**Methods**

88 participants were recruited through a combination of the University of Denver’s SONA system and flyers posted in and around campus. All participants were fluent in English with normal or corrected-to-normal vision and were consented and debriefed. Participants were compensated with extra credit or cash. Three participants were excluded for failing check trials in the risky decision-making task resulting in a total of 85 participants (47 female, 30 male, 4 gender nonconforming, and 1 other) between the ages of 18 and 35 years old (M = 19.8, SD = 2.63). 66 identified as White, followed by 4 Black/African-American, 4 Asian, 3 American Indian/Alaska Native, 3 Multiracial, 2 Other, and 3 Prefer not to say. The majority identified as non-Hispanic/Latinix (n = 73). This study was approved by the University of Denver Institutional Review Board.

**Procedure Overview**

After participants give informed consent and are found to have not consumed alcohol and/or used cannabis the day of the study (Substance Use Questionnaire, details below), they will move on to the risky monetary decision-making instructions. The participant will follow along as the experimenter reads the instructions aloud. To ensure comprehension of the instructions, participants will take a brief, simple comprehension quiz. If the participant demonstrates comprehension, they will then proceed on to the risky monetary decision-making task. In the risky monetary decision-making task, participants will first complete practice trials before moving onto the first round (Static Choice Set) and then the second round (Dynamic Choice Set) (details below). The first round will measure individual variability in participants’ risk preferences and the second round will consist of easy and difficult decisions tailored to the participant based on their risk preferences. The colors used (grey (RGB: 194, 194, 194); blue (RGB: 119; 209; 205)) in all presented stimuli across all trials will be matched for luminance to eliminate the influence of color luminance variation on task-evoked pupil responses (TEPRs). Following the risky monetary decision-making task, participants will then proceed on to the working memory tasks. First participants will complete the Operation Span before completing the Symmetry Span (details below). Neither are luminance controlled. Pupillometry will be recorded using an EyeLink 1000+ eye-tracker (details below) during the risky monetary decision-making task. Then, participants will complete a series of individual difference surveys, demographics, and a post-study questionnaire. Finally, participants will be debriefed and thanked for participating in the study.

**Risky Monetary Decision-making (RDM) Task**

The RDM task was adapted from Sokol-Hessner and colleagues (2009), similar to that in Brooks & Sokol-Hessner (*under review*), and nearly identical to that from the pilot study. All trials will be gain-only trials in which no losses will be incurred for choosing gambles.

*Decision-making Model*. The model is based on prospect theory (Kahneman & Tversky 1979, Tversky & Kahneman 1992). The model is identical to those used in previous studies (see equations 1 and 2 below; Brooks & Sokol-Hessner, 2020; Sokol-Hessner et al., 2009; Sokol-Hessner et al., 2016).

(1)

(2)

Equation (1), the utility function, calculates the subjective utility of the choice options, which is then entered into Equation (2), the softmax function, that calculates the utility of choosing one option over the other. Parameters, rho (ρ) and mu (μ), were used to create the monetary values in the choice options and measure a participant’s risk preferences. ρ values risk capture preferences/diminishing marginal utility (e.g., a greater subjective valued difference between $5 and $10 compared to the subjective valued difference between $100 and $105 despite the same objective difference of $5 in both) in the utility function (see equation 1). ρ values greater than 1 indicate more risk-seeking preferences while ρ values less than 1 indicate more risk-aversive preferences. ρ values of 1 indicate risk-neutral preferences. μ is the softmax function (see equation 2) that measures choice consistency of choosing one option or the other. Higher values of μ indicate more consistent decision-making across trials.

*Choice Options.* In each trial, participants will be presented and instructed to choose from a binary monetary choice between a gamble (risky option) and a guaranteed alternative (safe option). The gamble consists of two potential outcomes each with equal probability (50%) of receiving if chosen. The guaranteed alternative, if chosen, is received 100% of the time.

*Choice Selection.* The risky gamble and guaranteed alternative appear randomly on either side of the screen for each trial. For example, the gamble will appear on either the left or the right of the screen. To make a decision, participants have 4 seconds to press either the “V” or “N” key to choose the left and right choice option respectively. After a decision is made, participants will be presented with a choice option outcome (e.g., if the gamble is chosen, one of the two outcomes will be presented). If a choice is not made within the allotted time, participants will receive feedback that a choice was not made.

*Static Choice Set.* Participants will receive the same randomly presented 50 trials of choice options, which will measure their risk preferences. Of the 50 trials, 40 will identify the best fitting ρ and μ pair. The choice options across all 40 trials capture a range of risk preferences from ρ values 0.30 to 1.89 based on previous studies (e.g., mean (standard deviations): from Sokol-Hessner et al. (2009), ρ = 0.83 (0.04); from Sokol-Hessner et al. (2015) ρ = 0.91 (0.07)). These values represent the extreme ends of risk preference – very risk-averse to very risk-seeking respectively – and should capture a wide range of individual differences in risk preferences. Subsequently, this range should also capture a participant’s respective indifference point – where the participant should experience the most difficulty in accepting or rejecting a gamble (details in Dynamic Choice Set below).

Of the 50 trials, 10 are catch trials that assess whether or not the participants are paying attention and following instructions. If they positively value money, participants should choose the expected option regardless of risk preference. In half (5) of the catch trials, participants should choose the gamble because the expected gain in the gamble is always greater than the guaranteed alternative, regardless of risk preferences (e.g., a gamble of $10.35 and $0 compared to a guaranteed alternative of $0). In the other half (5) of the catch trials, participants should choose the guaranteed alternative because they will gain nothing ($0) or incur a net loss (the gain in the gamble is less than that of the guaranteed alternative) if they choose the gamble (e.g., a gamble of $0 and $0 compared to a guaranteed alternative of $7.55). Participants who choose all (100%) the expected options to be chosen are likely to be paying attention while participants who choose the expected options roughly half (50%) of the time are unlikely to be paying any attention. Replicating criteria from the pilot study, participants who miss more than 10% of the check trials (i.e., more than one out of the ten check trials) will be excluded. This criterion resulted in the removal of 21% of participants in the pilot data. We expect a lower rate of attrition in the current study due to its in-person nature (versus the online pilot study).

*Dynamic Choice Set.* Based on how the participant responded in the Static Choice Set, a grid search method will be used to quickly calculate and approximate the best fitting ρ and μ pair. Two hundred ρ values from 0.3 - 2.2 in increments of 0.01 and two hundred and one μ values from 7 - 80 in increments of 0.37 will be used maximize the likelihood of fit. After calculating the best fitting ρ and μ pair out of the 40,200 possibilities, participants receive a pre-created 120 trial bespoke choice set created for an individual with that pair of ρ and μ values.

Of the 120 trials, 60 will be easy decisions and 60 will be difficult decisions that best match the participants subjective experience of choice difficulty. Easy decision trials are defined as p(gamble) < 0.15 and p(gamble) > 0.85. The participant should easily reject the gamble in the former because the guaranteed alternative is subjectively the obvious, better option (*easy reject*) and easily accept the gamble in the latter because the gamble is subjectively the obvious, better option (*easy accept*). Easy decision trials are generally easier to make because the subjective values between the gamble and the guaranteed alternative are more different and therefore have less conflict. Difficult decision trials, on the other hand, are defined as 0.45 < p(gamble) < 0.55. This range captures the subjective probabilities of gambling close to chance (50%) at the indifference point. In other words, the better option is not as easily determined in the difficult decision trials because the subjective values between the gamble and guaranteed alternative are more similar in value and therefore have more conflict. Easy and difficult decision trials will not be labeled, nor will the participants be informed of their existence. Participants will only be aware that the current round is similar in structure to the previous round (Static Choice Set).

**Working Memory Tasks**

*Operation Span (OSpan; Kane et al., 2004; Unsworth et al., 2005).* Participants will be presented with a series of letters. These letters must be actively maintained in working memory. Participants will also be presented with simple math problems (e.g., (2 x 2) + 1) and then an answer to which they must determine is true or false. The math problems serve as a distractor task. Math problems and letters are randomly presented in pairs ranging from 3-7 pairs across a total of 5 trials (i.e., four pairs would be: math problem, letter, math problem, letter, math problem, letter, math problem, letter). After completing a given trial, participants will then recall the letters and their order of presentation. The accuracy of the letters recalled, and their presentation order reflects a participant’s WMC. Participants will be required to perform the math problems at or above 85% correct for trials to be used in subsequent analyses, so as to control the cognitive demands of the task. Before doing the paired version of the task (with math and letters interleaved), participants will first practice letters alone, and then practice math problems alone.

*Symmetry Span (SymSpan; Kane et al., 2004; Unsworth et al., 2009).* Participants are presented with red squares in a 4-by-4 square matrix. The red squares must be actively maintained in working memory. Participants are also presented with images in which they must judge for left-right symmetry. The red squares and images are randomly presented in pairs ranging from 2-5 pairs across a total of 4 trials (i.e., four pairs would be: image, red square, image, red square, image, red square, image, red square). After a given trial, participants will then recall the location of the red squares on the 4-by-4 grid and their order of presentation. The accuracy of the red square locations recalled, and their presentation order reflects a participant’s WMC. Participants will be required to perform the image symmetry judgment at or above 85% correct for trials to be used in subsequent analyses, so as to control the cognitive demands of the task. Before doing the paired version of the task (with image and red squares interleaved), participants will first practice red squares alone, and then practice image symmetry alone.

**Pupillometry**

Pupillometry will be recorded with an EyeLink 1000+ infrared eye-tracking camera with EyeLink acquisition software version 5.09 (SR Research Ltd., Mississauga, ON). The EyeLink 1000+ will be configured using a 35mm lens, a 9-point gaze location calibration, and a monocular sampling rate at 500Hz. Participants will be seated approximately 60 cm away from the monitor and rest their chin on a head mount. Eye data will be recorded throughout the RDM task.

*Pupil Preprocessing*. Pupil preprocessing will be conducted using R packages *gazeR* (Geller et al., 2020) and *dplyr* (Wickham et al., 2021). Pupil data will be inspected in R for missing timepoints. Trials missing more than 50% of samples within a trial will be removed, and participants with 20% or more trials missing will be excluded from pupillometry data analysis (following McLaughlin et al., 2022 using a young adult undergraduate sample). Blinks will be corrected using linear interpolation with correction extending from 100ms prior to missing data to 200ms following the missing data period. A five-point moving average will be applied to smooth the data. Pupil dilation on each trial will be calculated relative to pupil during a pre-trial baseline period. Average pupil dilation on each trial will be calculated for each decision window from when the choice options are presented to when one of the two choices is selected (up to a maximum of 4 seconds).

**Questionnaires**

All questionnaires, except for the Post-Study Questionnaire, will be administered on Qualtrics. The Post-Study Questionnaire will be administered using pen and paper.

*Substance Use Questionnaire (SUQ).* The SUQ is a 6-item questionnaire that will assess a participant’s frequency of alcohol consumption and cannabis use. Participants who have consumed alcohol or used cannabis the day of the study will be excused.

*Instructions Quiz.* Participants will take a 3-item quiz to assess their understanding of the RMD task. Participants will receive feedback and clarification on items they answer incorrectly. If a participant demonstrates poor understanding of the RMD task even after feedback and clarification, they will be excused from the study.

*Need for Cognition Scale (NCS-18; Cacioppo et al., 1984; Cacioppo & Petty 1982).* The NCS-18 is an 18-item scale that will assess a participant’s tendency to engage in and enjoy effortful cognitive activities (*Need for Cognition*; NFC; e.g., “I would prefer complex to simple problems”). Items are scored on a Likert scale from 1 (“Extremely uncharacteristic of me”) to 5 (Extremely characteristic of me). Final scores will range from 18 (indicating low NFC) to 90 (indicating high NFC).

*Perceived Stress Scale (PSS; Cohen et al., 1983).* The PSS is a 10-item scale that will assess a participant’s perception of stress in the past month of their life. Items are scored on a Likert scale from 0 (“Never”) to 4 (“Very Often”). Final scores will range from 0 (indicating low chronic stress) to 40 (indicating high chronic stress).

*Demographics.* Standardbasic participant demographic information (e.g., age, gender, race/ethnic identity) will be collected.

*Post-Study Questionnaire.* A self-report of the participant’s experience, strategies used, and points of confusion during the RDM task, OSpan, and SymSpan. Some questions will be short-answer, and some will be quantitative Likert ratings (e.g., of motivation in the task, current stress, experienced ease/difficulty, etc.).

**Results**

There were no significant differences on reaction times (RTs) between easy reject and easy accept, t(84) = 0.29, p = .77. Thus, we were able to combine both easy reject and easy accept into easy choices. When comparing choice difficulty, there was a significant difference between easy and difficult choices, t(84) = -10.37, p < .001. Participants took longer to make difficult choices (M = 1.69, SD = 0.34) than easy choices (M = 1.45, SD = 0.22).

We also examined whether combinations of previous and current difficult choices (Easy-Easy, Difficult-Easy, Difficult-Difficult, and Easy-Difficult) were different from each other in terms of RTs. Difficult-Easy was not significantly different from Easy-Easy, t(84) = 0.72, p = .47. Easy-Difficult was not significantly different from Difficult-Difficult, t(84) = 1.63, p = .11. Finally, Easy-Easy was not significantly different from Difficult-Difficult, t(84) = -0.08, p = .94. Altogether, participants did not differ in how long they took to make a choice depending on the different combinations of previous and current difficulty.

When examining choice difficulty effects on RTs for each WMC group, choice difficulty was associated with significant differences in RTs in both the low WMC group, t(40) = -8.05, p < .001, and the high WMC group, t(40) = -6.63, p < .001. Both groups took longer to make a choice when making difficult choices; low WMC group: difficult(M = 1.7, SD = 0.37), easy(M = 1.45, SD = 0.19) and high WMC group: difficulty(M = 1.69, SD = 0.32), easy(M = 1.47, SD = 0.25).

In model 1, we examined the role of current and previous difficulty, WMC, and NFC on subject-level average RTs. Regression coefficients revealed an effect of current difficulty, β = -0.23(0.03) , p < .001, but not previous difficulty, β = 0.02(0.13), p = .88, WMC, β = -0.01(0.03), p =.67, or NFC, β = 0.03(0.03), p = 0.38. When regressing only for current difficulty on subject level average RTs, regression coefficients indicate an effect of current difficulty, β = -0.24(0.3), p < .001.

In model 2, we examine the role of current and previous difficulty, WMC, and NFC on trial-by-trial RTs. Regression coefficients revealed an effect of current, β = -0.04(0.02), p < .001, and previous difficulty, β = 0.04(0.02), p < .01, but not WMC, β = -0.03(0.01), p = 0.8 or NFC, β = 0.1(0.01), p = 0.4. When regressing for only current and previous difficulty on trial-by-trial RTs, regression coefficients revealed an effect of current, β = -0.05(0.02), p < .001, and previous difficulty, β = 0.04(0.02), p < .01.

In model 4, we examined the role of current and previous difficulty, WMC, and NFC on subject level variability of RTs. Regression coefficients revealed an effect of previous difficulty, β = 0.05(0.02) , p < .01, and WMC, β = -0.03(0.01), p < .01 but not current difficulty, β = -0.05(0.02), p = .69, or NFC, β = -0.003(0.01), p = 0.75. When regressing for only previous difficulty and WMC on subject level average RTs, regression coefficients revealed an effect of current difficulty, β = 0.06(0.01) , p < .001, and WMC, β = -0.03(0.01), p < .01.