of time limit on time perception.

The third hypothesis was that there would be an interaction between task difficulty and knowledge of a time limit on time perception such that the greatest distortion of time would be experienced when the task is difficult and participants were provided an unspecified time limit. This hypothesis was also not supported, as there was no interaction between task difficulty and knowledge of a time limit on time perception. While there was no significance within these findings, participants generally *overestimated* the time spent on the given task. Thus, it is suggested that during the task, attention was directed towards an external threat, resulting in time appearing to slow down (Hancock & Weaver, 2005). The perceived external threat was potentially the passing of time or the anagram task itself. Interestingly, despite the overestimation of perceived time, a majority of participants recorded that time seemed to *speed up.* Such findings suggest that there is either a difference between how time is experienced and how long it is believed time has passed or that it is difficult to judge the speed at which time is moving.

The fourth hypothesis was that knowledge of an unspecified time limit and task difficulty would affect task performance such that when the task was hard and participants were given an unspecified time limit, participants would have the worst performance. While there were no significant findings that demonstrated an interaction between knowledge of an unspecified time limit and task difficulty on task performance, there was, however, a significant effect of task difficulty on task performance. Interestingly, participants performed significantly better in the hard task conditions compared to the easy task conditions. This may be due to the number of anagrams given within each task. As discussed earlier in this paper, the anagrams were derived from Tresselt and Mayzner (1966) based on the median amount of time it took participants to complete each anagram. The easy condition consisted of words that were lightly scrambled and took between 37-65 seconds to complete, and the hard condition consisted of words that were drastically scrambled and took between 91-132.5 seconds to complete (Tresselt & Mayzner, 1966). Given that participants were expected to complete the easy anagram task at a faster rate than the difficult anagram task, a total of ten anagrams were used for the easy condition, and a total of five anagrams were used for the hard condition. It is assumed that since the easy task condition contained *more* anagrams when compared to the hard condition, performance was higher in the hard anagram task. While statistically insignificant, it can also be noted that participants experienced an increase in stress during the easy anagram task condition when compared to hard task condition. This trend in the data may have been due to the number of individual anagrams within each task condition. Thus, it can be assumed that an increase in task materials may, in turn, increase one's stress state.

## Limitations and Future Directions

There were a number of limitations in the present study. First, the difficulty in replicating an authentic stress state within a laboratory (Hancock & Weaver, 2005). Many events associated with a distortion of time happen suddenly and in an extreme state of stress, such as during a life-threatening event (see Carson, 1999; Noyes & Kletti, 1976; and Safford et al., 2004), thus they cannot be properly re-created. Given that the replication of stress is necessary to investigate a relationship concerning time distortion, stress manipulation is crucial to observe any significance. As discussed, participants were initially told an extra SONA credit would be rewarded if all anagrams were completed correctly. Despite this, it is possible participants did not believe their performance mattered to get the extra point, thus a stress state was not produced. Due to this, investigating a relationship between task-induced stress and time distortion was extremely difficult. Another consideration is the subjectivity of a stress-state. Recall that stress is the physiological or psychological response to internal or external stressors (APA, 2022). There are no definite stressors experienced by all of the human population, thus what may be a stressor to one individual, may not be for another. This causes difficulty in manipulating a stress state, as there is no concrete stressor that can be utilized to replicate a physiological or psychological response. Additionally, the methods used to record the perceived and actual time spent on task were susceptible to human error. Participants were asked to rely on their memory to document their perceived passing of time without the aid of any time keeping devices. Research assistants also recorded the actual time spent on the task with a stopwatch, thus being extremely susceptible to errors or delays in the documented time.

The findings of the present study generate many potential future directions. First, the study can be replicated with the stress-task focused more on the quantity of tasks, rather than the quality. Given the statistically significant interaction between the hard task and performance, it can be assumed that this was caused by the number of anagrams within each task. Perhaps increasing the variables within the hard task would, in turn, increase one's stress state. Due to the inability to produce a statistically significant stress state, future research should also alter the stress-inducing task. It is hypothesized that the anagram task was not taken seriously by participants, thus a stress response was prohibited.

**Conclusions**

The passing of time is often perceived to move in a linear, synchronized fashion with events taking place within this passage (Hancock & Weaver, 2005). However, the documented warping of time, otherwise known as time distortion, suggests otherwise. Typically, the alteration of temporal passing occurs during states of extreme stress, such as life-threatening events (Hancock & Weaver, 2005). Thus, the replication of such phenomena within a laboratory setting is extremely difficult. Despite this, understanding the interaction between stress and time pressure on time perception can provide valuable information for real-life events, such as states of extreme stress or testing environments.

The present study aimed to induce such a state utilizing a stress-inducing task to observe the influence of stress and time pressure on temporal passing. Although a majority of the findings were insignificant, the effect of task difficulty on task performance, as well as the increasing of stress states within the hard condition can be noted. Such findings suggest that utilizing multiple tasks may be more successful at replicating such a stress state. Overall, the results of this study warrant further investigation and such future research is critical to understanding the interaction of stress and time pressure on temporal passing.

# APPENDIX A: SHORT STRESS STATE QUESTIONNAIRE (SSSQ)

# Appendix A
## Short Stress State Questionnaire (SSSQ)

| | Definitely false | Somewhat False | Neither True nor False | Somewhat True | Definitely True |
|---|---|---|---|---|---|
| I feel dissatisfied | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel alert | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel depressed | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel sad | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel active | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel impatient | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel annoyed | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel angry | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel irritated | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel grouchy | ☐ | ☐ | ☐ | ☐ | ☐ |
| I am committed to attaining my performance goals | ☐ | ☐ | ☐ | ☐ | ☐ |
| I want to succeed on the task | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| I am motivated to do the task | ☐ | ☐ | ☐ | ☐ | ☐ |
| I'm trying to figure myself out | ☐ | ☐ | ☐ | ☐ | ☐ |
| I'm reflecting about myself | ☐ | ☐ | ☐ | ☐ | ☐ |
| I'm daydreaming about myself | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel confident about my abilities | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel self-conscious | ☐ | ☐ | ☐ | ☐ | ☐ |
| I am worried about what other people think of me | ☐ | ☐ | ☐ | ☐ | ☐ |
| I feel concerned about the impression I am making | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| I expect to perform proficiently on this task | □ | □ | □ | □ | □ |
| Generally, I feel in control of things | □ | □ | □ | □ | □ |
| I thought about how others have done on this task | □ | □ | □ | □ | □ |
| I thought about how I would feel if I were told how I performed | □ | □ | □ | □ | □ |

# APPENDIX B: TIME DISTORTION SURVEY

## Appendix B
### Time Distortion Survey

1. What was the apparent effect of time during the task?

- ○ Time seemed to speed up (i.e., time felt as if it was moving faster than it normally does).
- ○ Time seemed to slow down (i.e., time felt as if it was moving slower than it normally does).
- ○ Both seemed to occur.
- ○ I am unsure.
- ○ Neither
- ○ Other (please specify).

2. Overall, how fast did time pass for you during the task?

| Time passed very slowly | Time did not change | Time passed very fast |
|---|---|---|
| 1 | 50 | 100 |

# APPENDIX C: DEMOGRAPHIC SURVEY

# Appendix C
## Demographic Survey

1. What is your age, in years and months?

______________________________________________________________

2. Which of the following best describes your gender identity?

○ Male

○ Female

○ Non-binary / third gender

○ Prefer not to say

○ Other (feel free to specify)

3. Which of the following best describes your racial identity/ethnicity? Select all that apply.

☐ White/Caucasian

☐ Black or African American

☐ Hispanic, Latino or of Spanish origin

☐ American Indian or Alaska Native

☐ Asian

☐ Native Hawaiian or Pacific Islander

☐ Other (feel free to specify)

☐ Prefer not to respond

# APPENDIX D: EASY ANAGRAM, NO TIME LIMIT

# Appendix D
## Easy Anagram, No Time Limit

**Instruction: "**You have a set of five anagrams in front of you and a blank piece of paper to work on if needed. The objective is to unscramble the letters to create a word. You must use all the letters and there is only one solution to each anagram. You may solve the anagrams in any order, and you need to write the solution in the provided space. When I say 'go' you may flip over your paper and begin solving the anagrams. When you finish solving the anagrams, verbally tell me and flip your paper back over. If you correctly solve all the anagrams, you will receive 1 extra SONA credit. Any questions?"

**(Anagrams are on a separate piece of paper)**

| Anagram | Solution |
|---|---|
| lomed | |
| hicar | |
| aohrc | |
| tanog | |
| elcsa | |
| dpaot | |
| augdr | |
| pncia | |
| atryp | |
| hecab | |

APPENDIX E: EASY ANAGRAM, UNSPECIFIED TIME LIMIT

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# Appendix E
## Easy Anagram, Unspecified Time Limit

**Instructions: "**You have a set of ten anagrams in front of you and a blank piece of paper to work on if needed. The objective is to unscramble the letters to create a word. You must use all the letters and there is only one solution to each anagram. You may solve the anagrams in any order, and you need to write the solution in the provided space. You have a time limit to complete these anagrams, but you will not be informed of what the time limit is. You will be informed when 50% of the time limit has passed. When I say "go" you may flip over your paper and begin solving the anagrams. After the time limit expires, when I say "stop," immediately stop working and flip your paper over. If you finish solving all the anagrams before the time limit, verbally tell me and flip your paper over. If you correctly solve all the anagrams within the time limit, you will receive 1 extra SONA credit. Any questions?"

**(Anagrams are on a separate piece of paper)**

| **Anagram** | **Solution** |
|---|---|
| lomed | |
| hicar | |
| aohrc | |
| tanog | |
| elcsa | |
| dpaot | |
| augdr | |
| pncia | |
| atryp | |
| hecab | |

APPENDIX F: DIFFICULT ANAGRAM TASK, NO TIME LIMIT

# Appendix F
## Difficult Anagram, No Time Limit

**Instructions: "**You have a set of five anagrams in front of you and a blank piece of paper to work on if needed. The objective is to unscramble the letters to create a word. You must use all the letters and there is only one solution to each anagram. You may solve the anagrams in any order, and you need to write the solution in the provided space. When I say 'go' you may flip over your paper and begin solving the anagrams. When you finish solving the anagrams, verbally tell me and flip your paper back over. If you correctly solve all the anagrams, you will receive 1 extra SONA credit. Any questions?"

**(Anagrams are on a separate piece of paper)**

| **Anagram** | **Solution** |
|---|---|
| piaot | |
| oapnr | |
| reeckl | |
| antir | |
| ocbna | |

# APPENDIX G: DIFFICULT ANAGRAM TASK, UNSPECIFIED TIME LIMIT

## Appendix G
### Difficult Anagram, Unspecified Time Limit

**Instructions: "**You have a set of ten anagrams in front of you and a blank piece of paper to work on if needed. The objective is to unscramble the letters to create a word. You must use all the letters and there is only one solution to each anagram. You may solve the anagrams in any order, and you need to write the solution in the provided space. You have a time limit to complete these anagrams, but you will not be informed of what the time limit is. You will be informed when 50% of the time limit has passed. When I say "go" you may flip over your paper and begin solving the anagrams. After the time limit expires, when I say "stop," immediately stop working and flip your paper over. If you finish solving all the anagrams before the time limit, verbally tell me and flip your paper over. If you correctly solve all the anagrams within the time limit, you will receive 1 extra SONA credit. Any questions?"

**(Anagrams are on a separate piece of paper)**

| **Anagram** | **Solution** |
|---|---|
| piaot | |
| oapnr | |
| reeckl | |
| antir | |
| ocbna | |

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