# Time Preferences under Stress*

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**Abstract**

We test whether acute psychosocial stress affects time preferences in a laboratory experiment. Using a validated stress induction and an incentive-compatible elicitation method, we find no effect of acute stress on patience or present bias, despite strong physiological and self-reported stress responses. Our results suggest that acute stress may not meaningfully distort intertemporal decision-making and highlight the need to examine whether chronic or domain-specific stressors have more robust effects.

*This study was approved by the Human Research Ethics Committees (HRECs) of the University of Sydney (HREC: 2023/HE000483). The study was preregistered at AsPredicted (Registration No. 145,682). All remaining errors are our own.

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# 1 Introduction

Our willingness to trade off present enjoyment for future well-being, known as time preferences, plays a central role in decision-making across many domains, from financial planning to health behaviors and educational investment. Individuals who place less value on future outcomes are more likely to accumulate credit card debt (Meier and Sprenger, 2010), struggle with obesity (Schiff et al., 2016), and earn lower lifetime incomes (Golsteyn et al., 2014). Understanding what shapes time preferences is therefore essential, not only for modeling behavior, but also for designing policies aimed at improving long-term welfare outcomes.

Stress has emerged as a particularly compelling, though complex, factor in this context. Existing work has documented a stable relationship between poverty and elevated discount rates (Lawrance, 1991; Epper et al., 2020), and some have proposed that stress may act as a mediating mechanism. For instance, Haushofer and Fehr (2014) describe a feedback loop in which poverty induces stress, stress increases time-discounting and risk aversion, and these behavioral shifts reinforce long-term disadvantage. This idea—that impatience may be caused by stress, rather than merely correlated with it—has been further supported in experimental work involving pharmacological stress manipulation (Riis-Vestergaard et al., 2018) and large-scale cash transfer programs (Haushofer and Shapiro, 2018).

Yet despite its intuitive appeal, there remains limited experimental evidence on the direct causal impact of stress on time preferences. A small number of studies have attempted to manipulate stress experimentally, but the results are mixed. For example, Riis-Vestergaard et al. (2018) show that pharmacologically increasing cortisol levels via hydrocortisone administration leads to higher discount rates, suggesting that elevated physiological stress can increase impatience. In contrast, Haushofer et al. (2018) find that only certain types of experimentally induced stress—specifically, economic stress via a competitive game—affect time preferences, while social and physical stressors do not. Related evidence points to substantial heterogeneity in stress responses: Lempert et al. (2012) show that experimentally induced stress increases discounting only among individuals with low perceived stress. Furthermore, Haushofer et al. (2021) report that although acute stress may increase the choice of sooner outcomes, it does not lead to systematic changes in estimated discounting parameters.

In this study, we address this gap by combining a validated acute stress induction protocol (Kirschbaum et al., 1993) with an incentive compatible method for eliciting time preferences. Our design separately measures patience and present bias, allowing for a more nuanced examination of whether different components of discounting behavior respond to stress.

We successfully induce acute psychosocial stress, as confirmed by both self-reported and physiological measures, but find no evidence that it alters either patience or present bias. These findings are consistent with prior studies that find no effect of social or physical stress on discounting (Haushofer et al., 2018, 2021), and suggest that acute stress, at least in laboratory settings, may not meaningfully distort intertemporal decision-making. It remains possible that only certain stress domains, such as economic or chronic stressors, affect discounting behavior in a robust and sustained way.

Our study contributes to this literature in several ways. First, we separately identify the effects of stress on patience and present bias, allowing us to distinguish between changes in long-run discounting and time-inconsistent behavior. Second, despite successfully inducing acute psychosocial stress, we find no effect on either component of time preferences. This absence of an effect helps clarify the conditions under which stress may or may not influence intertemporal choice. Third, by comparing our findings to those from studies showing that chronic financial stress can increase impatience (Haushofer and Shapiro, 2018), or that domain-specific stressors such as economic competition affect discounting (Haushofer et al., 2018), we highlight the importance of stress type and context in shaping time preferences.

The remainder of the paper is organized as follows. Section 2 reviews related literature, and Section 3 describes the experimental design and stress induction protocol. Section 4 presents the reduced-form results, and Section 5 reports the structural estimation results. Section 6 concludes with a discussion of implications and directions for future research.

## 2 Related Literature

A growing body of research examines how stress affects intertemporal decision-making, with particular attention to its implications for time preferences. A prominent framework, proposed by Haushofer and Fehr (2014), emphasizes a poverty–stress–impatience feedback loop, whereby economic hardship induces stress, which in turn increases impatience and reinforces disadvantage. Empirical evidence consistent with this view primarily comes from settings involving chronic or economically salient stressors. For example, Riis-Vestergaard et al. (2018) show that pharmacological elevation of cortisol increases impatience, while Haushofer and Shapiro (2018) find that alleviating financial stress through unconditional cash transfers reduces discount rates, suggesting that lower economic strain promotes more future-oriented behavior.

In contrast, studies that causally manipulate acute stress in laboratory settings have yielded mixed and often inconclusive results. Table 1 summarizes key experimental evidence on the effects of acute stress on intertemporal choice. Several studies report that acute stress increases discounting or impulsive choice (e.g., Delaney et al., 2014; Kimura et al., 2013; Koppel et al., 2017), whereas others find no effect on delay discounting (e.g., Haushofer et al., 2013; Amlung and MacKillop, 2014). More recent work highlights important sources of heterogeneity. For instance, Diller et al. (2011) document gender-specific effects, Lempert et al. (2012) show that stress effects depend on individual differences in perceived stress, and Haushofer et al. (2018) demonstrate that only economically salient stressors affect discounting, while psychosocial or physical stressors do not. Moreover, Haushofer et al. (2021) and Simon et al. (2021) suggest that acute stress may affect choice behavior toward sooner rewards even when underlying discounting parameters remain unchanged.

A key limitation of this experimental literature concerns how intertemporal preferences are

Table 1: Laboratory Evidence on Stress and Time Preferences

| **Study** | **Stress Type** | **Delays** | **Main Findings** |
|---|---|---|---|
| Diller et al. (2011) | Serial subtraction task (TSST component) | 7–25 years | Stress response linked to greater discounting (females only) |
| Lempert et al. (2012) | Acute stress via videotaped speech task | Immediate to various delays | Stress effects depend on individual differences; higher discounting among low perceived-stress individuals |
| Delaney et al. (2014) | Cold pressor task / Quiz | 1 week / 1 month | Increased delay discounting |
| Kimura et al. (2013) | TSST | 1 year | Increased delay discounting |
| Amlung and MacKillop (2014) | Lab-based psychosocial stress (non-TSST) | 7 days | No effect on delay discounting; increased alcohol demand |
| Haushofer et al. (2013) | TSST | 2–180 days | No effect on delay discounting |
| Koppel et al. (2017) | Acute thermal pain | 1–5 days | Increased delay discounting |
| Riis-Vestergaard et al. (2018) | Hydrocortisone | 7–180 days | Increased delay discounting |
| Haushofer et al. (2018) | TSST / Cold pressor / Economic stress (Centipede game) | Tomorrow–12 months | Stressor type matters: economic stress increases discounting, but psychosocial/physical stressors show no effect |
| Haushofer et al. (2021) | TSST | 2–30 days | Increased choice of sooner reward; no effect on delay discounting |
| Simon et al. (2021) | MAST (lab-based acute stress) | 1 week–1 year | Increased choice impulsivity; heterogeneous cortisol effects |

identified. Most studies rely on relatively restricted delay structures, typically varying only back-end delays, which makes it difficult to disentangle distinct components of intertemporal preferences, such as overall patience and present bias. In the absence of orthogonal variation in front-end and back-end delays or structural estimation of discounting models, existing evidence offers limited insight into which aspects of time preferences are influenced by stress.

Table 2: Field and Non-Laboratory Evidence on Stress and Time Preferences

| **Study** | **Stress Type** | **Delays** | **Main Findings** |
|---|---|---|---|
| Takahashi et al. (2004) | Baseline cortisol (correlational) | N/A (hypothetical questionnaire) | Higher baseline cortisol associated with steeper discounting |
| Shavit et al. (2014) | Skydiving (field; anticipatory acute stress) | N/A (subjective discount-rate measure) | More present-focused choices among inexperienced skydivers before the jump; no effect among experienced skydivers |
| Chen (2021) | Financial strain / income shocks (field) | N/A (field; timing varies/unclear) | Greater financial strain associated with higher discounting |

Beyond laboratory experiments, related evidence from field and other non-laboratory settings points to a potentially different role of stress in shaping time preferences. Table 2 summarizes such evidence. Using correlational data, Takahashi et al. (2004) find that higher baseline cortisol levels are associated with steeper discounting. Field studies further suggest that naturally occurring or economically meaningful stressors may increase impatience: Shavit et al. (2014) report more present-focused choices among inexperienced skydivers facing anticipatory stress, and Chen (2021) show that financial strain and income shocks are associated with higher discount rates. Together, these studies indicate that stress effects on time preferences may be more pronounced in chronic, economically salient, or real-world contexts than in short-lived laboratory stress inductions.

Our study contributes to this literature by addressing the methodological limitations of prior experimental work in three key ways. First, we employ a validated stress induction protocol and measure stress both physiologically (via cortisol) and subjectively (via self-reports), ensuring reliable identification of stress exposure. Second, we use an experimental design with orthogonal variation in front-end and back-end delays, allowing us to separately identify patience and present bias. Third, we estimate structural models of exponential and hyperbolic discounting with stress-augmented parameters, enabling a more precise test of whether acute stress alters intertemporal preferences.

Consistent with Haushofer et al. (2013) and Haushofer et al. (2021), we find no evidence that acute psychosocial stress meaningfully affects either component of discounting. By distinguishing between types of delay and directly estimating discount functions, our results clarify the boundary conditions under which stress distorts intertemporal decision-making. In particular, they align with the view that chronic or economically salient stressors, rather than brief psychosocial stress, are more likely to affect time preferences.

# 3 Experimental Design

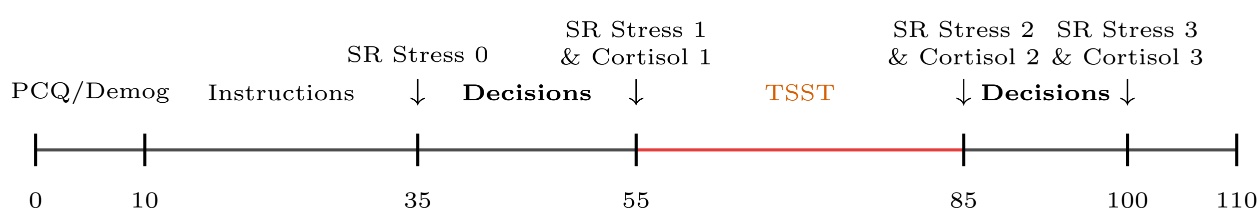



Figure 1: Session Timeline

Figure 1 shows the overall structure of experimental sessions. Before their arrival, registered participants received a reminder email to abstain from food, caffeine, alcohol, exercise, and medication for the required duration. They were also asked to confirm their attendance by informing us of their dream job, which was later used during the stress induction process to enhance realism.

At the start of the session, participants completed a demographic questionnaire covering age, education, employment, financial status, sleep habits, alcohol and caffeine consumption, compliance with abstinence requirements, and some indicators of mental health (PCQ/Demog). Following this, instructions for the experiment were presented, including details about the experimental tasks, payment method, and procedures. For a complete version of the instructions, see Appendix A.

The numbers on the timeline indicate minutes elapsed since the beginning of the session. *Decisions* refers to tasks eliciting both time preferences and risk preferences. *TSST-G* (in red) indicates the Trier Social Stress Test for Groups, used to induce acute psychosocial stress. *SR Stress* and *Cortisol* represent repeated measures of self-reported stress and salivary cortisol levels, respectively.

## 3.1 Time Preferences

To elicit time preferences, participants made a series of choices between sooner and later monetary payments. They made a total of 30 choices in two blocks of 15 identical questions, one presented before and one after stress induction. The sooner amounts were offered with front-end delays of 0 (indicating 'TODAY'), 1, or 7 days from the present. This variation in the timing of the sooner payments facilitates the identification and modeling of present bias. The later amounts were set to be received 1, 7, 30, 90, or 180 days later, allowing us to identify the shape of long-run discounting. We combined every front end delay with every back-end delay for a total of 15 unique questions. The order of questions within each block was randomized.

In each question, participants were offered $30 to be received at a later date and asked to provide their sooner equivalent, the amount such that they were indifferent between receiving the later $30 or their sooner equivalent at a specified sooner date.[1] To induce truthful reporting of preferences, we employed the Becker–DeGroot–Marschak (BDM) procedure (Becker et al., 1964).

The question presented as: "To me, ____ TODAY is as good as $30 in 7 days." Figure 2

[1]The concept of an indifference amount was clarified with instructions based on Healy (2020).

provides an example of the slider interface used in the experiment.

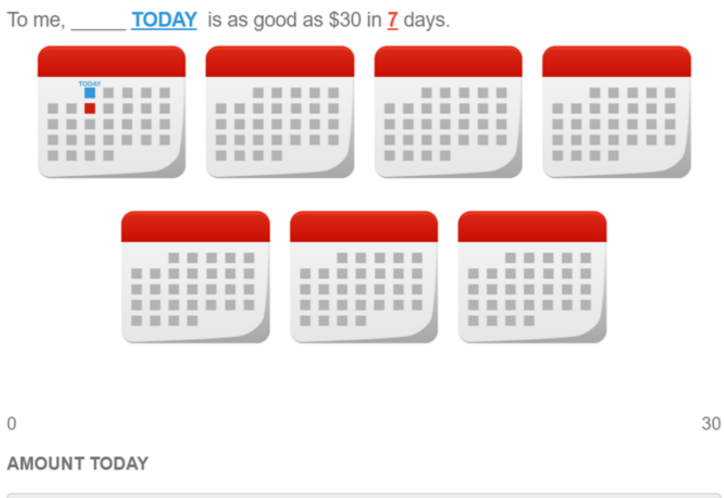



Figure 2: Example of the slider interface used to elicit the sooner equivalent.

After participants completed the experiment, the computer randomly selected one question for actual payment. It also generated a random number between 0 and 30, representing the computer's offer for an earlier payment. If the participant's stated sooner equivalent was higher than the computer's offer, they will choose to wait for the later \$30 payment. Conversely, if their sooner equivalent is lower than the computer's offer, they will accept the offer for an earlier date and receive the amount of the random number. Participants were required to complete comprehension questions, with incorrect answers resulting in additional questions being asked. Among 54 participants, only 2 failed two different comprehension questions and required further explanation from the research team.

## 3.2 Risk Preferences

To isolate the effect of time preferences from the intertwined effects of risk preferences, we employ the same incentive mechanism and decision task design used for measuring risk attitudes.

Participants were asked to report a certainty equivalent for a simple binary lottery paying a positive amount or zero. The design of the lottery followed the same incentive mechanism as the time preference task but was structured so that the expected value was not straightforward to compute, thereby discouraging simple heuristic responses.

## 3.3 Stress Induction

We used the Trier Social Stress Test for Groups (TSST-G) protocol (von Dawans et al., 2011) to induce acute psychosocial stress in a controlled laboratory setting. This protocol is widely used and has been shown to produce consistent results with the individual TSST in both quantitative (Childs et al., 2006) and qualitative studies (Vors et al., 2018; Boesch et al., 2014).

The TSST-G is designed to create a socio-evaluative threat and a sense of uncontrollability through three stages: an anticipatory period, a speech task, and an arithmetic task.

### 3.3.1 Anticipatory Period

When participants registered for an experiment session, we asked them to confirm their attendance by replying with their dream job. During the anticipatory period, they were reminded about the dream job information we had received and were told they would need to convince an evaluating panel of their suitability for this position in a two-minute speech. The panel, introduced as experts in human behavior, required participants to focus on their personal qualities. A $15 speech prize was offered as an incentive for effort and compliance. To increase uncontrollability, a second, unspecified task was also mentioned, with details to be provided by the panel later. Participants were given an unspecified period to read these instructions and were provided with blank paper and pens for notes. The duration of the anticipatory period, four minutes, was selected to provide insufficient preparation time. The full instructions are available in Appendix B.

### 3.3.2 Speech Task

For the speech task, we implemented a set of procedures to help elevate and maintain engagement throughout the induction. Participants were brought into an unfamiliar room and were asked to hand over their notes to the evaluating panel, limiting reliance on prior preparation. They were positioned between large dividers that fully blocked their view of others, and a camera adjusted to eye level emphasized the individual nature of the task. The evaluating panel consisted of one male and one female researcher[2], both wearing lab coats and maintaining neutral expressions throughout the task.

The panel instructed participants to speak for the full two minutes while standing straight with their hands by their sides. If they placed their hands in their pockets or behind their backs, they were reminded to return to the instructed posture. To maintain the formal setting and focus on self-presentation, evaluators maintained steady eye contact and refrained from offering any non-verbal encouragement. They referred to participants only by their ID numbers. When participants stopped early, the panel maintained silence for 20 seconds before asking them to continue. Evaluators also interjected when participants shifted toward describing professional experiences rather than personal attributes. The panel took notes throughout and occasionally followed up with questions even after the speech had ended, helping to sustain participants' attention. Full instructions and interjection prompts are provided in Appendix B.

### 3.3.3 Calculation Task

After 12 minutes, the second task was introduced: a mental calculation exercise. Participants were instructed to count backward aloud in steps of a specific, non-trivial number (e.g., 13, 16, or 17), starting from a given four-digit number, and to do so as quickly and accurately as possible. The duration of the task was not disclosed in advance. While correct answers received no feedback, any mistakes were immediately corrected by the panel, and participants

[2]We maintained a balanced panel in all sessions, as some studies have found gendered effects where young participants only showed a cortisol increase with opposite-sex panel members (Duchesne et al., 2012).

were asked to restart from the original number. Participants were called upon in random order and often asked to resume from where the previous participant had made a mistake or stopped. This structure encouraged sustained attention and reinforced the possibility of being called on at any time. During the task, the panel took visible notes, adjusted the camera, refrained from giving verbal or non-verbal encouragement, and occasionally urged participants to speed up, introducing a sense of time pressure.

## 3.4 Stress Measurements

We measured stress using two complementary methods: participants' self-reports of stress and the biochemical measurement of cortisol levels in saliva.

### 3.4.1 Self-Report Stress

We measured self-reported stress using a visual analogue scale (VAS) (Lesage et al., 2012), a method commonly used for capturing subjective stress levels. This technique has comparable reliability to Likert scales (Van Laerhoven et al., 2004) and may be more sensitive to subtle effects (Allen et al., 2014). This measure is labeled as *SR Stress* in the session timeline (Figure 1).

Participants rated their current stress in response to the prompt: "In the present moment, I feel..." using a 0–100 scale. To obscure the purpose of the study and minimize experimenter-demand effects, this item was embedded among six randomly ordered prompts measuring both positive and negative affect. Self-reported stress was measured four times throughout the session. The first measurement, labeled as *SR Stress 0* on the timeline and taken before the decision tasks, was excluded from the analysis. The remaining three measurements coincided with salivary cortisol collection, which is discussed in the next section.

### 3.4.2 Salivary Cortisol

Salivary cortisol is recognized as a useful marker due to the extensive evidence supporting its response to the TSST. Serving as a biomarker of hypothalamic-pituitary-adrenal (HPA) axis activity, it is notably effective because it is selectively responsive to stress rather than to general arousal (Allen et al., 2014). Additionally, measuring salivary cortisol is much less invasive than blood sampling, offering a practical method for obtaining biometric stress measures. It also correlates strongly with matched serum cortisol concentrations (Harrison et al., 2019). The utilization of this measure is well-documented across the psychological and medical research literature, making it a prevalent method for assessing stress response (Kirschbaum and Hellhammer, 1989; Haushofer et al., 2021).

Salivary samples were measured using a commercially available ELISA assay (Salimetrics, USA). Saliva was collected through passive drool, considered the gold standard for biological testing of oral fluids. Participants received a labeled vial and a saliva collection aid, and had up to 5 minutes to provide a sample. Immediately after collection, the samples were frozen at $-20$°C in cryostorage boxes.

The assays demonstrated good reproducibility and a high sensitivity of 0.003 $\mu$g for cortisol measurement. A meta-analysis by Goodman et al. (2017) identified a prototypical peak in cortisol levels 38 minutes after exposure to a psychosocial stressor, like the TSST. In alignment with this finding, our study was designed to capture the peak effects of stress during the decision-making task. Accordingly, salivary samples were collected at two critical points: 25 minutes and 45 minutes after initiating the stress induction protocol. This timing ensured that we could observe the stress response at its peak, consistent with established literature.

Salivary samples were obtained three times during the session (*Cortisol 1-3*), each corresponding to a self-reported stress measurement. The first sample, taken immediately after the first block of time preference decisions, served as the baseline cortisol measure. The second sample was collected five minutes after the stress induction protocol to validate the treatment.

The final sample was obtained after the second block of time preference decisions to assess whether the stress effects persisted during the decision-making process.

### 3.5 Procedure

79 males participated in the study between October and November 2023, of whom 54 provided complete data and were included in the analysis. Participants were recruited from The University of Sydney's Online Recruitment System for Economics Experiments (ORSEE) participant pool (Greiner, 2015), comprising current students. Our sample was aged between 18 and 30 years old, with a mean of 21 years, and 85% currently studying for an undergraduate degree.

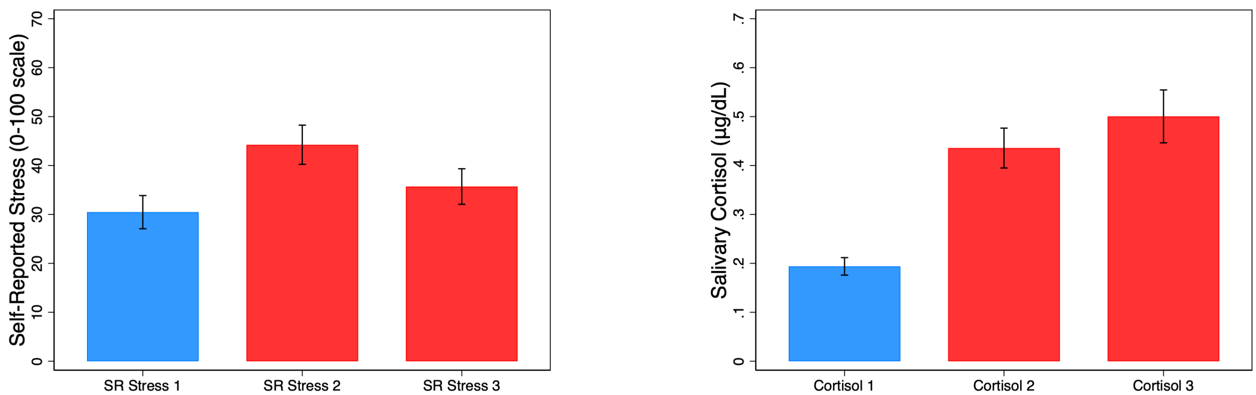
The 2.5-hour sessions were conducted between 2:30 p.m. and 7:30 p.m. to minimize natural circadian fluctuations in cortisol levels, as suggested by prior research (Pruessner et al., 1997; Izawa et al., 2013). At the end of the session, payment amounts were determined according to the incentive mechanism, and participants were informed of their earnings. Payments were made via PayPal. Participants received a flat participation fee of $20 on the day of the session. In addition, they could earn an additional amount of up to $50, payable within six months after the session date.

The study was approved by the university's ethics committee. Participants were required to abstain from consuming food, caffeine, alcohol, and exercise for 2 hours before the session, and from taking any medication for 24 hours beforehand. Female participants were excluded to eliminate the effects of menstrual cycles on stress hormone reactivity, in accordance with existing literature on stress and time preferences (Takahashi et al., 2004; Haushofer et al., 2013; Maki et al., 2015; Margittai et al., 2015).

# 4 Reduced Form Results

## 4.1 Effectiveness of Stress Induction

The stress induction procedure was effective in significantly increasing both self-reported and cortisol biomarker measures of stress levels, as shown in Figure 3.




(a) Self-reported stress

(b) Cortisol level

Figure 3: Stress measurements: self-report and cortisol

Figure 3a displays changes in self-reported stress levels at three time points during the session; error bars represent standard errors. The blue bar (Self-Reported Stress 1) represents stress reported before the stress induction (mean = 30.46), while the two red bars (Self-Reported Stress 2 and 3) represent stress levels measured after the treatment (means = 44.20 and 35.70, respectively). Paired t-tests confirm that both post-treatment measures are significantly higher than the stress reported before the induction ($p < 0.001$), indicating that the stress induction effectively elevated subjective stress.

Figure 3b presents salivary cortisol levels measured at three time points. The blue bar (Cortisol 1) represents cortisol concentration before the stress induction (mean = 0.194 $\mu$g/dL), while the two red bars (Cortisol 2 and 3) correspond to measurements taken after the induction (means = 0.436 and 0.500 $\mu$g/dL, respectively). Similar to the self-reported stress measure, paired t-tests confirm that both post-treatment levels are significantly higher than the pretreatment level ($p < 0.001$), providing clear evidence of a strong physiological stress response.[3]

To examine the effect of stress on time preferences, we use the average of measurements 2 and 3 for both self-reported stress and salivary cortisol as post-stress indicators. This approach accounts for the sustained nature of the stress response across both physiological and subjective measures, rather than capturing a potentially transient peak. Averaging across the two post-treatment time points provides a more reliable estimate of participants' stress levels during the decision-making phase.

## 4.2 Effects of Stress on Time Preferences

In this section, we examine whether and how stress influences individuals' time preferences, with a particular focus on two components: patience and present bias. To measure these, we construct a discounting variable based on choices in the intertemporal task. Specifically, we define the discount factor as the ratio of the sooner equivalent to a delayed reward fixed at \$30.

$$\text{Discount} = \frac{\text{Sooner Equivalent}}{30},$$

Using this measure, we define *patience* as the average discount factor conditional on the presence of a front-end delay:

$$\text{Patience} = \mathbb{E}[\text{Discount} \mid \text{FE} > 0].$$

where $\mathbb{E}[\cdot]$ denotes the average across choices. This captures the overall willingness to wait for delayed rewards when the immediate option is not available.

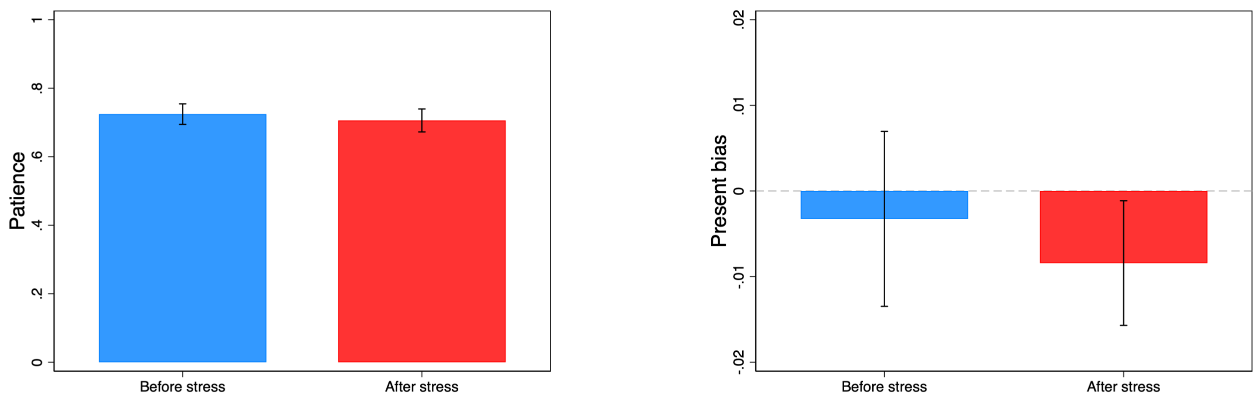
To capture *present bias*, we compare each participant's discounting behavior between

[3] Lange et al. (2017) suggest that a meaningful increase in cortisol following the TSST should exceed 0.091 $\mu$g. In our study, the average increase from baseline to post-stressor was 0.242 $\mu$g.

choices with and without a front-end delay. Formally, for each participant $i$, we compute

$$\text{Present Bias} = \mathbb{E}[\text{Discount} \mid \text{FE} > 0] - \mathbb{E}[\text{Discount} \mid \text{FE} = 0].$$

This approach allows us to distinguish between general patience and deviations from time-consistent preferences, which reflect present-biased behavior. The subsequent analysis investigates how these measures differ before and after the stress induction.

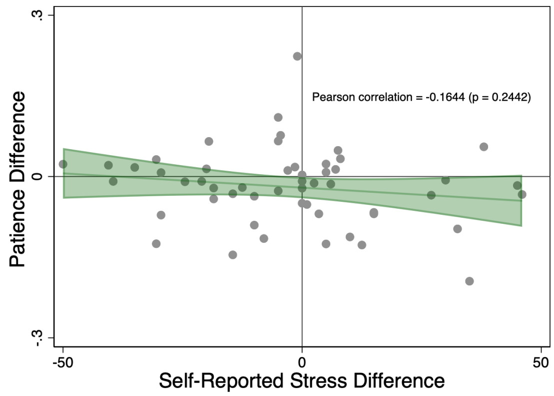



(a) Patience (b) Present bias

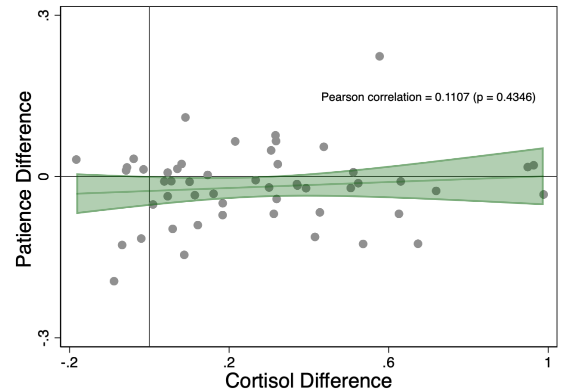
Figure 4: Time preferences before and after stress induction

Figure 4 summarizes average patience and present bias before and after the stress induction. Using paired t-tests that compare outcomes within individuals across periods, we find no statistically detectable change in either measure following the stress manipulation (patience: $p = 0.055$; present bias: $p = 0.689$). This suggests no systematic shift in aggregate time preferences in response to stress. To examine whether this aggregate null result masks heterogeneity in individual responses, we next study the relationship between changes in stress and changes in time preferences at the individual level.

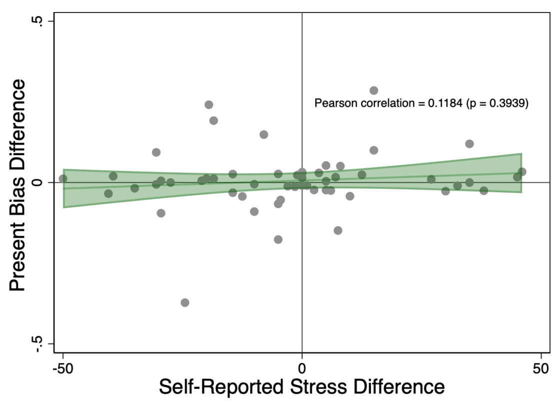
Figure 5 plots changes in stress against changes in time preferences. The shaded green area shows the 95% confidence interval around the fitted line. Across all four panels, there is no statistically significant association between stress and time preferences.



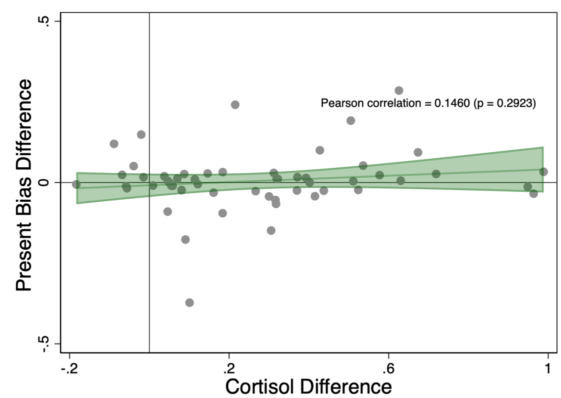

(a) Scatter plot of self-reported stress difference and patience difference




(b) Scatter plot of cortisol difference and patience difference




(c) Scatter plot of self-reported stress difference and present bias difference




(d) Scatter plot of cortisol difference and present bias difference

Figure 5: Scatter plots of stress differences (self-reported and cortisol) and time preference differences (patience and present bias)

Figure 5a and Figure 5b examine whether changes in stress levels are associated with changes in patience. Figure 5a shows the relationship between self-reported stress difference and patience difference, but the correlation is statistically insignificant (Pearson correlation $= -0.1644$, $p = 0.2442$). Similarly, Figure 5b shows the relationship with cortisol difference and also reveals no statistically significant association (Pearson correlation $= 0.1107$, $p = 0.4346$).

Likewise, Figure 5c and Figure 5d examine the relationship between stress changes and present bias. Figure 5c examines the association between self-reported stress difference and present bias difference, but the relationship is not statistically significant (Pearson correlation

= 0.1184, $p$ = 0.3939). Figure 5d also shows no statistically significant relationship between cortisol difference and present bias difference (Pearson correlation = 0.1460, $p$ = 0.2923).

Taken together, these findings suggest that the stress induction did not have a statistically detectable effect on time preferences, either in terms of overall patience or present-biased behavior.[4]

# 5 Structural Estimation Results

To complement the reduced-form analysis in Section 4, we estimate structural models of time discounting.

Before introducing the models, we note that a paired t-test comparing certainty equivalents elicited in Section 3.2 before and after the stress induction reveals no significant differences ($p$ = 0.9906). This indicates that participants' risk attitudes remained stable across conditions, which justifies our use of a linear utility specification in the structural estimation.

## 5.1 Model Frameworks

We consider three widely used models of intertemporal choice: the exponential, the hyperbolic, and the quasi-hyperbolic discounting models.

**Exponential Discounting.** The exponential model (Ramsey, 1928; Samuelson, 1937) assumes dynamically consistent preferences and discounts future utility at a constant rate. The discount function is

$$D(t) = \delta^t, \tag{1}$$

[4] For a full comparison of Sooner Equivalent measures before and after stress induction, see Appendix C.

where $\delta \in (0, 1)$ is the discount factor. A smaller $\delta$ reflects greater impatience. This model is analytically convenient, but it often fails to capture behavioral patterns such as declining impatience and preference reversals.

**Hyperbolic Discounting.** To address these behavioral regularities, the hyperbolic model (Mazur, 1984) is often used. Its discount function is

$$D(t) = \frac{1}{1 + \alpha t}, \tag{2}$$

where $\alpha > 0$ represents the degree of impatience. Relative to exponential discounting, the hyperbolic model places more weight on near-term outcomes and produces dynamically inconsistent preferences, consistent with empirical findings (Benzion et al., 1989; Kirby and Herrnstein, 1995).

**Quasi-Hyperbolic Discounting.** Finally, we consider the quasi-hyperbolic model (Laibson, 1997; O'Donoghue and Rabin, 1999), often referred to as the $\beta$–$\delta$ model, which is the standard framework for explicitly capturing present bias. Unlike the exponential or hyperbolic models, which cannot separately identify short-run and long-run components of discounting, the quasi-hyperbolic model distinguishes between immediate impatience and long-run patience. The discount function is

$$D(t) = \begin{cases} 1, & t = 0, \\ \beta \cdot \delta^t, & t > 0, \end{cases} \tag{3}$$

where $\delta \in (0, 1)$ governs long-run patience and $\beta \in (0, 1]$ captures short-run present bias. A smaller $\beta$ implies stronger present bias, while $\beta = 1$ reduces the model to standard exponential discounting.

Including this model is important in our context because our design with orthogonal variation in front-end and back-end delays allows us to separately identify $\delta$ and $\beta$. This ensures consistency with our reduced-form analysis, where we emphasize both patience and present bias, and directly addresses the concern that present bias should be modeled structurally rather than inferred indirectly.

**Stress-Augmented Formulations.** To test whether acute stress alters intertemporal choice, we allow the key parameters of each model to depend on a binary post-treatment indicator. Let $\textit{stress} \in \{0, 1\}$ equal 1 for choices made after the TSST induction and 0 for choices made before the induction. The models take the following forms:

- **Exponential:**

  $$D(t) = (\delta + \theta \cdot \textit{stress})^t,$$

  where a negative $\theta$ indicates greater impatience under stress.

- **Hyperbolic:**

  $$D(t) = \frac{1}{1 + (\alpha + \theta \cdot \textit{stress}) \cdot t},$$

  where a positive $\theta$ indicates greater impatience under stress.

- **Quasi-hyperbolic 1 (stress on $\delta$):**

  $$D(t) = \begin{cases} 1, & t = 0, \\ \beta \cdot (\delta + \theta \cdot \textit{stress})^t, & t > 0, \end{cases}$$

  where a negative $\theta$ indicates greater impatience under stress by reducing long-run patience $\delta$, while leaving $\beta$ unchanged.

- **Quasi-hyperbolic 2 (stress on $\beta$):**

$$D(t) = \begin{cases} 1, & t = 0, \\ (\beta + \theta \cdot \mathit{stress}) \cdot \delta^t, & t > 0, \end{cases}$$

  where a negative $\theta$ indicates greater impatience under stress by reducing the effective present-bias parameter $\beta$.

These alternative formulations allow us to test whether stress shifts the discount factor ($\delta$), which governs how value declines over longer horizons and can be interpreted as *long-run patience*, the hyperbolic discount rate ($\alpha$), which shapes the steepness of near-term discounting and thus reflects *short-run impatience*, or the present-bias parameter ($\beta$), which captures the additional weight placed on immediate outcomes relative to all delayed ones.

## 5.2 Parameter Estimates

Table 3 reports parameter estimates from the exponential, hyperbolic, and quasi-hyperbolic models with stress-augmented specifications. Across all models, the core parameters fall within expected ranges: the exponential discount factor $\delta$ is close to unity, the hyperbolic discount rate $\alpha$ is small but positive, and the quasi-hyperbolic estimates yield $\beta < 1$, consistent with present-biased preferences documented in the literature.

Turning to the stress coefficient $\theta$, the estimates are small in magnitude and statistically insignificant in every specification. In the exponential and hyperbolic models, this indicates that stress does not shift the discount factor or the discount rate. In the quasi-hyperbolic models, we estimate $\beta \approx 0.87$, confirming the presence of present bias. However, the stress coefficient $\theta$ remains small and insignificant: in the specification where stress affects the discount factor (quasi-hyperbolic 1), we find no evidence that stress shifts $\delta$, and in the specification where stress affects the present-bias parameter (quasi-hyperbolic 2), we find no evidence that stress shifts $\beta$. Taken together, these structural estimates reinforce the reduced-form findings: our stress induction successfully elevated stress levels but did not translate into systematic changes in intertemporal choice.

| | Exponential | Hyperbolic | Quasi-hyperbolic 1 | Quasi-hyperbolic 2 |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $\delta$ (discount factor) | 0.9959*** | – | 0.9964*** | 0.9962*** |
| | (0.0005) | – | (0.0004) | (0.0004) |
| $\alpha$ (discount rate) | – | 0.0059*** | – | – |
| | – | (0.0009) | – | – |
| $\beta$ (present bias) | – | – | 0.8671*** | 0.8750*** |
| | – | – | (0.0268) | (0.0273) |
| $\theta$ (stress effect) | -0.0003 | 0.0005 | -0.0002 | -0.0158 |
| | (0.0002) | (0.0004) | (0.0002) | (0.0155) |
| Observations | 1620 | 1620 | 1620 | 1620 |

Notes: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. For the discount factor $\delta$ and present-bias parameter $\beta$, statistical significance is reported relative to the null hypothesis that the parameter equals one (i.e., no long-run impatience and no present bias, respectively). For all other parameters, significance is reported relative to zero.

Table 3: Structural estimation results: exponential, hyperbolic, and quasi-hyperbolic models

# 6 Discussion

This study investigates whether acute stress affects time preferences using a controlled experimental design. We successfully induce a robust stress response, as confirmed by both self-reported measures and salivary cortisol levels. However, across multiple specifications of time-discounting behavior, we find no evidence that acute stress influences present bias or diminishing impatience.

One possible explanation for our null results is that acute psychosocial stress affects decision processes rather than underlying time preferences. Prior studies often interpret increases in sooner choices under stress as heightened impatience; however, such patterns may also reflect changes in attention, cognitive load, or heuristic use, without implying shifts in discounting preferences. Accordingly, our results do not rule out the possibility that stress influences decision making through changes in attention or heuristic use, even though traditional time-preference parameters remain unaffected.

In addition, acute stress may generate heterogeneous cognitive responses across individuals. Some individuals may become more impulsive under stress, while others may exhibit more cautious or deliberative processing (Lupien et al., 2007; Starcke and Brand, 2012). Moreover, cortisol may buffer the subjective experience of stress in some individuals (Het et al., 2012), leading to behavioral responses that vary across participants and potentially offsetting any aggregate effect.

Our findings suggest that acute psychosocial stress, at least as induced in laboratory settings, may not be a consistent driver of impatience. Future work should explore whether chronic stress or repeated exposure has a more systematic influence on time preferences. Understanding how different types of stress, such as acute versus chronic or physiological versus psychological, interact with time preferences and broader decision-making processes remains essential for developing accurate behavioral models and designing targeted interventions.

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*Supplemental Appendices*

# A Instructions

We will now begin with instructions for how to complete the monetary decision tasks. One of the 32 questions that you answer today will be selected for real payment. That means that these instructions are very important, and you should pay careful attention. There are no wrong choices in this task, as everyone will have different preferences and yours will remain anonymous. However, you should make sure you answer truthfully. Otherwise, the outcome you get might be not what you would really prefer.

To understand the decision task, we will start with the following example.

| Q# | | Option A | | Option B |
|---|---|---|---|---|
| 1 | Would you rather have: | $0.10 TODAY | or | $50 in 6 MONTHS |
| 2 | Would you rather have: | $0.20 TODAY | or | $50 in 6 MONTHS |
| 3 | Would you rather have: | $0.30 TODAY | or | $50 in 6 MONTHS |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 499 | Would you rather have: | $49.90 TODAY | or | $50 in 6 MONTHS |
| 500 | Would you rather have: | $50.00 TODAY | or | $50 in 6 MONTHS |

Imagine that in each question you have to pick either Option A (an amount of money today) or Option B ($50 in 6 months). After you answer all 500 questions, suppose I will randomly pick one question and pay you the option you chose on that one question. Each question is equally likely to be chosen for payment. Obviously, you have no incentive to lie on any question, because if that question gets chosen for payment, then you'd end up with the option you like less.

I assume you're going to choose Option B in at least the first few questions, but at some point switch to choosing Option A. So, to save time, just tell me at which dollar value you'd switch. In other words, your task is to state the dollar amount today that this delayed $50 is worth to you. To decide what that amount is, you may want to think about what amount of money today would make it really hard for you to choose between this amount in column A and the later $50 payment. At which dollar value would you start preferring money TODAY?

When you tell us this amount, I can then 'fill out' your answers to all 500 questions based on your switch point (choosing Option B for all questions before your switch point, and Option A for all questions at or after your switch point). At the end of today's session, we will randomly choose one question you answered, and then randomly choose one of the rows in that question for payment. Again, if you lie about your true switch point, you might end up getting paid an option that you like less. Now that you know the rows you are choosing from each time, we won't keep showing them visually for every question. The same question can equivalently be written like this:

**To me, ____ TODAY is as good as $50 in 180 days.**

In the task, you would move the slider until it displays the amount where you would switch columns and start preferring the amount today. You may choose any amount from $0 to $50 in $0.10 increments.

Once you make your decision, you will press next. After you press next, you will not be able to go back and change your decision. Please choose carefully, as each of the decisions you make has equal chance to be selected for payment.

Notice that we can use the same procedure to ask you about your valuation of products, foods, and lotteries. For example, we could ask you

**To me, ____ for sure is as good as a 50% chance of $20.**

This question is equivalent to asking you this set of questions:

| Q# | | Option A | | Option B |
|---|---|---|---|---|
| 1 | Would you rather have: | $0.10 for sure | or | 50% chance of $20 |
| 2 | Would you rather have: | $0.20 for sure | or | 50% chance of $20 |
| 3 | Would you rather have: | $0.30 for sure | or | 50% chance of $20 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 199 | Would you rather have: | $19.90 for sure | or | 50% chance of $20 |
| 200 | Would you rather have: | $20.00 for sure | or | 50% chance of $20 |

Again, I assume you would prefer Option B in the top rows and then as the value of Option A increases, at some point you would switch to choosing Option A. Your task is to tell us at what value you would first start choosing A, or would feel the same about A and B.

To familiarise yourself with the slider, we prepared five questions for you to try. These are just for practice and your decisions in these trials will not affect your payment. If you have any questions at any time, please put your hand up and the experimenter will come to answer your question. When you are finished, please display your signal.

## How is my payment determined?

You will answer 32 of these questions today, and the computer will randomly select one. Suppose the computer randomly chose the fourth practice question we just asked.

**4. To me, ____ now is as good as $30 in 25 years.**

Remember that this question can be visualised in rows.

| Q# | | Option A | | Option B |
|---|---|---|---|---|
| 1 | Would you rather have: | $0.10 TODAY | or | $30 in 25 YEARS |
| 2 | Would you rather have: | $0.20 TODAY | or | $30 in 25 YEARS |
| 3 | Would you rather have: | $0.30 TODAY | or | $30 in 25 YEARS |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 299 | Would you rather have: | $29.90 TODAY | or | $30 in 25 YEARS |
| 300 | Would you rather have: | $30.00 TODAY | or | $30 in 25 YEARS |

Then, the computer will randomly choose a row where the amounts range from $0.10 to $30. Suppose that it randomly picks the row where Option A is $19.20 now and Option B is $30 in 25 YEARS. You told us what amount now is as good as $30 in 25 years.

*Scenario 1* You tell us an amount lower than $19.20. For example, you said that to you $5 now is as good as $30 in 25 years. We will therefore infer that for you $19.20, which is more than $5, must be better than $30 in 25 years and we will pay you $19.20 now.

*Scenario 2* You tell us an amount higher than $19.20. For example, you said that to you $22 now is as good as $30 in 25 years. We will therefore infer that for you $19.20 which is less than $22 must be worse than $30 in 25 years and we will pay you $30 in 25 years.

Now suppose the computer randomly chose the fifth practice question we just asked.

**To me, ____ for sure is as good as a 50% chance of $20.**

This question can be visualised in rows in the same way: Then, the computer will randomly choose a row where the amounts range from $0.10 to $20. Suppose that it randomly picks the row where Option A is $2.70 for sure or Option B is a 50% chance of $20.

Suppose you said that to you, an amount for sure is as good as a 50% chance of $20.

*Scenario 1* You tell us an amount lower than $2.70. For example, you said that to you $1 is as good as a 50% chance of \$20. We will therefore infer that for you \$2.70 which is more than \$1 must be better than a 50% chance of \$10 and we will pay you \$2.70 for sure.

*Scenario 2* You tell us an amount higher than \$2.70. For example, you said that to you \$4 is as good as a 50% chance of \$20. We will therefore infer that for you \$2.70 which is less than \$4 must be worse than a 50% chance of \$20. You will toss a fair coin and if it lands on heads, we will pay you \$20 and if it lands on tails, we will pay you \$0.

**Can I get a better outcome by choosing a number that is larger or smaller than my real preference?**

No. If you choose an amount that is different from your true preferences, you run the risk of not receiving your preferred option. Let's consider an example.

Suppose that, to you \$5 now is as good as \$30 in 25 years.

*Scenario 1* You misreport by providing a smaller number. Suppose you say that to you \$1 is as good as \$30 in 25 years. We will therefore infer that you prefer any amount larger than \$1 to \$30 in 25 years.

Suppose the computer draws the following row:

| Q# | | Option A | | Option B |
|---|---|---|---|---|
| 1 | Would you rather have: | \$2.10 now | or | \$30 in 25 years |

Based on your stated preference, we will infer that you prefer \$2.10 now than \$30 in 25 years and we will pay you \$2.10.

You are worse off because your true preference would be to wait for \$30 in 25 years. In this scenario, if the computer generates any number between \$1 and \$5, you will be worse-off.

*Scenario 2* You misreport by providing a larger number. Suppose you say that to you \$28.50 is as good as \$30 in 25 years. We will therefore infer that you prefer \$30 in 25 years to any amount smaller than \$28.50 now.

Suppose that the computer picks the following row: Suppose the computer draws the following row:

| Q# | | Option A | | Option B |
|---|---|---|---|---|
| 1 | Would you rather have: | \$26.90 now | or | \$30 in 25 years |

Based on your stated preference, we will infer that you prefer \$30 in 25 years than \$26.90 now and we will pay you \$30 in 25 years.

You are worse off because your true preference would be to receive \$26.50 now. In this scenario, if the computer generates any number between \$5 and \$28.50, you will be worse-off.

If you misreport the amount that you choose, you run the risk of being worse-off than if you had chosen the true amount. You should take the time to carefully consider what amount instinctively feels as good.

# B TSST-G Protocol

The researchers will now come around to unlock the next section.

For the next task we will have a few minutes of silence. You may now click next. The instructions will be on the screen in front of you. Your time starts now.

*Instructions will be displayed on Qualtrics and they will start opening the envelopes. Wait 4 minutes.*

Your time is up. Can all participants please click next, stand up and collect their papers. Please follow me to the front of the room.

Please hand your notes to [EVALUATOR] and take your places on the spots marked with an X.

*PANEL collects their notes without smiling or thanking them and adjusts the camera to eye-height.*

I will now ask you to deliver your speeches. When asked to speak, you should speak for the full two minutes. Number X: Please begin.

*Ends early:*

- 10-20 second silence – “You still have time. Please continue.”
- Another 10 seconds – questions
  - Why do you think you are especially well-qualified for this task?
  - Why do you think you are better qualified than the other applicants?

  - You said you have a particular talent for []. What other special talents would you say that you possess?
  - You were just speaking about []. What do you think about []?
  - Please complete this sentence: "I am the best at...."
  - Describe your leadership abilities.
  - How would your family and friends describe you?
  - What qualities do you value in a friend?
  - What qualities do you value in a co-worker?
  - What are your long-term career goals?
  - What is your opinion about teamwork?

- Calm, fluent first minute – interrupt with questions
  - Thank you, but we would prefer to hear more about your strengths.
  - Thank you, but we would prefer to hear more about your problem-solving abilities
- Please stay straight. Please take your hands out of your pocket.
- You are required to either participate or withdraw from this study

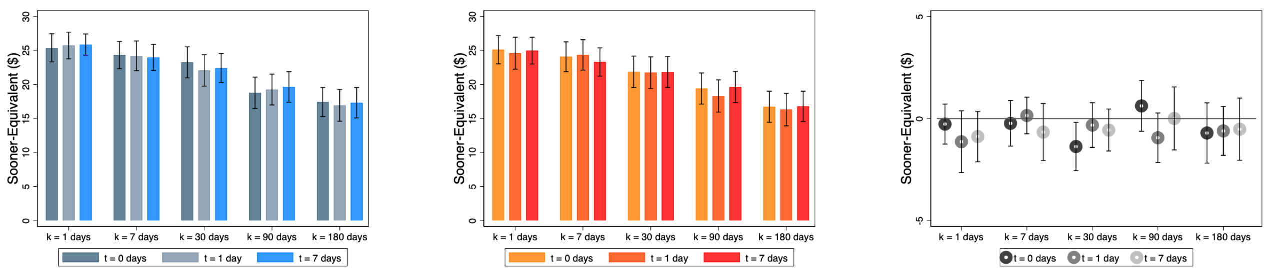
*After two minutes has finished, stop move onto another participant.*

That's enough, thank you. Number Y: Please begin.

We now want you to solve a calculation task. Please count aloud backwards from the number we give you down to zero in 16-step sequences. For example, if you are given number 102, you should calculate 102–86–70–54 and so on. Please calculate as quickly and correctly as possible. Should you miscalculate, we will point out your mistake and either you or another participant will have to try again or start over. We will call on you with your participant number. You may also be called on multiple times. Number X: Please begin with the number

[]. *If the research participant miscalculates, the chair should respond with the standard phrase:* Incorrect. Please begin again with []. *If slow/without mistakes:* Please calculate faster (speak louder). *Total 8 minutes.* Thank you, that's enough. You can now return to your seats. Please remain silent.

## C Sooner Equivalent Before and After Stress Induction




(a) Sooner Equivalent (Pre-Stress)

(b) Sooner Equivalent (Post-Stress)

(c) Difference in Sooner Equivalent

Figure 6: Sooner Equivalent measures before and after stress induction, and the change between them.

Figure 6 presents Sooner Equivalent (SE) values across different delay conditions before and after the stress induction. As the backend delay increases, SE values consistently decrease, indicating that participants appropriately discounted delayed rewards. This pattern suggests that they understood the tradeoff between sooner and later payments built into the task. In contrast, the presence of a front-end delay appears to have little effect on SE. However, there is no statistically significant difference in SE before and after stress induction, suggesting that stress did not meaningfully alter participants' valuation of delayed rewards.