

Using Visualization to Counteract Discounting

by

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Abstract

When it comes to decisions between payoffs sooner or later in time, people tend to over discount the later reward and choose the sooner option. Discounting can manifest itself in decisions regarding finance, health, and the environment, is ubiquitous, and transcends cultures. The quality of life and life expectancy can be negatively impacted, especially in later years, as the negative consequence of myopic decisions accumulate over time. As of 2023, forty-three percent of Americans could not pay for a one-thousand-dollar emergency from savings and over half of Americans self-report they are behind on their retirement savings. Intertemporal choice decisions are malleable, and discounting can be counteracted by how attention is focused, and time is represented. Visualization is a powerful tool for influencing these factors. Can visualization be used to reduce discounting in money choice decisions? To test this hypothesis, we visualized Money Earlier or Later (MEL) questions and measured how visualization influenced participants to choose the larger later option. We implemented a single page React application which presented participants with three different treatments of MEL questions; a worded version found in much of the existing literature and a bar chart with and without the horizontal time axis extending past the larger later bar creating space to the right. We found both bar chart visualizations increased the proportion of later choices over the worded with the extended axis bar chart increasing later choices the most. We believe these results can help create bar chart visualizations of intertemporal choice decisions to influence people to choose the larger later option at least one out of eight times more often vs. a worded form.

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I dedicate this thesis to my father Nicholas Cordone whose life experience inspired my interest in political economy.

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Chapter 1

Introduction

Decisions at one point in time that have consequences at another point in time are referred to as intertemporal choice decisions (Frederick et al., 2002). When it comes to intertemporal choice decisions involving rewards at two different times, people tend to over discount the later reward and choose the earlier one even when it's more advantageous to choose the later. Intertemporal choice decisions are ubiquitous, transcend national borders (Wang et al., 2016), and are dependent on many factors including uncertainty, history of trauma (Imas et al., 2015), financial education (Lührmann et al., 2018; Lusardi & Mitchell, 2014), sense of purpose about life (Hill et al., 2016), and others. These decisions are malleable, and discounting can be counteracted through how the decision is framed and how time is represented. For example, presenting dates instead of delay times of when a reward will be received appears to reduce discounting (Read et al., 2005). Orienting choice displays vertically instead of horizontally reduces discounting (Romero et al., 2019) and changing the way attention is focused on time can alter discounting (Ebert & Prelec, 2007). Visualization offers a powerful tool that can influence these factors. In this paper we explore using visualization to do just that.

1.1 Our Contributions

Can visualization be used to influence intertemporal choice decisions? We investigate this question by focusing on the following two questions through an experiment we conducted:

- 1. Is the choice frequency of earlier vs. later amounts for the worded vs. bar chart visualization of MEL choice decisions the same?*
- 2. For the bar chart visualization in question one, does extending the time axis past the bar representing the larger later amount creating space to the right cause the participant to choose the larger later option more often?*

We based our hypothesis of the following statements. We know that visualizations can influence economic decisions compared to their worded counterpart (Bancilhon et al., 2020; Fernandes et al., 2018; Kale et al., 2021). In Western cultures time is represented horizontally (Romero et al., 2019) and horizontal representation is spatially oriented while vertical orientation is object based (Nicholls et al., 2004). Mental zooming and spatial zooming influence each other (Trope & Liberman, 2010) and mentally zooming out can reduce discounting (Yi et al., 2017). A bar chart seemed to be the best visualization to explore the spatial relationship between visualization and discounting since it uses the most effective channels of vertical and horizontal distance on a common axis (Cleveland & McGill, 1984) and by Steven's power law perception sensitivity is linear for length. We chose to focus on the time axis because we also know that time horizons have more of an effect on discounting than amounts (Holden & Quiggin, 2017).

Based on the assertions above, we assert that a bar chart visualization of a MEL question that extends the time axis past the larger later bar will cause participants to mentally zoom out to a larger time window causing them to choose the larger later option more often. To the best of our knowledge no research has been conducted on measuring how visualization of MEL questions affects a person's choice of earlier vs. later options and space has not been manipulated in the visualization along the horizontal time axis to see if that choice can be influenced. The intent of the first question is to establish a baseline of how the proportion of choosing the later option for a worded version of MEL question compares to a bar chart representation. We then test our hypothesis of mentally zooming out participants by extending the time axis past the larger later bar creating space to the right to nudge them toward choosing the later option.

We created a single page React app visual survey tool we call Vizurvey to conduct a between-subject experiment with one hundred participants we recruited through the online research platform Prolific. We presented eight Money Earlier or Later (MEL) questions in three different treatments. The first was in a worded form found in existing literature. The second treatment used a bar chart visualization with amount on the vertical axis and delay time on the horizontal axis, and the third treatment was a bar chart that extended the time axis past the larger later bar creating horizontal space to the right of the larger later bar.

Our experimental results confirmed our hypothesis. When the data was analyzed across participants, it suggests a small to medium effect in participants choosing the larger later option between the worded and bar chart with space to the right, a small effect between the worded and

bar chart without space to the right, and a small effect between the two bar charts. When we analyzed the data with the questions as the unit of analysis (across the questions), it suggests a large effect size between the worded and bar chart with space to the right, small to medium between the worded and bar chart without space to the right, and large effect between the two bar charts. While we did not reach statistical significance in our analysis across participants the trend line from worded to bar chart without space to bar chart with space was toward statistical significance. We did reach statistical significance in our analysis across questions. We call this discovery the space-zoom effect and believe it can be used to influence people at least one out of eight times on average to choose the larger later option vs. the worded form. We also concluded there was a lot of noise in the experiment due to the psychological aspects and to reach statistical significance in the analysis across participants we would need to either rerun the experiment with one hundred participants per treatment or design a new within subject experiment using the same visualizations or both. We also concluded increasing the number of questions from eight for the across question analysis would be beneficial since we would have a larger sample size.

Chapter 2

Background

2.1 The Utility Function, Intertemporal Choice, and Discounting

In economics, the utility function relates consumption to the utility realized by the person. When consumption decisions have consequences at another point in time they become intertemporal choice decisions (Frederick et al., 2002). When people are faced with intertemporal choice decisions, they tend to prefer the immediate rewards over delayed rewards even when the sooner reward is smaller and choosing it may have worse outcomes in the future than if they chose the larger, later reward. Two studies done by Mischel *et al.* (Mischel et al., 1972; Mischel & Ebbsen, 1970) explored how the focus of attention effected delayed gratification in preschool children and are popularly known as the Stanford Marshmallow Experiment. Children from Stanford Universities preschool were recruited in a between-subject experiment designed to measure how long the child could delay gratification when left in a room alone and presented with more and less desirable rewards in the form of snacks. The child could signal the researcher to re-enter the room at any time; however, the child would get the less favorable snack. In the first study, the treatments were dependent on what snacks were in the room with the child while they waited; both, the less desirable, the more desirable, and neither. The researchers expected the longest wait time would be with both snacks in the room and found the exact opposite results; those children who had neither snack in the room had the longest wait time. The second study explored how external and cognitive distractions effected wait time. They found being distracted from thinking about the rewards, especially positive thoughts, increased wait times while thinking about the rewards or sad thoughts decreased wait time. There was a follow-up study that determined the ability of a child to delay gratification by waiting for a larger, later treat was an indicator for success later in life (Mischel et al., 1989), although the results were disputed in later studies (Benjamin et al., 2020; Watts et al., 2018).

Attributing less value to rewards as their realization is further from the present is discounting or the opposite of delayed gratification. By perceiving the future reward value as diminished, we are less likely to delay gratification. There have been many models of discounting proposed

including discount utility (exponential) (Samuelson, 1937), hyperbolic (Ainslie, 1975; Ainslie & Herrnstein, 1981; Loewenstein & Prelec, 1991; Mazur, 1987), and descriptive heuristic-based models such as ITCH (Marzilli Ericson et al., 2015) and DRIFT (Read et al., 2011, 2013). One experimental paradigm for measuring intertemporal choice decisions that became popular in the 1980's is Money Earlier or Later (MEL) questions (Cohen et al., 2020). With MEL experiments, questions follow a format like "Would you rather receive \$300 in 2 months or \$700 in 7 months?" where the participant chooses the earlier or later amount/delay pair. MEL design paradigm follows one of three designs. Multiple Price Lists (MPL) sometimes called Multiple Choice List (MCL) or Choice Lists (CL) (Andersen et al., 2008) where a participant is presented with an amount/delay pair and the delay of the second amount is fixed. The participant chooses from an order list for the delayed pair amount. Randomized Binary Choice is where the earlier and later delay and amount pairs are presented randomly and in isolation. Matching is when participants are given an open-ended response for a delay time or amount, and they fill in the blank to make the amount/delay pairs seem equal.

Some have questioned the validity of the MEL paradigm since it is based on income flows and the input to the utility function is generally accepted to be consumption. Using income implies the person is either completely myopic or has perfect liquidity constraints since all the income would be immediately spent on consumption. Still MEL experimental design is widely used due to its convenience (Cohen et al., 2020) and we will use it in our experiment.

In the literature, present bias is discussed as offering an immediate reward with no delay compared to a delayed reward, and discounting when the choice is between too delayed rewards, one sooner and one later. Asset integration is the idea that a choice will be made based on the total amount of money the person would have after the decision and not only on the amount of the reward (Green et al., 1997).

When talking about discounting we want to be mindful of not seeing it as a judgement of morality or will power. Recent work suggests that discounting results from imperfect foresight (Gabaix & Laibson, 2017). The authors start with a Bayesian decision model with perfect time preferences and show that lack of perfect foresight creates behavior that is consistent with classical discounting of future rewards.

2.2 Mental Zooming, Attention, and Discounting

Construal Level Theory (CLT) states that to transcend our immediate experiential reality of the self, here, and now, we create representations of objects and events called construals at various levels of abstraction (Trope & Liberman, 2010). This enables us to mentally zoom in and out along different psychological dimensions of time, space, social distance, and hypotheticality. The relationship between abstractness level of construals and psychological distance on a dimension is proportional and bidirectional; that is, the more abstract a construal, the further away it is psychologically and the further the psychological distance of a construal, the more abstract it will be. CLT also suggests that a common dimension of psychological distance underlies the different spatiotemporal distance dimensions and that we automatically associate the distance of a stimulus on one dimension with other dimensions (i.e., a socially distant person will be perceived to be spatially more distant). Because CLT uses the self as the starting point, estimating distances from us to objects in a room have been shown to be altered by priming a person from more concrete to more abstract states of mind. A person's estimate of distances between other objects in the room however, was not altered (Liberman & Förster, 2009). CLT predicts that as outcomes are shifted into the future, overall value will shift to the high-level construal value and whether discounting takes place is based on the relative value of the low-level construal compared to the high level one and that priming participants to think abstractly reduces discounting in worded MEL choice decisions (Yi et al., 2017) and that priming participants to think concretely about future events and to think abstractly about sooner events reduced delay discounting (Yi et al., 2017).

Recent literature uses a mental zooming model to explain hyperbolic discounting and magnitude effects (Holden et al., 2020; 2017). The hypothesis behind their model is that cognitive limitations cause us to mentally zoom in and out. The authors analogize this mental zooming process to google Earth. Their model has base consumption as an argument to the utility function where a person will integrate the sooner or later amount as a function of their daily wage rate (average daily amount of money they earn), the difference between later and sooner times, and the larger amount in the MEL question. Their experiments show that changes in the time horizon and magnitude amounts do not have the same effect on discounting. “A doubling of the time horizon leads to close to a four-fold increase in the level of asset integration. In contrast, a doubling of the amount has only half the effect, a (close to) two-fold effect on the level of asset integration. This

indicates that time effects (hyperbolic) are relatively stronger than magnitude effects. This comparison is dimensionless and hence independent of how time and money are measured. It is an intriguing possibility that this asymmetry between time and magnitude is a robust characteristic of human nature just like loss aversion is.“ This relationship persisted independent of the two countries studied.

Studies have shown that discounting can be reduced through the spatial representation of monetary decisions. Orienting time in advertisements vertically instead of horizontally for a Western audience (Westerners time orientation is horizontal) reduces discounting (Romero et al., 2019). The authors attribute orienting time congruent with the participants spatial representation of time increases attention to time causing delays to be perceived longer. Read *et al.* (2005) show that using dates instead of delay in units of time reduces or eliminates discounting and call this the date/delay effect.

2.3 Visualization and Decision Making

The human vision system is a high bandwidth communication channel into the human brain through parallel processing at the preconscious level (Munzner, Tamara & Maguire, Éamonn, 2015). Figure 2.3.1 shows Anscombe’s Quartet which illustrates how effective visualization can be. Four datasets with the same summary statistics (mean, variance, linear regression line, etc.) are readily apparent to be very different. Visualization can be broken down into the representation of data and relationships with simple geometric elements (points, lines, areas) called marks arranged to control their appearance. Channels include spatial position that is planar aligned or unaligned, spatial region, and use the color attributes of hue, saturation, and luminance. In their paper on perception and graphical methods, Cleveland & McGill (1984) identify elementary perceptual tasks people perform when reading a graph. These perceptual tasks can be ranked by how accurately people access information from them. The elementary tasks in order are position along a common scale, position along nonaligned scales, length, direction, angle, area, volume, curvature, shading, and color saturation. Differences in perception of these perceptual tasks is called psychophysics or the study of the human perception of physical stimuli. Steven’s Psychophysical Power Law (Stevens, 1975) states that $S = I^n$ where S is the perceived sensation, I is the physical intensity of stimuli and n is a factor determined by the type of physical stimulation

(illustrated in Figure 2.3.2). The visual channel of position along a common scale is the most accurately perceived of the visual channels. It also has a direct spatial relationship to distance so we will make use of that channel in our visualization of MEL questions.

Does perception of vertical and horizontal space differ? Through three experiments with thirteen stimuli that engaged both vertical and horizontal dimensions simultaneously, Churches *et al.* (2017) found no correlation between the vertical and horizontal perceptual biases though they did find consistent correlation between the degree of bias in each dimension. They conclude: “This study has produced converging evidence that horizontal and vertical biases in spatial judgments rely on separate cognitive mechanisms. To account for these results, we discuss a model whereby horizontal asymmetries rely more on space-based mechanisms whereas vertical asymmetries rely more on object-based mechanisms.” Space based attention can be thought of as a spotlight that moves through space to bring items of interest into its beam while object based attention is directed to candidate objects identified by a pre-attentive segmentation of the visual scene (Nicholls *et al.*, 2004). The spotlight of spatial attention is elongated along the horizontal axis relative to the vertical axis (elliptical along the horizontal axis) and the authors speculate that a stimulus that is elongated along the horizontal axis may have more attention given to the leftward portion than the right. Increases in the aspect ratio of the stimulus may dilute the asymmetry so that the aspect ratio approaches 1:1.

Recent work has studied how decisions involving economics and uncertainty are influenced through visualization. M. Bancelhon *et al.* (Bancelhon *et al.*, 2020) designed an experiment to investigate how different visualization of Prospect Theory (Kahneman & Tversky, 1979) lottery decisions effects choice riskiness. They visualized risky money choice decision as an icon array, pie chart, triangle, circle and bar graph. They found participants making decisions based on the visualizations were consistent with Prospect Theory and a statistically significant effect where participants exhibited a greater average risk-seeking behavior with the circle and triangle visualizations over the worded form. M. Fernandes *et al.* (Fernandes *et al.*, 2018) designed an experiment to measure how visualization of the uncertainty of bus arrival times as quantile dot plots effected the decision of which bus to catch. The experiment provided rewards for people to optimize their bus catching decision (minimizing bus wait time, and not missing the bus) and saw better and more consistent outcomes in riders’ decisions with the visualization over the worded form. In their work on visual reasoning and effect size judgement, A. Kale *et al.* (Kale *et al.*, 2021)

conduct an experiment involving visualization of economic decisions with uncertainty and suggest visualization guidelines dependent on “the user’s task, variance of the distributions, and design choices about axis scales.” Their research also suggests that visualization designs which support the least biased don’t always result in the best decisions.

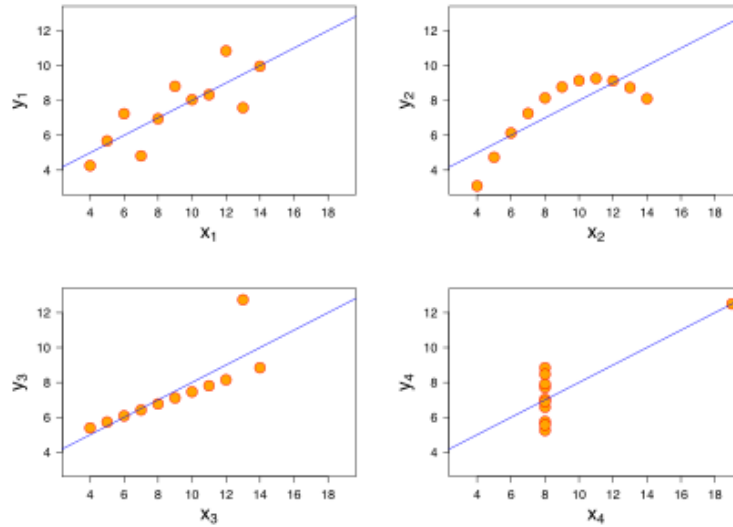


Figure 2.3.1: All four datasets have the same summary statistics; however, when visualized their difference is obvious (<https://en.wikipedia.org/wiki/Anscombe>).

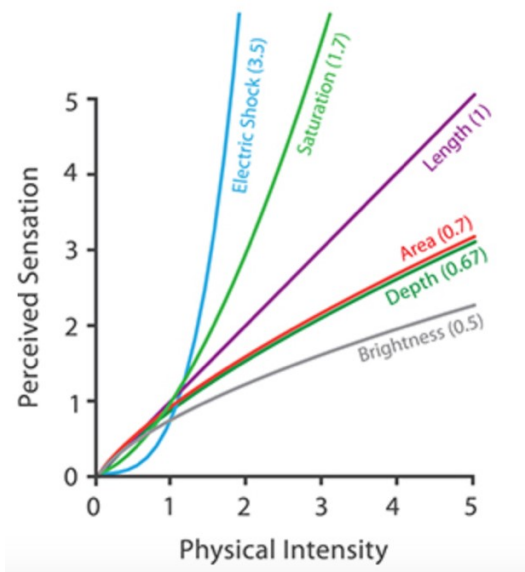


Figure 2.3.2: Steven’s Psychophysical Power Law (Stevens, 1975).

Chapter 3

Methodology

3.1 Vizsurvey Tool

To conduct the visual survey experiment Yahel Nachum (a fellow graduate student at Worcester Polytechnic Institute) and I wrote a single page React application (SPA) in JavaScript using D3 visualization library and Redux that presented participants with MEL questions and supplemental survey questions in the experiment. The SPA was hosted using AWS Amplify. Recruited participants clicked on a link that downloaded and launched the SPA in the participants browser. Participants were then presented with the survey screens which sent data back to an AWS S3 bucket in comma separated value (CSV) format every time a page was loaded, the user made a selection, or clicked to go to the next page. Figure 3.1.1 is a diagram of how the application interacted with Prolific, Amplify, and S3. We captured other data about the participant such as the browser user agent string, screen resolution and orientation. The source code is hosted on github (<https://github.com/The-Discounters/vizsurvey>) where you can find the latest version on the main branch.

We also wrote a command line tool in JavaScript to perform routine manual functions like downloading the CSV files from the Amazon S3 bucket, merging the CSV files for each participant into one file, and monitoring the status of participants taking the survey in real time. Figure 3.1.2 is a screen shot of the monitoring tool.

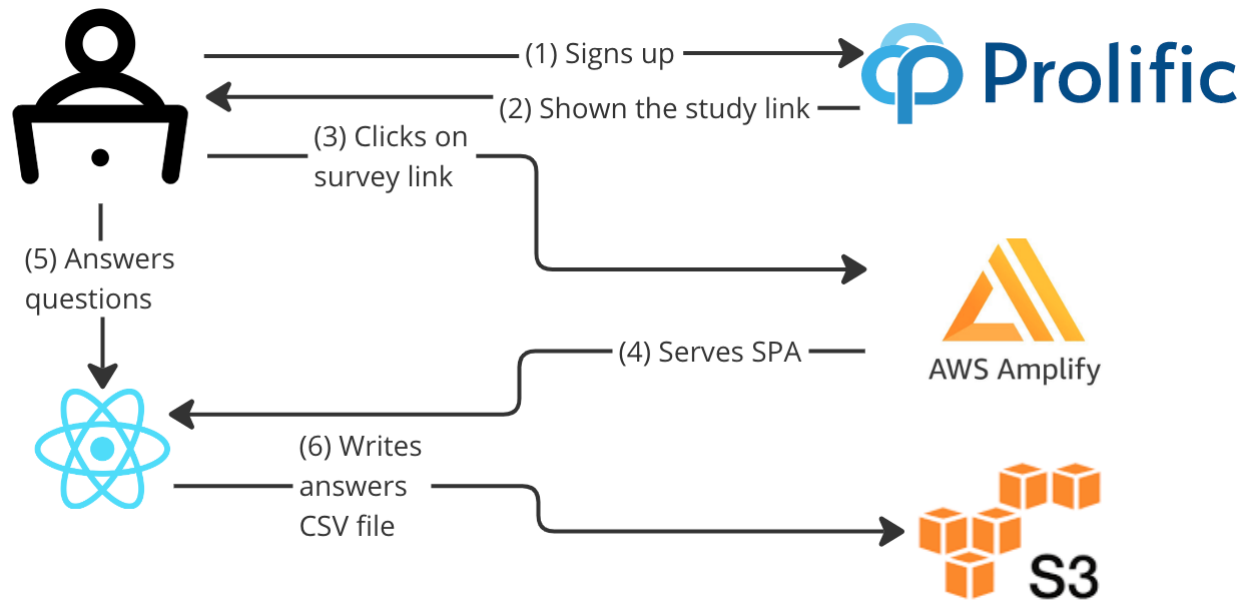


Figure 3.1.1: Architecture of Vizsurvey tool used to perform the experiment. Matched participants (steps 1 and 2) click on the link in Prolific (step 3) which passes the Prolific participant id, session id, and study id through the URL to the React SPA. The SPA downloads to the participants browser from AWS Amplify (4) and launches. As the participant answers questions (step 5) they are written to the AWS S3 bucket in a CSV file format (step 6).

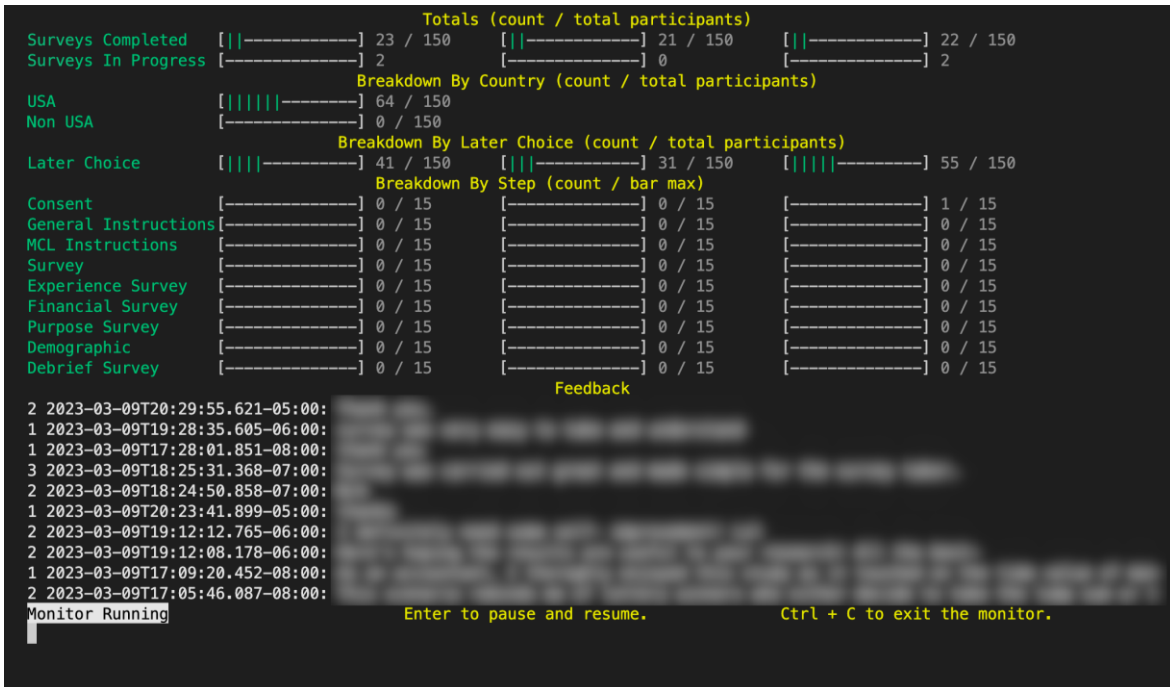


Figure 3.1.2: Vizsurvey monitoring tool showing experiment status in real time. Participant feedback is redacted to honor privacy in the consent form.

3.2 Participants

Participants were recruited through the online platform Prolific (<https://www.prolific.co/>) whose purpose is to match researchers with vetted participants. Below are summary statistics of the one hundred participants we recruited for the experiment.

Gender	%
female	34
male	61
non-binary	4
transgender	1

Table 3.2.1: Participant percentage by gender as self-reported in the experiment.

Avg	Std. Dev.	Min	Max	Median
36.5	13.3	19	72	33

Table 3.2.2: Participant age summary statistics as self-reported in the experiment.

Employment Status	%
Full Time	48
Part Time	25
Retried	2
Self-Describe	5
Unemployed	19
Blank	1

Table 3.2.3: Participant percentage by employment status as self reported in the experiment.

Timezone	%
America/Cancun	1
America/Chicago	21
America/Denver	5
America/Los_Angeles	21
America/New_York	47
America/Phoenix	3
Asia/Shanghai	1
Europe/Berlin	1

Table 3.2.4: Participant percentage by timezone as reported by the web browser. Note that the browser reported some participants as not in the United States. This could have been due to a VPN connection or the participant could have taken the survey while traveling. Filters set in Prolific were for people located in the United States only.

3.3 Measures

For each of the three treatments that were presented, the experiment captured data by writing it as a comma separated value (CSV) file to an amazon S3 bucket. The Prolific participant id, session id and study id were passed by Prolific through the URL to the SPA and stored in the CSV. The treatment id for the corresponding treatment the participant was presented with was also stored in the CSV.

For all the pages that were shown in the application (consent, general instructions, MEL question instructions, eight MEL questions, attention check, experience survey, purpose survey, financial literacy survey, demographic, and debrief) a timestamp was recorded when the page was shown and when the user clicked the next button to go to the next page. The time spent on each page in seconds was also calculated and reported in the CSV.

The screen attributes of the participants computer including screen color depth, height, width, orientation, pixel depth, window device pixel ratio, window inner height and width, outer height and width, and screen left and top of the browser page for the participant were also reported in the CSV. We also recorded the user agent string as reported by the browser.

The participants choice selection of earlier or later for each of the eight MEL questions was also reported along with the treatment definition parameters so that we knew the parameters that were used in the visualization when the question was displayed to the participant. We had an attention check question between the fourth and fifth MEL questions and the participants selection was recorded.

Participants were asked a series of questions on three additional surveys (experience, financial literacy, and purpose survey) to get gather more information about them. For each questionnaire, a list of choice options was offered and all answers the participant selected were reported. All questions on the three supplemental survey questionnaires did not require an answer for the participant to proceed.

The demographic screen asked for country of residence, data viz experience, age, current profession, gender, self-described gender, employment status and self-described employment status and any answers were recorded. All questions were optional.

The last screen was a debrief that explained the purpose and theory behind the experiment. It also offered a free form text field where feedback from the participant could be provided and was

recorded.

3.4 Experiment Design

We conducted a between subject experiment design. We first recruited thirty participants in a pilot study to validate the SPA was launched correctly by Prolific and reporting data correctly. After fixing some bugs, setting our Prolific screening correctly, and refining the survey screens, we recruited one hundred participants and used their responses in the analysis. For all recruited participants we set Prolific to screen for people who were located in the United States only with standard sampling and compensated them \$3 USD to complete the survey which we estimated at 10 minutes. We also excluded anyone who had taken the survey from the pilot group and excluded mobile and tablet devices since visualization experiments are usually designed to be taken on desktops (see the appendix for the Prolific configuration settings). The participants were assigned to one of the three treatments described below at random when they started the survey by the JavaScript `Math.random` function. After being presented with a consent screen where they needed to agree to the terms of the experiment by clicking a checkbox and the next button, they were presented with a general instruction screen that described the overall flow of the survey (MEL choice questions followed by supplemental survey questions). The general instructions were the same for each of the three treatments. The second instruction screen gave directions on how to make a MEL question selection for the visualization the participant was assigned at random. The participant had to make a practice selection before they could advance to the first MEL question. The MEL choice decision instructions were parameterized to make differences between the treatments instructions as little as possible to remove any potential bias.

The MEL questions were presented one at a time with the participant making their selection of earlier or later delay time/amount pair to advance to the next question. The sooner and later delay time/amount pairs and order the questions were presented in were the same across the treatments. The visualization was presented 300 pixels high by 600 pixels wide for the bar chart with no space to the right and 300 pixels high by 1200 pixels wide for the bar chart with space to the right. We did not control how the image was rendered on the participants browser. Their choice and length of time spent on the question was reported back in the CSV. Halfway through the MEL questions (before question number 5), participants were presented with an attention check question

that asked them to select the strongly agree option from a series of options presented as radio buttons. All MEL questions were not optional; a participant had to make a choice to advance to the next screen.

After the MEL choice decision questions, three additional survey question pages were presented. The first survey accessed the participants experience with the survey. The second had three questions used by a number of other researchers to assess their financial literacy (Lusardi & Mitchell, 2008). The third survey questions accessed their sense of purpose in life (Sharma et al., 2018). The last two pages were demographic questions and a debrief page that explained the purpose and theory behind the experiment and presented the prolific code with instructions so that the participant could claim their \$3 USD compensation. There was also a free form text box where the participants could provide feedback. All the supplemental survey and demographic questions and the feedback prompt on the debrief page were optional. None of the monetary rewards in the questions were awarded since there is no evidence that hypothetical and real monetary rewards effect discounting (Johnson & Bickel, 2002).

The three treatments consisted of the same MEL amounts and time delays and varied by how the information was represented. Representations were in a worded form with the choice of amounts and delays as radio buttons (Figure 3.4.1), a bar chart visualization where the time axis ended right after the bar representing the larger later amount (Figure 3.4.2), and a bar chart visualization where the time axis was extended past the bar representing the larger later amount for the same amount of time as to the left of the bar (Figure 3.4.3). For the worded treatment the participant clicked on a radio button to make a selection of earlier of later delay time/amount pair. For both bar chart visualizations, the participant clicked on the bar to make their choice selection of earlier or later delay time/amount pair. The colors and styling of the worded form including the radio button choices and bar chart graph visualizations were made as consistent as possible to try and minimize any confounding factors, such as extraneous design elements that might be common in visualizations people encounter on the web. We filled both the bar chart bars and radio button groups so that the worded and bar chart treatments had a color filled area associated with the MEL question amount/delay pairs. When the participant hovered over their selection of radio button or bar chart with the pointer, the color lightened to indicate their potential selection and when they clicked to make a selection, the color stayed lighter. We were seeking to limit the differences in the treatments to spatial aspects of representation of the MEL question amounts and time delays.

Make a choice to receive \$350 in 4 months or \$430 in 13 months.

\$350 in 4 months \$430 in 13 months

NEXT

(a)

Make a choice to receive \$350 in 4 months or \$430 in 13 months.

\$350 in 4 months \$430 in 13 months

NEXT

(b)

Make a choice to receive \$350 in 4 months or \$430 in 13 months.

\$350 in 4 months \$430 in 13 months

NEXT

(b)

(c)

Figure 3.4.1: (a) The worded version of a MEL question as first presented to the participant. (b) When the participant hovered over a radio button it highlighted their selection by lightening the fill color. (c) When the participant clicked on a radio button it changed the radio button color to lightened to indicate their selection. The participant needed to select a radio button to enable the next button before they could advance to the next question.



(a)

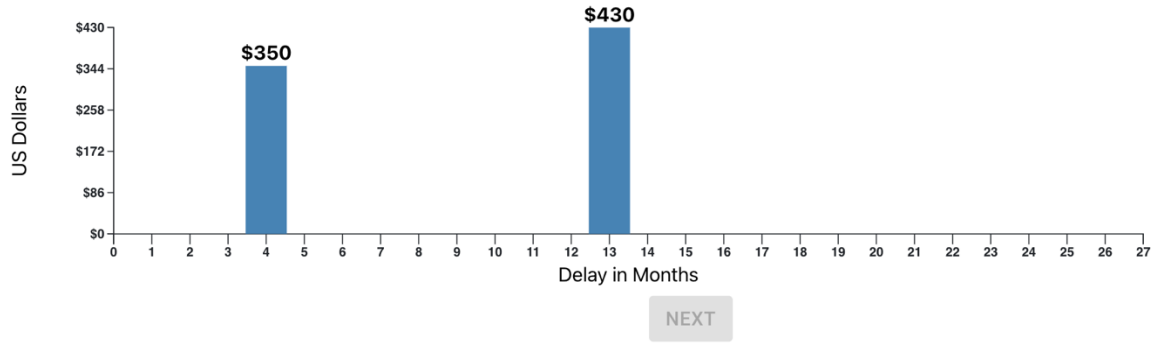


(b)



(c)

Figure 3.4.2: (a) The bar chart visualization of a MEL questions with no space to the right as first presented to the participant. (b) When the participant hovered over a bar it highlighted their selection by lightening the fill color. (c) When the participant clicked on a bar it changed the bar color to lightened to indicate their selection. The participant needed to select a bar to enable the next button before they could advance to the next question.



(a)



(b)



(c)

Figure 3.4.3: (a) The bar chart visualization of a MEL question with the time axis extended creating space to the right as first presented to the participant. (b) When the participant hovered over a bar it highlighted their selection by lightening the fill color. (c) When the participant clicked on a bar, it changed the bar color to lightened to indicate their selection. The participant needed to select a bar to enable the next button before they could advance to the next question.

The amounts and delay times from Read *et al.* (Read et al., 2005) experiment numbers one and three were used as a starting point since they resulted in about thirty percent of participants choosing the larger later option in the treatment that used time delay. We didn't want to select amount and delay values that resulted in either almost everyone picking the sooner or later amounts in the worded treatment since it might be more difficult to detect an effect. Their research was conducted in the United Kingdom, so their amounts were in British Pound Sterling (GBP). Since our experiment was performed on participants located in the United States, we converted the amounts from GBP to US Dollars (USD) using the exchange rate from 2003, the year they performed their experiment. The 2003 USD amounts were then adjusted for inflation to bring them to 2022 values. The final treatment values are shown in table 3.1.4.

Question	SS USD	LL USD	SS months	LL months
1	\$350	\$430	4	13
2	\$490	\$700	2	18
3	\$720	\$1,390	6	36
4	\$840	\$1,120	3	16
5	\$32	\$39	4	13
6	\$45	\$70	2	18
7	\$66	\$110	6	23
8	\$77	\$118	3	16

Table 3.4.1: MEL questions earlier and later amounts and delays used for all three treatments.

Chapter 4

Results

4.1 Data Conversion

We converted all survey question text responses into numbers before performing any statistical analysis where “earlierAmount” = 0 and “laterAmount” = 1. We coded the experience survey responses as follows “not at all or very slightly” = 1, “a little” = 2, “moderately” = 3, “quite a bit” = 4, “extremely” = 5. The financial literacy survey questions answers were coded as a 1 for correct answers and 0 for incorrect. Next we summed the three questions to calculate a financial literacy score (scale of 0 to 3). The sense of purpose responses was coded as follows “strongly disagree” = 1, “disagree” = 2, “neutral” = 3, “agree” = 4, “strongly agree” = 5 and then a score was calculated by averaging each respondent’s answers. The attention check response was used to flag any participants that answered it incorrectly (none did).

For the demographic information, data viz experience was measured on a scale from 1 to 7. Gender was coded as follows; “female” = 1, “male” = 2, “transgender” = 3, “non binary” = 4, “intersex” = 5, “self describe” = 6. Employment status was converted as follows; “full time” = 1, “part time” = 2, “unemployed” = 3, “retried” = 4, “self describe” = 5.

4.2 Proportion of Later Choice and Choice Time Results

Figure 4.2.1 is a bar chart showing the proportion of later choices by question number and treatment where blue is the worded treatment, orange is bar chart with no space to the right treatment, and grey is bar chart with space to the right treatment. The chart suggests a trend that supports our hypothesis; adding space to the right of the largest later bar by extending the time axis past the bar will increase the proportion of later choices. The grey bar (with space to the right) is higher than the orange bar (without space to the right) for all questions except question number five. It is higher than the blue bar (worded) for all questions. The orange bar (without space to the right) is higher than the blue (worded) in five out of the eight questions. Figure 4.2.2 shows the proportion of participants that chose the earlier or later option to all questions with the green

bar all earlier or later choices, yellow bar all earlier choices, and the grey bar all later choices. We can see the worded treatment had no one choosing the later option to all questions, the bar chart without space to the right was next with some choosing the later option for all questions, and the bar chart with space to the right had approximately double choosing the later option for all questions than the bar chart without space to the right.

We calculated the Cohen’s *d* effect size between the worded and bar chart with space to be $(0.33 - 0.21)/0.324052 = 0.370$, between the two bar charts to be $(0.330 - 0.254)/0.357033 = 0.213$, and between the worded and bar chart with no space to be $(0.254 - 0.21)/0.301839 = 0.146$. Using an effect size categorization of: very small effect $d=0.01$, small effect $d=0.2$, medium effect $d=0.5$, and large effect $d=0.8$, we determined that the effect size for the worded to bar chart with space was small to medium, the effect size between the two bar charts was small, and between the worded to bar chart without space was very small to small.

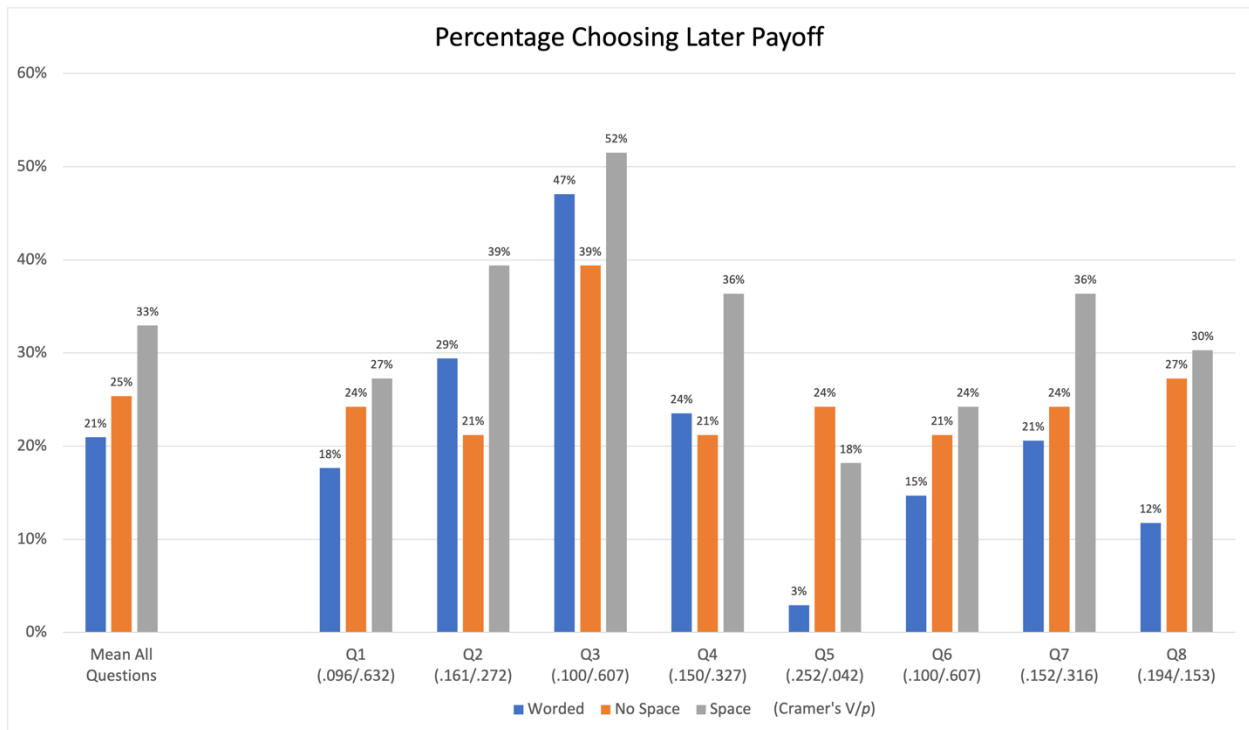


Figure 4.2.1: Bar chart of percentage of later choice answers by question and treatment. The proportion of later choices for the worded (blue bar), bar chart (orange bar), and bar chart with the extended time axis creating space to the right (grey bar) is shown. Cramer’s V correlation value and significance is shown in paranthesis for each question. Mean percentage of later choice for all questions is shown in the left most cluster.

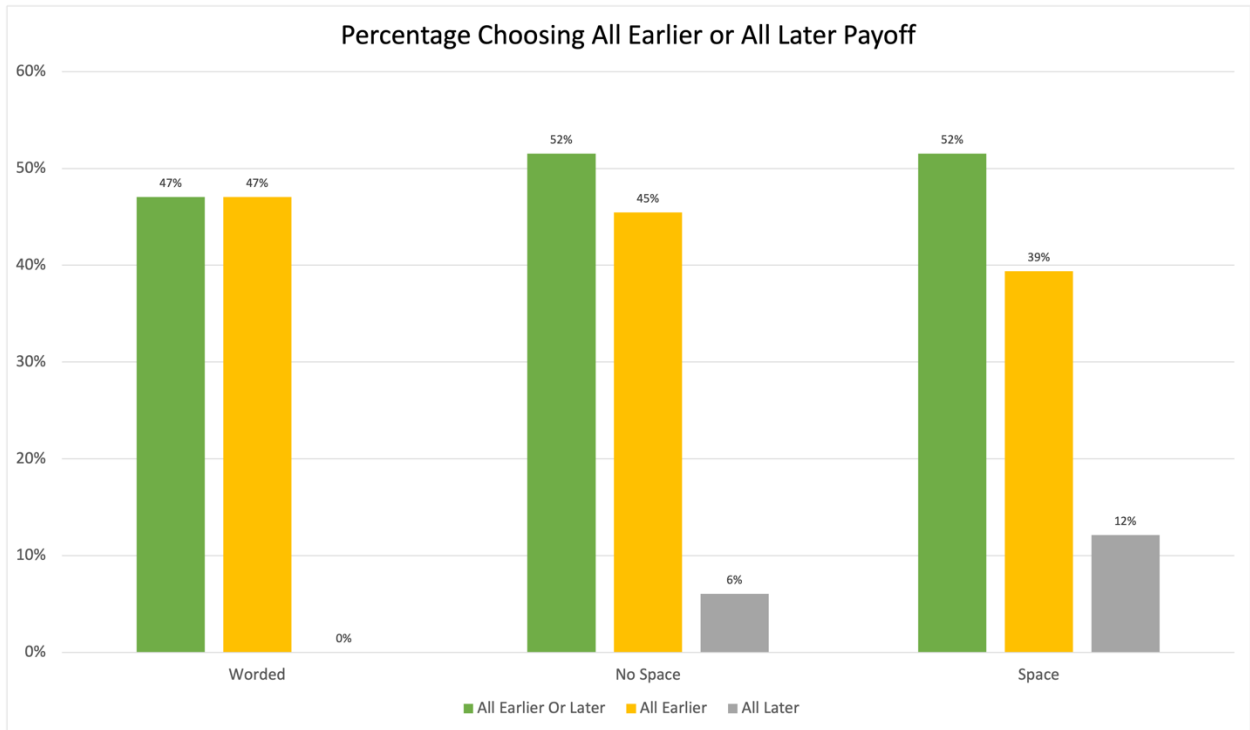


Figure 4.2.2: Percentage of participants who answered all questions earlier or later (green bar), all earlier (yellow bar), or all later (grey bar) by treatment. The trend shows that the number of participants choosing all later increases from worded to bar chart with no space to bar chart with space suggesting support for our hypothesis that extending the time axis and adding space to the right influenced people to choose the larger later option more often.

Question	Worded	No Space	Space	Mean
1	18%	24%	27%	23%
2	29%	21%	39%	30%
3	47%	39%	52%	46%
4	24%	21%	36%	27%
5	3%	24%	18%	15%
6	15%	21%	24%	20%
7	21%	24%	36%	27%
8	12%	27%	30%	23%

Table 4.2.1: Percentage of participants choosing later payoff by treatment and question. This data is shown in Figure 4.2.1.

As planned, we did comparisons between each of the two bar chart conditions and the worded condition for the proportion of later choices. We performed a general ANOVA with the treatment as an independent variable and the proportion of late choices as a dependent variable. No statistically significant difference among the conditions was detected, $F(2, 97) = 1.143, p = .323$. We also ran a linear regression and results are reported in table 4.2.2. The proportion of late choices was not significantly different in the bar without space treatment compared to the word treatment ($B = 0.044$ and $p = 0.582$). Similarly, the proportion of late choices was not significantly different in the bar with space treatment compared to the word treatment ($B = 0.120$ and $p = .138$ value). We did not reach statistical significance on the coefficients and the standard error was 1.8 times the coefficient for the bar without space and 0.667 times the coefficient of the bar with space.

Variable	Unstandardized Beta	Coefficients Std. Error	Standardized Beta	t	<i>p</i> -value
No Space	0.044	0.080	.064	0.552	.582
Space	0.120	0.080	.173	1.497	.138

Table 4.2.2: Linear regression coefficients for the treatment as the independent variable and proportion of later choices as the dependent variable.

Next we performed a general ANOVA with the treatment as an independent variable and the choice time as a dependent variable. There was no statistically significant difference among conditions, $F(2, 97) = 1.571, p = .213$ but it did show people spent less time in the bar conditions which was what we expected. Once again, we also ran a linear regression for the bar with space compared to the worded and bar without space compared to the worded. Results are reported in table 4.2.3. The regression indicates that descriptively, choice time was shorter for both bar treatments compared to the worded with the bar without the space taking slightly less time than the bar with the space. The choice time was not significantly different in the bar without space treatment compared to the word treatment ($B = -13.174$ and $p = .117$). Similarly, the choice time was not significantly different in the bar with space treatment compared to the word treatment ($B = -12.276$ and $p = .144$ value).

Variable	Unstandardized Beta	Coefficients Std. Error	Standardized Beta	t	<i>p</i> -value
No Space	-13.174	8.324	-.182	-1.583	.117
Space	-12.276	8.324	-.169	-1.475	.144

Table 4.2.3: Linear regression model with treatment as the independent variable total choice time as dependent variable.

We then performed an analysis with the question as the unit of analysis. For each of the study conditions, we calculated the proportion of later choices for each question. The summary statistics

are shown in table 4.2.4 and show that a normal distribution can be assumed. The Cohen's d effect size between the worded and bar chart with space is $d = (0.330 - 0.210)/0.118391 = 1.01$, between the two bar charts is $d = (0.33 - 0.254)/0.084288 = 0.902$, and between the worded and bar chart with no space is $d = (0.254 - 0.210)/0.102528 = 0.429$. We then calculated the adjusted Cohen's d effect size due to the small sample size of eight by multiplying the values above by a factor of $\frac{8-3}{8-2.25} \sqrt{\frac{8-2}{8}} = 0.625$. For the worded and bar chart with space $d = (1.01)(0.429) = 0.6344$, between the two bar charts $d = (0.902)(0.625) = 0.561$ and worded and bar chart with no space $d = (0.625)(0.429) = 0.269$. Using an effect size categorization above on our adjusted values we determined that the effect size for the worded to bar chart with space was large, between the two bar chart visualizations was large, and worded to bar chart without space was small.

We conducted a paired samples t -test for differences in the proportion of later choices for every two conditions. There was a significant difference between the worded ($M=0.210$, $SD=0.132$) and bar chart with space ($M=0.330$, $SD=0.103$) conditions; $t(7) = 7.565$, $p < .001$. There was also a significant difference between the bar chart with no space ($M=0.254$, $SD=0.060$) and bar chart with space ($M=0.330$, $SD=0.103$) conditions; $t(7) = 2.646$, $p = .033$. There was not a significant difference between the worded ($M=0.210$, $SD=0.132$) and bar chart with no space ($M=0.254$, $SD=0.060$) conditions; $t(7) = 1.194$, $p = .271$.

Due to small sample size, we also conducted Wilcoxon test values for worded and bar chart with no space $Z = -0.840$, $p < .401$, worded and bar chart with space $Z = -2.521$, $p < .012$, and bar chart with no space and bar chart with space $Z = -1.973$, $p < .049$.

	N	Min.	Max.	Mean	Std. Dev.	Skewness	Skewness Std. Error	Kurtosis	Kurtosis Std. Error
Worded	8	0.029	0.471	0.210	0.132	0.954	.752	1.701	1.481
No Space	8	0.212	0.394	0.254	0.060	2.187	.752	5.229	1.481
Space	8	0.182	0.515	0.330	0.103	0.462	.752	.435	1.481

Table 4.2.4: Summary statistics, skewness, and Kurtosis calculations for analysis using the question as the independent variable.

Treatment	Analysis across participants		Analysis across questions	
	Cohen's <i>d</i>	Effect Size	Cohen's <i>d</i>	Effect Size
Worded to Space	0.370	Small to medium	1.01	Large
No Space to Space	0.213	Small	0.902	Large
Worded to No Space	0.146	Very small to small	0.429	Medium to large

Table 4.2.5: Summary of Cohen's *d* effect sizes between different treatments for analysis across participants and questions. We used the following for effect size categorization; very small effect $d=0.01$, small effect $d=0.2$, medium effect $d=0.5$, and large effect $d=0.8$

4.3 Credibility Checks Analysis

First, we verified that each participant only took the survey once by checking the revision history on the participants CSV file written back to the S3 bucket (S3 was configured to record all versions of the file written where each file was unique to a participant so if a participant took the survey twice it would show in the history). We also used the same Prolific experiment id for so that Prolific would not recruit people from previous runs. Finally, we validated that all participants completed the attention check question correctly.

We Performed several credibility checks. The browser random function assigned 34

participants to the worded treatment, 33 to the bar chart without space, and 33 to the bar chart with space. To make sure there wasn't a bias in the participant population of any one of the treatments, we checked that the participants across the three treatments didn't significantly differ in terms of the mean and standard deviations of demographics and responses on the three supplemental measures that were presented after the MEL questions. After mapping the text choice options to numbers as described above, we calculated the average across the sample of each treatment. Table 4.3.1 presents the mean and standard deviation of the supplemental survey answers and dependent variables of viz familiarity, age, experience survey answers, financial literacy survey score, purpose survey scale, and total money choice decision time with for the three treatments separately.

Independent Variable	Word		No space		Space	
	M	SD	M	SD	M	SD
Viz familiarity	3.53	1.83	3.85	1.70	3.42	2.03
Age	37.7	12.5	37.3	14.5	34.5	13.0
Experience survey enjoy	3.65	1.012	3.91	0.723	3.45	1.003
Experience survey clarity	4.79	0.479	4.79	0.415	4.76	0.751
Experience survey understand	4.79	0.410	4.91	0.292	4.88	0.331
Experience present	4.88	0.327	4.70	0.467	4.76	0.561
Experience survey imagine	4.56	0.613	4.52	0.667	4.70	0.770
Experience survey easy	4.03	0.797	4.30	0.585	4.18	0.727
Experience survey format	3.56	1.24	3.79	1.32	3.67	1.11
Financial literacy score	2.47	0.706	2.48	0.870	2.61	0.609
Purpose scale	3.67	0.431	3.67	0.620	3.62	0.747
Money decision choice time	49.3	39.0	36.1	23.6	37.0	37.3
Proportion of late choices	.210	0.262	0.254	0.337	0.330	0.376

Table 4.3.1: Summary statistics of experimental data used for validation of treatment populations.

Chapter 5

Discussion and Future Work

The results of this experiment suggest that a bar chart visualization of MEL questions will influence participants to choose the larger later option over the worded and that extending the time axis by adding space to the right of the larger later bar will influence a later choice even more. While we didn't reach statistical significance in the analysis across participants, the trend seems to be in the right direction from worded to bar chart without space to bar chart with space. The trend line of participants who chose the later option to all questions also seems to support this claim. We did achieve statistical significance in the analysis across questions; however, the sample size was small with only eight questions. There was a lot of noise in the experiment. This isn't unexpected given the psychological nature of the experiment and the complexity and variation among participants in making MEL question decisions. Feedback from participants indicated some don't believe in saving money and some people did mental math to determine they could take the earlier money and invest it in the stock market.

With regard to choice times, the negative regression coefficients suggest that participants were quicker to decide with the bar chart visualization treatments. Our speculation is that even a simple bar chart visualization of the MEL decision questions is more quickly comprehended than reading the words. The bar chart with space took slightly longer than the bar chart without and we speculate it's because participants aren't accustomed to seeing bar chart visualizations with time extending past the larger later bar (the timeline usually ends at the larger later bar), and it may have taken them slightly longer to process the visualization.

Given the high level of noise we suggest two options. We could repeat the between subject experiment with a larger population. Based on power analysis performed we estimate we would need one hundred participants per treatment to achieve statistical significance. We could also use an in subject design where differences in individuals would be minimized across the treatments. Asking more MEL questions would also increase our sample size for analysis across questions.

Because we weren't sure if our hypothesis was correct, we chose to design a simpler experiment by measuring the proportion of later choices vs. earlier and did not attempt to measure the discount rate. More complex experiments can be constructed using known techniques for

measuring discount rates. Choice titration (Read, 2001) is one technique where participants make an earlier or later choice and then are presented with the same choice where the earlier or later amount is incrementally changed to try and flip their decision. This is done until a transition point from earlier to later or vice versa is performed. The discount rate of the person can then be determined from the switch amounts and delay times. We could perform a bar chart visualization of choice titration to see how an individual's discount rate is affected. We could do a visual form of Multiple-Choice List type design by presenting a multiple views visualization where many bar graphs are presented on the screen at once and the larger later amount is incrementally varied. The participant would then choose one of the bar charts that they believe represent equivalent amount/delay pairs. A visual form of matching design would be an interactive visualization where the participant drags the amount bar of the earlier or later amount vertically or moves the bars along the horizontal axis to change the delay time to make the amount/delay pairs seem equivalent.

The visual equivalent of asset integration could be represented by extending the vertical amount axis above the larger later bar amount creating space above the amount bars. A worded form of a MEL choice questions that incorporate asset integration could be "Imagine that you have \$500 in the bank, and you are offered \$300 in two months or \$700 in seven months". The bar chart equivalent could extend the vertical axis to a maximum of \$1,200 or \$500 above the larger later bar amount of \$700. To the best of our knowledge, this worded form of MEL questions incorporating asset integration has never been performed. We speculate that adding space to the vertical axis above the larger amount would influence participants to choose the later option but may be a smaller effect based on discounting being more sensitive to manipulating time than amounts.

We can explore varying other aspects of the visualization to see what effect they have on influencing the proportion of larger later choices. We rendered the bar chart visualizations at fixed pixel size. An experiment using adaptive layout that allows the visualization to scale to fit the participants screen while maintaining the aspect ratio (the ratio of bar chart width to height) is one possibility. Elongating the vertical axis (decreasing aspect ratio) could be explored as the visual equivalent of asset integration to see how discounting is affected. Other spatial aspects we could explore are rendering the bar chart smaller and larger on the screen and rendering it to an absolute size (i.e., in inches) to look for a correlation between real world measurements and discounting. We also did not explore the data for correlation between the participants screen resolution and

proportion of later choices. That analysis can be performed on data we have already collected and could inform any of the ideas listed above.

Instead of using MEL choice design, we could also create a visual representation of convex time budgets (Andreoni & Sprenger, 2012). Convex time budgets present participants with a finite amount of money they are asked to allocate to a sooner time or a later time with an exchange rate where the gross interest rate can be calculated by the relative rate amounts are allocated. A visualization could be designed asking a participant to move a visual representation of a stack of tokens to sooner and later times where there is a return of an interest rate on any tokens allocated to the later time. We coded Vizsurvey to be easily reconfigurable so the experiments above could be performed with relatively little effort.

Chapter 6

Conclusion

This research suggests that a bar chart visualization of a MEL decision question has a higher proportion of later choices and adding space to the right of the larger later bar by extending the time axis may influence people to choose the larger later option even more often. We believe extending the axis causes the participant to mentally zoom out to a longer time frame diminishing the perception of the delay period influencing them to choose the larger later option. We call this effect the space-zoom effect.

One application could be in visualizing the earnings consequence of the decision to pursue post-secondary education. A bar chart showing short term income resulting from starting work earlier vs. higher income in the future due to earning a credential like a college degree with the time axis extended could influence the person to defer immediate income and enroll in an educational program.

Another potential application is in a visualization for a person deciding whether to retire early. Imagine the person has \$1,000,000 in retirement savings and is considering whether to retire at age 62 or age 65. If they retire early and we assume an average annual return of 7% based on stock market historical averages they would lose out an additional $P((1+r/n)^{nt} - 1) = \$1,000,000((1+0.07)^3 - 1) = \$225,043$ in returns. Visualizing this choice as a bar chart with the early and later total return values and extending the time axis past the larger later bar could influence their decision to delay retirement. A related application would be in nudging people toward saving more for retirement. Structural changes in the United States legal system and economy have changed fundamental aspects of US household finances; retirement savings have shifted away from Social Security and employer sponsored Defined Benefit (DB) plans where employers made savings and investment decisions to Defined Contribution (DC) plans and individual retirement accounts (IRAs) where responsibility for savings and investing lies solely on the individual. Increases in life expectancy require the accumulation of more savings so that retirees don't outlive their assets. With some thought, we could construct a visualization that presents the intertemporal choice tradeoff of foregoing income now for consumption to build retirement savings for a better standard of living in retirement.

We believe that there is still work to be done to explore visualization of intertemporal choice decisions and how visualization design can influence discounting. We believe this work is important and time and money spent in further investigation will help in creating visualizations for better future outcomes.

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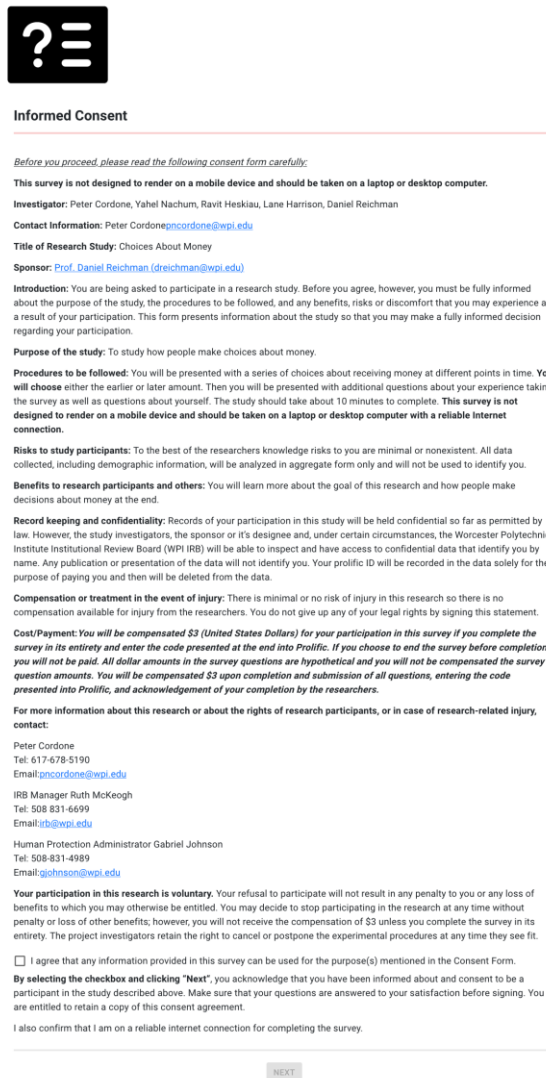
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Appendix

The following appendix contains more information about the experiment that was performed. Also see the supplemental files `experiment_parameters.xlsx` and `vizsurvey-src.zip`.

A.1 Consent Form Screen



Informed Consent

Before you proceed, please read the following consent form carefully.

This survey is not designed to render on a mobile device and should be taken on a laptop or desktop computer.

Investigator: Peter Cordone, Yael Nachum, Ravit Heskiau, Lane Harrison, Daniel Reichman

Contact Information: Peter Cordone pncordone@wpi.edu

Title of Research Study: Choices About Money

Sponsor: Prof. Daniel Reichman (dreichman@wpi.edu)

Introduction: You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: To study how people make choices about money.

Procedures to be followed: You will be presented with a series of choices about receiving money at different points in time. You will choose either the earlier or later amount. Then you will be presented with additional questions about your experience taking the survey as well as questions about yourself. The study should take about 10 minutes to complete. **This survey is not designed to render on a mobile device and should be taken on a laptop or desktop computer with a reliable Internet connection.**

Risks to study participants: To the best of the researchers knowledge risks to you are minimal or nonexistent. All data collected, including demographic information, will be analyzed in aggregate form only and will not be used to identify you.

Benefits to research participants and others: You will learn more about the goal of this research and how people make decisions about money at the end.

Record keeping and confidentiality: Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you. Your prolific ID will be recorded in the data solely for the purpose of paying you and then will be deleted from the data.

Compensation or treatment in the event of injury: There is minimal or no risk of injury in this research so there is no compensation available for injury from the researchers. You do not give up any of your legal rights by signing this statement.

Cost/Payment: You will be compensated \$3 (United States Dollars) for your participation in this survey if you complete the survey in its entirety and enter the code presented at the end into Prolific. If you choose to end the survey before completion, you will not be paid. All dollar amounts in the survey questions are hypothetical and you will not be compensated the survey question amounts. You will be compensated \$3 upon completion and submission of all questions, entering the code presented into Prolific, and acknowledgement of your completion by the researchers.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:

Peter Cordone
Tel: 617-678-5190
Email: pncordone@wpi.edu

IRB Manager Ruth McKeogh
Tel: 508-831-6699
Email: irb@wpi.edu

Human Protection Administrator Gabriel Johnson
Tel: 508-831-4989
Email: gjohnson@wpi.edu

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits; however, you will not receive the compensation of \$3 unless you complete the survey in its entirety. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

I agree that any information provided in this survey can be used for the purpose(s) mentioned in the Consent Form. **By selecting the checkbox and clicking "Next", you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.**

I also confirm that I am on a reliable internet connection for completing the survey.

NEXT

Figure A.1.1: The consent form presented to participants. The participant must click the checkbox agreeing that the information provided in the survey can be used for this research project.

The consent form text is below:

Before you proceed, please read the following consent form carefully:

This survey is not designed to render on a mobile device and should be taken on a laptop or desktop computer.

Investigator: Peter Cordone, Yahel Nachum, Ravit Heskia, Lane Harrison, Daniel Reichman

Contact Information: Peter Cordone pncordone@wpi.edu

Title of Research Study: Choices About Money

Sponsor: [Prof. Daniel Reichman \(dreichman@wpi.edu\)](mailto:dreichman@wpi.edu)

Introduction: You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: To study how people make choices about money.

Procedures to be followed: You will be presented with a series of choices about receiving money at different points in time. **You will choose** either the earlier or later amount. Then you will be presented with additional questions about your experience taking the survey as well as questions about yourself. The study should take about 10 minutes to complete. **This survey is not designed to render on a mobile device and should be taken on a laptop or desktop computer with a reliable Internet connection.**

Risks to study participants: To the best of the researchers knowledge risks to you are minimal or nonexistent. All data collected, including demographic information, will be analyzed in aggregate form only and will not be used to identify you.

Benefits to research participants and others: You will learn more about the goal of this research and how people make decisions about money at the end.

Record keeping and confidentiality: Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you. Your Prolific ID will be recorded in the data solely for the purpose of paying you and then will be deleted from the

data.

Compensation or treatment in the event of injury: There is minimal or no risk of injury in this research so there is no compensation available for injury from the researchers. You do not give up any of your legal rights by signing this statement.

Cost/Payment: You will be compensated \$3 (United States Dollars) for your participation in this survey if you complete the survey in its entirety and enter the code presented at the end into Prolific. If you choose to end the survey before completion, you will not be paid. All dollar amounts in the survey questions are hypothetical and you will not be compensated the survey question amounts. You will be compensated \$3 upon completion and submission of all questions, entering the code presented into Prolific, and acknowledgement of your completion by the researchers.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:

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Email: gjohnson@wpi.edu

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits; however, you will not receive the compensation of \$3 unless you complete the survey in its entirety. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

I agree that any information provided in this survey can be used for the purpose(s) mentioned in the Consent Form.

By selecting the checkbox and clicking “Next”, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

I also confirm that I am on a reliable internet connection for completing the survey.

A.2 General Instructions

This screen provides an overview of the survey and what indicating that the participant needs to answer the MEL decision questions to participate in the study. It also lets the participant know it will take about ten minutes to complete the survey.

General Instructions

In the first set of questions, you will be asked to make money choices as instructed in the next screen. You will need to answer all these questions in order to remain in the study.

Then, you will be presented with three short sets of questions about your experience answering the survey, as well as about you in general.

Finally, you will then be presented with a more detailed explanation of the goals behind this research along with an opportunity to submit feedback and a **code you must enter into Prolific to get paid**.

The entire survey will take about 10 minutes to complete.

Click the Next button to start.

NEXT

Figure A.2.1: Screenshot of general instructions page.

A.3 Money Choice Instructions

This screen gives instructions on how to complete the survey with an animated gif. There are a separate set of instructions for each of the treatments; worded, bar chart with no time shown to the right, and bar chart with time show to the right.

Money Choice Instructions

You will be presented with a series of hypothetical choices of receiving two different amounts of money at two different times. Both amounts are in United States Dollars (USD) and both times are the delay in months from now. **All amounts and delay times in the questions are hypothetical. We do ask that you imagine to the best of your ability that you are in this situation and need to make a choice between the two payments. These are very realistic choices that can present themselves to anyone, so for each question, please think which option you would choose if you were truly in this situation.**

The amount and delay time for each option will be represented as radio buttons. You will make your choice by clicking on one of the buttons.

Make a choice to receive \$300 in 2 months or \$700 in 7 months.

\$300 in 2 months \$700 in 7 months

Try it out below: In the example below, the button on the left represents the choice of receiving \$300 two months from now and the button on the right receiving \$700 seven months from now. Select one of the options by clicking the button for your choice.

Make a choice to receive \$300 in 2 months or \$700 in 7 months.

\$300 in 2 months \$700 in 7 months

Once you have made your selection, the Next button will be enabled to allow you to advance to the next question. You must make a selection to proceed onto the next question.



Figure A.3.1: Screenshot of MEL decision question worded treatment.

Money Choice Instructions

You will be presented with a series of hypothetical choices of receiving two different amounts of money at two different times. Both amounts are in United States Dollars (USD) and both times are the delay in months from now. **All amounts and delay times in the questions are hypothetical. We do ask that you imagine to the best of your ability that you are in this situation and need to make a choice between the two payments. These are very realistic choices that can present themselves to anyone, so for each question, please think which option you would choose if you were truly in this situation.**

The amount and delay time for each option will be represented as radio buttons. You will make your choice by clicking on one of the buttons.

Make a choice to receive \$300 in 2 months or \$700 in 7 months.

\$300 in 2 months \$700 in 7 months

Try it out below: In the example below, the button on the left represents the choice of receiving \$300 two months from now and the button on the right receiving \$700 seven months from now. Select one of the options by clicking the button for your choice.

Make a choice to receive \$300 in 2 months or \$700 in 7 months.

\$300 in 2 months \$700 in 7 months

Once you have made your selection, the Next button will be enabled to allow you to advance to the next question. You must make a selection to proceed onto the next question.



Figure A.3.2: Screenshot of MEL decision question bar chart with no space to the right of the larger later amount bar treatment.

Money Choice Instructions

You will be presented with a series of hypothetical choices of receiving two different amounts of money at two different times. Both amounts are in United States Dollars (USD) and both times are the delay in months from now. **All amounts and delay times in the questions are hypothetical. We do ask that you imagine to the best of your ability that you are in this situation and need to make a choice between the two payments. These are very realistic choices that can present themselves to anyone, so for each question, please think which option you would choose if you were truly in this situation.**

The amount and delay time for each option will be represented as a bar chart. You will make your choice by clicking on one of the bars.



Try it out below: In the example below, the bar on the left represents the choice of receiving \$300 two months from now and the bar on the right receiving \$700 seven months from now. Select one of the options by clicking the bar for your choice.



Once you have made your selection, the Next button will be enabled to allow you to advance to the next question. You must make a selection to proceed onto the next question.



Figure A.3.3: Screenshot of MEL decision question bar chart with space to the right of the larger later amount bar treatment.

A.4 Attention Check Question

The survey included an attention check question that appears halfway through the MEL decision questions to validate that the user wasn't just clicking through. Figure A.4 is a screen shot of the question asked.

The middle step in this survey is to answer the attention check question below.

1. Please select 'strongly agree' to show that you are paying attention to this question. *

strongly disagree disagree neutral agree strongly agree

NEXT

Figure A.4.1: Screenshot of the attention check question. The participant must select an option to be able to advance to the next question.

A.5 Survey Experience Questions

The participant was asked eight questions to assess their experience performing the survey including the amount of mental effort they invested. All questions were optional.

Additional Questions 1 of 3

We would like to know what you thought of this survey. Please indicate your agreement or disagreement with the following statements.

Did you enjoy completing the survey questions?

not at all or very slightly

a little

moderately

quite a bit

extremely

Did you find the instructions clear?

not at all or very slightly

a little

moderately

quite a bit

extremely

Did you understand what the questions were asking you to consider?

not at all or very slightly

a little

moderately

quite a bit

extremely

Were the questions presented clearly?

not at all or very slightly

a little

moderately

quite a bit

extremely

Were you able to imagine these money choices as real?

not at all or very slightly

a little

moderately

quite a bit

extremely

On average, were the money choice decisions easy to make?

not at all or very slightly

a little

moderately

quite a bit

extremely

Would you like real life money decisions to be presented to you in this format?

not at all or very slightly

a little

moderately

quite a bit

extremely

Did you invest mental effort in the choice questions?

not at all or very slightly

a little

moderately

quite a bit

extremely

[NEXT](#)

Figure A.5.1: Screenshot of survey experience question screen.

A.6 Financial Literacy Questions

The participant was asked three questions to assess how financially literate they are (Lusardi & Mitchell, 2008). All questions were optional.

Additional Questions 2 of 3

Please answer these questions to the best of your ability.

Suppose that you had \$100 in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow? *

- more than \$102
- exactly \$102
- less than \$102
- do not know

Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, would you be able to buy more than, exactly the same as, or less than today with the money in this account? *

- buy more today than a year ago
- buy exactly the same today as a year ago
- buy less today than a year ago
- do not know

Do you think that the following statement is true or false? 'Buying a single company stock usually provides a safer return than a stock mutual fund.' *

- true
- false
- do not know

NEXT

Figure A.6.1: Screenshot of financial literacy survey questions screen.

A.7 Sense of Purpose Questions

The participants were asked questions to assess their sense of purpose in life. All questions were optional.

Additional Questions 3 of 3

The following questions ask you generally about your life. Please indicate your agreement or disagreement with the following statements.

I am striving to make a positive difference in society.

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

Through my career I aim to make the world a better place.

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

I seek to serve society in many ways, large and small.

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

I have started thinking about what I truly want to achieve.

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

I can describe my life's purpose.

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

I make efforts to promote other people's wellbeing.

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

NEXT

Figure A.7.1: Screenshot of purpose survey questions screen.

A.8 Demographic Data

The participants were asked to provide demographic information about themselves. All questions were optional.

Demographic Questions

Please tell us about yourself by answering the questions below. All data collected will be analyzed in aggregate form only and will not be used to identify you.

Country of residence ▼ The country you are living in now	Dataviz experience ▼ Your experience with data visualizations and charts	Age	Current Profession
Gender ▼	Self Describe Gender	Current Employment ▼	Describe Employment

NEXT

Figure A.8.1: Screenshot of demographic data survey questions screen.

A.9 Study Explanation

Participants were then provided with a screen that gave more details about the study they just participated in and its motivations. There was also the opportunity to provide feedback through email or the text box on the screen and the contact information was repeated.

Study Explanation

Your answers have been recorded.

When it comes to decisions between payoffs sooner or later in time, people tend to place less value on the later reward and choose the sooner option even at the cost of larger later rewards. This is called discounting the later reward. Discounting can manifest itself in decisions regarding finance, health, and the environment. Life expectancy and quality of life can be negatively impacted, especially in later years as the negative consequence of choosing the shorter term option accumulate over time. Decisions like these are malleable and discounting can be counteracted by how attention is focused, how a reference point is framed, and how time is represented. Visualization offers a powerful tool that influences all three of these factors.

This experiment seeks to examine how visualization can be designed to influence people in making long term decisions differently. For this purpose, participants in this experiment are randomly assigned to be presented with word choices or different versions of graphical displays, such as a bar graph. In particular, we examine how space can be used in the time (horizontal) axis to increase the likelihood of choosing the longer-term option.

For more information about this research or about the rights of research participants, or if you would like to get in touch with us for any other reason the contact information is below:

Peter Cordone
Tel: (617)678-5190
Email: pncordone@wpi.edu

IRB Manager Ruth McKeogh
Tel: (508)831-6699
Email: irb@wpi.edu

Human Protection Administrator Gabriel Johnson
Tel: (508)831-4989
Email: gjohnson@wpi.edu

Please remember to enter the code C1KQNGZK into Prolific so that you will be paid \$3.

We hope you have enjoyed taking this survey and welcome any feedback or questions by filling out the text box below and clicking submit & exit.

Feedback

SUBMIT FEEDBACK & EXIT

Figure A.9.1: Screenshot of study explanation screen.

A.10 Treatment Time Delays and Amounts

See the supplemental excel file `experiment_parameters.xlsx`, “treatment CL parameters” sheet. The file also contains a sheet “CL parameter derivation” that shows the calculations for how the parameters were derived from the Read *et al.* (Read et al., 2005) paper. Their amounts were in Pound Sterling (GBP), so we converted them to USD using exchange rates from the web site.

<https://www.poundsterlinglive.com/bank-of-england-spot/historical-spot-exchangerates/gbp/GBP-to-USD-2003> for 2003; the year their survey was conducted. We then adjusted the equivalent USD 2003 amounts for inflation using the web site.

<https://www.in2013dollars.com/us/inflation/2003?amount=1>.

A.11 Vizsurvey Source Code

The survey tool source code at the time the experiment was performed can be found in the additional attachments `vizsurvey-src.zip` and is hosted on github <https://github.com/The-Discounters/vizsurvey>. Tag v-1.1 is the code that was used to conduct the first full run of one hundred participants. See github for the latest code on the main branch.

A.12 Prolific Experiment Parameters

Participants were recruited using the online research platform Prolific (<https://app.prolific.co>). Below are screen shots of the experiment configuration.

STUDY COST

How long will your study take to complete? ⓘ Max. time: 44 mins

Participants are paid according to your estimated study completion time. If the median completion time exceeds your estimate we will ask you to make additional payments. [Read more about study completion time](#)

How much do you want to pay them?

18.00/hr

Hourly rate

\$8.00 \$18.00 Great!

Figure A.12.1: Screenshot of Prolific study cost configuration.

Study distribution

How do you want to distribute your sample?

Representative sample

Distribute your study based on UK or USA census data.

Balanced sample

Distribute your study evenly to male and female participants.

Standard sample

Distribute your study to available participants.

✔ Selected

Prescreen participants ⓘ

YOUR CRITERIA

Exclude participants from previous studies Edit Remove

MQP-Discount Rate, MQP-Discount Rate, MQP-Discount Rate-Main-2023.3.9

+ Add screener

We've found **38,223** matching participants who have been active in the past 90 days

Figure A.12.2: Screenshot of Prolific study distribution configuration.

AUDIENCE

Recruit participants

How many participants are you looking to recruit?

Location

Where should your participants be located?

All countries available

USA

UK

More

Figure A.12.3: Screenshot of Prolific screening configuration.

How to confirm participants have completed your study

When participants start your study they will leave the Prolific app. When they return, we need to capture a unique Completion Code to prove they completed your study.

[Read more about study completion](#)

How do you want to confirm participants have completed your study? *(Select an option below for instructions)*

I'll redirect them using a URL I'll give them the Completion Code to copy & paste

Completion code

As a last step, give participants this Completion Code to manually enter on Prolific when they finish the study.

Submissions will be:	<input type="text" value="Manually reviewed"/>
Code for participants:	<input type="text" value="C1KQNGZK"/> <input type="button" value="Copy"/>

Figure A.12.4: Screenshot of Prolific survey code configuration.

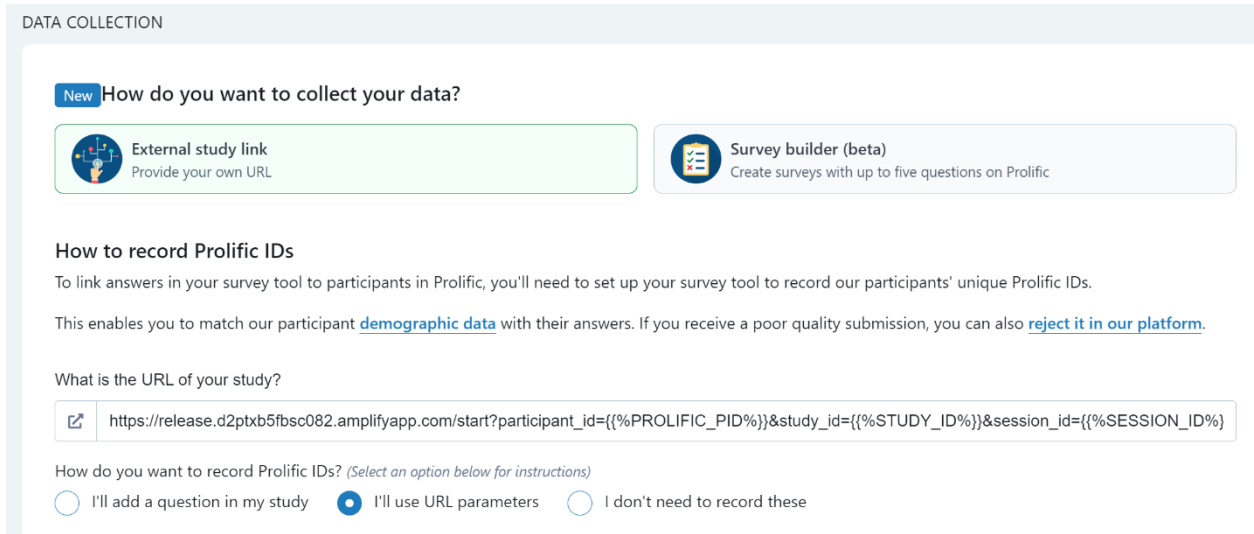


Figure A.12.5: Screenshot of Prolific survey link configuration.

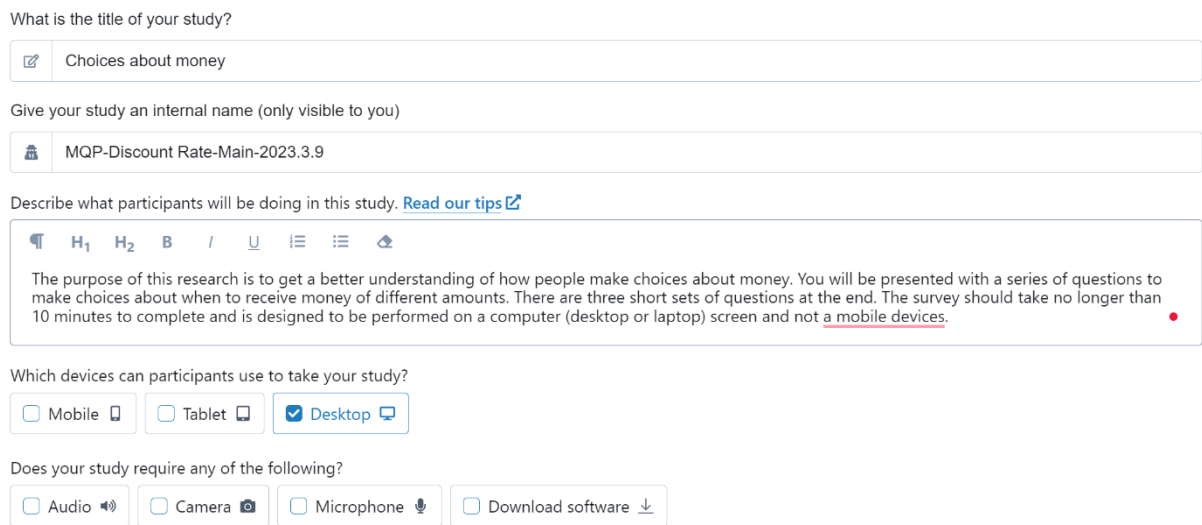


Figure A.12.6: Screenshot of Prolific survey title and description configuration.