Temporal Attention, the Sunk Cost Effect, and Delay Discounting

By

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Abstract

The sunk cost effect, known as the degree to which an initial investment of time, effort, or money increases the likelihood of continued investment, and delay discounting, defined as how rapidly the subjective value of a reward declines as a function of the delay to its receipt, incorporate the role of temporally distant stimuli, but have not been evaluated simultaneously. One process that may link the two phenomena is the temporal attention hypothesis, which holds that the degree to which one perceives distant events as close to the present, and one's ability to shift their temporal focus from now to not now, jointly contributes to the mechanism of delay discounting. The first of the two experiments showed that participants with higher subjective time perception (i.e., perceived distant objective time points as subjectively closer to the present) committed more sunk cost across hypothetical temporal gaps between the initial and terminal links, and exhibited lower rates of delay discounting than those with lower subjective time perception. In Experiment 2, the same sunk cost procedure was used, except that four temporal gap conditions were used that matched the time points used in the delay discounting task. Further, participants experienced either negative, neutral, or positively valenced income narratives, which have previously been shown to alter rates of delay discounting. Additionally, probed time points in the future and past subjective time perception tasks more closely matched those used in the delay discounting and sunk cost tasks, and both future and past subjective time perception were derived used Mazur's (1987) hyperbolic model. A series of Quade non-parametric ANCOVAs failed to reveal a significant effect of income narrative on delay discounting, any measure of sunk cost, future or past subjective time perception, and past, present, and future temporal focus. Extra sum of squares tests revealed, however, that hyperboloid models of mean sunk cost and median indifference data across the three groups were better fit to separate curves than one curve. Hyperbolic decline in subjective time perception (Ln (*k*)) for future and past subjective time perception were strongly correlated and were combined together to form the measure joint time perception, which correlated with delay discounting, but did not correlate with any measure of sunk cost. Future subjective time perception was divided by past subjective time perception to form the measure of time perception index, which was only correlated with sunk cost measures, but not delay discounting. Overall sunk cost (i.e., terminal investment percentage of $5 initial investments subtracted by $35 initial investments) was directly correlated with delay discounting such that greater amounts of sunk cost related to lower rates of delay discounting, providing added evidence that the sunk cost effect may relate to lower rates of discounting. Implications, limitations, and future directions related to these findings are discussed.

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Behavioral economics has been defined as the systematic evaluation of responding under constraints (Bickel, Green, & Vuchinich, 1995). A particularly popular domain of behavioral economics is concerned with patterns of choice and the potentially maladaptive (or adaptive) contexts under which such behavior occurs (Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012). Increasingly, behavioral economic insights have been used to understand the etiology of clinical problems (Bickel et al., 2013; Bickel, Madden, & Petry, 1998). Further, behavioral economic researchers, including behavior analysts, do not use normative conceptualizations of "rational" behavior, and instead focus on the functional processes by which behavior occurs. Broadly, much of behavioral economics is conceptualized as a ratio of costs over benefits. In the context of decision-making, time either is typically used as a variable constraining the utility of the benefit (Jarmolowicz & Hudnall, 2014), or as a cost factor (Killeen, 2009). In either case, however, time is often experimentally pitted against some dimension of reward. When given a systematic series of choices between smaller sooner and larger later rewards, for example, preferences for more proximal and larger rewards are pitted against each other (Rachlin, Raineri, & Cross, 1991). Interestingly, although current behavior is perpetually at the locus of past and future events, there is comparatively little research evaluating how past versus future events might function similarly within decision-making contexts. (cf. Radu, Yi, Bickel, Gross, & McClure, 2011; Yi, Gatchalian, & Bickel, 2006).

Delay Discounting

Delay discounting can be described as the degree to which the current subjective value of a reward declines as a function of the delay to its receipt (Green & Myerson, 2004). Delay discounting tasks typically pit smaller yet more immediate amounts of money against larger yet more delayed amounts by titrating reward amount (Rachlin et al., 1991; Richards, Mitchell, de Wit, & Seiden, 1997), or delay (Koffarnus & Bickel, 2014), while holding the other variable constant. Indifference points (i.e. the point at which the subjective value between the smaller sooner and larger later rewards are roughly equivalent), are determined for each of the parametric values of the adjusting variable (e.g., delay or amount). A discount function is often expressed visually, wherein each of the indifference points are plotted as a function of the nominal delays. Delay discounting is commonly quantified and expressed using hyperbolic discounting functions. Mazur's (1987) hyperbolic equation takes the form:

$$V = \frac{A}{1+kd}, \tag{1}$$

where *V* corresponds to the subjective value of some amount (*A)* of a commodity, which decreases as a function of the delay *(d)* to receiving the commodity. The rate at which this subjective value decreases is quantified by the only fitted parameter, *k*. A hyperbolic-like variation of this function, derived from Rachlin (2006), is a hyperboloid model that adds an additional fitted parameter (*s)* to characterize psychophysical scaling of delay:

$$V = \frac{A}{1+kd^{s}} \tag{2}$$

In addition to describing discounting data, the hyperbolic and hyperboloid functions account for seemingly inconsistent choices (i.e., preference reversals across time). A college student may initially indicate a preference to stay in to study for an exam early in a given day (presumably the larger later reward); only to reverse preference by attending an evening party (presumably the smaller sooner reward) as the time to the celebration becomes increasingly proximal. Importantly, normative economic models of discounting choice typically use an exponential function to represent the discount rate (Monterosso & Ainslie, 2007), which usually predict that one's reward preference will remain constant across time. Unlike exponential functions, hyperbolic discount functions are thought to better predict seemingly irrational changes in preference (Kirby, 1997; Kirby, Petry, & Bickel, 1999). An exponential discounting function, as depicted in panel A of Figure 1, corresponds to an initial preference for the larger later reward at T_0 that will maintain until the receipt of the larger later reward at T_2. By contrast, a hyperbolic discounting function, as shown in panel B of Figure 1, shows that an initial preference for the larger later reward reverses prior to T_2. Therefore, the smaller sooner reward would be selected if the choice is made at T_1 (Ainslie & Haslam, 1992). Higher relative rates of hyperbolic delay discounting have been shown to correspond to more preference reversals (Yi, Matusiewicz, & Tyson, 2016), and are often theoretically linked by the hyperbolic model (Equation 1; Bickel & Marsch, 2001; Rachlin & Raineri, 1992). In addition, higher relative rates of discounting are linked to a greater propensity to exhibit problems such as substance abuse (Bickel, Koffarnus, Moody, & Wilson, 2014; Kirby & Petry, 2004) obesity (Bickel, Wilson, et al., 2014; Epstein, Salvy, Carr, Dearing, & Bickel, 2010) and ADHD (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Wilson, Mitchell, Musser, Schmitt, & Nigg, 2011). Further, delay discounting procedures provide a seemingly straightforward assessment of maladaptive (higher relative rates of discounting) to adaptive (lower relative rates of discounting) decision-making. Unfortunately, little is known regarding how cost and reward variables associated with temporally distant past events might relate to future delay discounting (Bickel, Wilson, Chen, Koffarnus, & Franck, 2016b).

Past delay discounting. One approach to better understanding valuation of past events is delay discounting of past rewards (Bickel et al., 2016b; Radu et al., 2011; Yi et al., 2006). In such tasks, participants indicate their preference for smaller monetary rewards recently received, or larger but more temporally distant rewards. Delay discounting of past rewards tend to be symmetrically related to delay discounting of future rewards (Radu et al., 2011). The study of delay discounting of past events may be useful for two primary reasons. First, past and future delay discounting may bi-directionally influence one another (Yi et al., 2006), thereby providing two unique but related treatment targets. Second, although past and future delay discounting are positively correlated, there are individual differences in the degree to which future and past discounting overlap, which suggests that another temporal factor (e.g., time perception) may influence the relation between future and past discounting (Radu et al., 2011). Exploring past delay discounting may therefore provide an empirical and conceptual framework conducive to investigating how other variables might affect delay discounting.

Despite this, discounting of past rewards comes with two notable limitations. First, it is always in the organism's best interest to choose the more temporally distant but larger reward because the larger and more temporally distant option provides both a large amount of money and an added opportunity to gain interest. Second, delay discounting of past rewards and delay discounting of future rewards are typically provided on a within-subject basis such that all participants complete both procedures. It is possible that the observed symmetrical patterns of discounting are merely an artifact of procedural similarities between the two tasks. In other words, regardless of counterbalancing the order of past and future discounting tasks, experience completing one of the tasks may increase the likelihood of similar responding on the other. Although delay discounting of past rewards has provided interesting findings, addressing the above limitations through alternative methods may create a context to investigate how cost and reward variables are associated with temporally distant past events.

Temporal Attention

The *temporal attention hypothesis* posits that decision-making patterns during both past and future delay discounting assessments may not necessarily reflect an inability to delay gratification, but the degree to which an individual's behavior is impacted by temporally distant events (Radu et al., 2011). In a series of studies investigating the manipulation of time to both past and future events, Radu and colleagues (2011) evaluated how providing information both on what you would receive and not receive for the immediate and delayed options affected rates of past and future delay discounting (i.e., the hidden zero affect). The hidden zero effect (Magen, Dweck, & Gross, 2008a) is a product of procedures wherein participants are presented with what they would and would not receive for both the immediate and delay options (e.g., ''$50.00 today and $0 in 14 days, vs. $0 today and $100 in 30 days''). According to the temporal attention hypothesis, hidden zero manipulations may reduce delay discounting rates by mitigating the attractiveness of the immediate option. Specifically, the unpleasant consequence of choosing the immediate option (i.e., $0 will be received for the delayed outcome) is made more salient, thus that reducing the appeal of the immediate reward by placing it in the same temporal frame as the unpleasant and distant long term consequence (Radu et al., 2011).

In Experiment 2 of Radu et al. (2011), delay discounting was assessed with and without hidden zero manipulations for both past and future outcomes for each participant. Hidden zero manipulation resulted in greater preference for the temporally distant option for both past and future discounting procedures. Further, the degree of change between the hidden zero and non-hidden zero versions for past and future discounting were significantly correlated. In Experiment 4 of Radu et al. (2011), participants were either instructed to estimate how long ago they experienced each of seven common events (temporal priming group), or estimated caloric content of seven common food items (control group). Those in the temporal priming group discounted past rewards at lower rates than those in the control group. The authors postulated that valuation of past events may affect delay discounting of future rewards, prompting subsequent interest in the joint implications of past and future discounting within clinical contexts. As mentioned previously, choosing the more temporally distant reward is always the more functional choice within past delay discounting paradigms. Further, observed symmetrical effects observed between past and future discounting may be an artifact of procedural similarities. These potential limitations incentivize the development of new methods of investigating the impact of temporally distant rewards on current behavior.

The Sunk Cost Effect

Examining the extent to which subjects commit the *sunk cost effect*, defined as allowing an initial investment of time, effort, or money to increase the likelihood of their continued investment (Arkes & Ayton, 1999; Arkes & Blumer, 1985; Staw, 1976), may be an ideal alternative approach to evaluating the impact of temporally distant past stimuli on current behavior. Typically, the sunk cost is discussed as a subcategory of escalation, or the tendency to continue to invest resources despite negative consequences (Sofis, Jarmolowicz, Hudnall, & Reed, 2015; Staw, 1976, 1997). Interestingly, the oft-cited definition of escalation from Staw (1976) was not intended as an argument that escalation is exclusively irrational or maladaptive (Staw & Ross, 1989). Instead, escalation was conceptualized as unexpected persistence that appears insensitive to particular costs or rewards (Staw, 1976, 1997; Staw & Ross, 1989). Pioneering researchers on the sunk cost effect were less concerned with the adaptive or rational nature of the sunk cost effect or escalation than the psychological determinants of the phenomena (Staw & Ross, 1989). Instances of escalation, however, do not necessarily exemplify the sunk cost effect. For example, someone who is more likely to persistent in overeating in a given sitting may persist as a function of specific characteristics of the reinforcer (i.e. escalation only), or because of stimulus control exerted by a previous investment (i.e., sunk cost; which is escalation under the stimulus control of an initial investment). Although seemingly semantic in nature, the sunk cost and escalation likely involve unique processes underlying the overeating tendency, and thus may demonstrate notable translational utility.

Sunk cost vs. escalation. Unfortunately, operant researchers often use the terms escalation and sunk cost interchangeably (Macaskill & Hackenberg, 2012; Navarro & Fantino, 2005; White & Magalhaes, 2015), without demonstrating that characteristics of initial bouts of responding (i.e. initial investment) differentially relate to continued investment (Macaskill & Hackenberg, 2012; Navarro & Fantino, 2005). In a study by Navarro and Fantino (2005), for example, pigeons earned reinforcement on one key for pecks on one of four, fixed ratio (FR) values (10, 40, 80, and 160) presented on 50%, 25%, 12.5%, and 12.5% of trials, respectively. On a separate key, pigeons could escape each trial at any point following the first 10 responses on the FR key. This escape option was signaled in one condition but unsignaled in another. The sunk cost effect was conceptualized as completing any of the FRs above an FR10, because an escape response was most likely to result in an FR10 (i.e., 50%) on the following trial, thereby making the expected value of escaping normatively greater than persisting. There are several potential issues, however, with this conceptualization of the sunk cost effect. First, it is unlikely that responses before and after the 10^{th} response were discriminable, as was suggested by findings that the pigeons persisted through nearly 100% of all FR trials during the unsignaled condition and 0% in the signaled condition. These data suggest that FR responding likely occurred in functional units that were void of discrete initial and terminal investment runs.

Therefore, it is difficult to provide empirical support that initial investment amounts were differentially related to continued investment.

By contrast to many operant researchers, the predominate approach to evaluating sunk costs entails assigning independent groups to different initial investment conditions and identical terminal investment conditions (Arkes & Blumer, 1985; Brockner, 1992; Staw, 1976). In a famous study by Arkes and Blumer (1985), for example, individuals who purchased season tickets to the university theatre were randomly assigned to either pay $5, $10, or $15 (i.e., the initial link) for access to all shows for the upcoming academic year. Attendance was calculated for the first and second semesters and the more money participants paid for the theatre tickets initially, the more frequently they attended during the first semester of shows (i.e., the sunk cost effect).

In a study by Sofis et al. (2015), however, the sunk cost effect and escalation were empirically differentiated. Specifically, participants made forced choice initial investments ($5, $20, or $35, randomized) prior to choosing whether to complete or pass on projects in a terminal link ($5, $20, $50, $80, or $95, randomized). In this paradigm, completing any $80 or $95 investment was considered an instance of escalation, as either cost is greater than escaping to experience the average cost of a new trial (i.e., $70). The sunk cost effect was defined as passing on a specific escalation amount (i.e., completing an $80 or $95 terminal investment) when the initial investment was $5, and completing that same escalation amount on a separate trial when the initial investment was $35. Similar to the findings reported by Arkes & Blumer (1985), there was a systematic effect of initial investment amount and proportion of choices made to complete the $95 terminal investment. Notably, 54% of participants exhibited the sunk cost effect, while 87% engaged in at least one instance of escalation. In other words, there were participants who engaged in only escalation, only the sunk cost effect, and both, providing clear evidence that the sunk cost effect may be a related, but independent phenomenon of escalation.

The sunk cost as temporal decision-making paradigm. Similar to delay discounting, the sunk cost effect provides a context for evaluating how time between a temporally distant event and the present affects current decisions. Unlike delay discounting, wherein decisions are all made at a single choice point, the sunk cost effect is often explored using a sequential paradigm with two links (i.e., initial investment [forced choice] & terminal investment [free choice]), removed from each other in time. From a normative perspective, only prospective value (i.e., potential future reward), not previous costs, should affect current decision making (Staw, 1976). Interestingly, the potential adaptability of the sunk cost from a psychological, not economic, perspective has engendered significant debate, in part, because there is limited empirical evidence in support of either viewpoint (Siniver & Yaniv, 2012). Some have argued that an underlying propensity to exhibit the sunk cost effect can function as a form of self-control and facilitate persistence necessary to obtain larger later rewards (Fantino & Stolarz-Fantino, 2002; Rachlin, 2000). Large down payments for gym memberships, for example, might result in increased gym attendance and have been discussed as commitment responses (Rachlin, 2000; Rachlin & Green, 1972). Interestingly, Coleman (2010a) found that even small differences in monetary initial investments for college courses increased the likelihood of self-reported time participants would dedicate to continuing their education.

Normative accounts hold that the sunk cost effect violates the economic principle that investments of time, effort, and money should only be made when future benefit exceeds future costs (Staw & Ross, 1989). Such normative theories on the maladaptive nature of the sunk cost effect often come from the organizational decision-making literature, wherein decision-makers continue to invest resources due to past investment and fail to consider current and future circumstances (Brockner, 1992; Staw, 1976, 1997; Staw & Ross, 1989). As noted by Rachlin (2000) and Fantino and Stolarz-Fantino (2002), however, a propensity to continue investments after an initial effort may be fundamental to persisting in behaviors that have resulted in larger yet delayed rewards in the past [e.g., persisting in completing educational goals (Coleman, 2010b)]. Past investments in gym memberships or yearlong subscription services, for example, hold considerable prospective value by providing less-constrained access to rewarding services or commodities following the initial investment. An ability to recognize the potentially controlling influence of such an initial investment on prospective value has been discussed as an important form of self-control (Fantino & Stolarz-Fantino, 2002; Rachlin, 2000). A conservative approach, and one in line with the broader behavioral economic and behavior analytic literatures, would be to hold that the sunk cost effect is contextually dependent. Specifically, it may be adaptive to exhibit in some instances and maladaptive in others (Fantino & Stolarz-Fantino, 2002; Rachlin, 2000; Zeelenberg, 1999).

Understanding if, and under what conditions the sunk cost effect relates to delay discounting, however, may facilitate an increased understanding of the temporal characteristics underlying adaptive and maladaptive decision-making (e.g., self-control vs impulsivity). Scholars have hypothesized, for example, that exhibiting the sunk cost as a may be adaptive in the context of commitment towards larger deferred rewards (Fantino & Stolarz-Fantino, 2002; Rachlin, 2000; Rachlin & Green, 1972; Seigel & Rachlin, 1995). One method of testing this assertion is to test whether a greater propensity to exhibit the sunk cost effect relates to lower rates of discounting. Relatedly, if the sunk cost effect is as well-explained by temporal attention as is delay discounting (Radu et al., 2011), then one would expect lower rates of discounting to correspond to greater levels of the sunk cost effect. Further, the hypothesized process by which the hidden-zero affect alters delay discounting is by putting the smaller sooner and larger later rewards in the same temporal frame (Radu et al., 2011). Specifically, the hidden zero effect could influence discounting through altering subjective perceptions of time, making distant events appear more proximal than before, thus enhancing relative preference for larger later past and future rewards. Therefore, a key process that could underlie temporal attention, delay discounting, and the sunk cost effect is subjective time perception (Radu et al., 2011).

Time Perception

Time perception can broadly be described as the perception of the periodicity between presentations of stimuli and responses compared to the actual periodicity between the same events (Allman & Meck, 2012; Gibbon, 1977) (See Table 1 for a review of time perception constructs). More simply, time perception has been described as the perceived duration between time points as a function of the objective time passed i.e., clock time; Kim and Zauberman (2009). Time perception, however, is often confused with temporal perspective or time horizon, which often refer to measures derived from personality scales (Strathamn, Gleicher, Boninger, & Edwards, 1994; Zimbardo, 1992). Measures of time perspective are typically thought to measure stable individual differences in relative consideration of past, present, and future personality or trait characteristics (Keough, Zimbardo, & Boyd, 1999; Strathamn et al., 1994). Unfortunately, such measures of time perspective often include additional assumptions about the adaptive or maladaptive nature of future or past-oriented thinking and evaluate a multitude of non-time-oriented constructs. The Zimbardo Time Perspective Inventory (ZTPI), for example, asks questions related to the "past" that suggest that temporal attention directed towards the past can only be maladaptive (e.g., "I think about bad things that have happened to me in the past").

Although used frequently in conjunction with delay discounting, a systematic review by Teuscher and Mitchell (2011) revealed inconsistent, weak, and difficult to replicate correlations between rates of delay discounting and measures of time perspective. The mixed findings between time perspective and delay discounting and the confounding role of non-temporal constructs prompts exploration of alterative temporal measures.

As shown in Figure 2, time perception can be separated into the categories of subjective time perception (i.e., past and future in the context of intervals ranging from days to years) and time estimation (i.e. past and future in the context of time intervals ranging from seconds to hours). Time estimation procedures typically entail asking participants to estimate durations of particular time intervals (Wittmann et al., 2011). Task instructions usually urge participants to provide their best possible estimate of the objective time that has passed. Time estimation procedures are generally categorized as either prospective time estimation, wherein participants are told in advance that they will be estimating duration, or retrospective time estimation, wherein participants are asked to estimate duration after experiencing an experimental task (Wearden, 2008). There is some evidence that those who overestimate how much time has passed in time estimation procedures tend to exhibit higher rates of delay discounting than those who do not overestimate how much time has passed (Baumann & Odum, 2012; Wittmann & Paulus, 2008). Baumann and Odum (2012), for example, used a temporal bisection procedure wherein participants were asked to judge the duration of a presence of circles as long or short. After training participants on the duration of short trials (i.e., circle presented for 2s) and long trials (i.e., circle presented for 4s), participants had to categorize a series of durations between 2-4s as either short or long. The authors found that those with higher mean proportions of long responses as a function of the same stimuli (i.e., those who overestimate the duration of the intervals) showed higher rates of discounting. In other words, the amount of time passed may seem subjectively longer in those who discount at higher rates. Further evidence of this came from Reynolds and Schiffbauer (2004), who found that overestimation of time intervals from sleep deprivation corresponded with higher rates of discounting. The authors hypothesized the sleep-deprived participants may have subjectively perceived the delay intervals to be longer than those who were not sleep deprived. Despite these findings, there are multiple limitations of the literature synthesizing discounting and time estimation.

Unfortunately, time estimation measures often inconsistently or weakly relate to delay discounting (Teuscher & Mitchell, 2011) In a study by Berry, Sweeney, Morath, Odum, and Jordan (2014), for example, a temporal bisection task was unrelated to delay discounting despite significant relations between multiple other temporal measures. One explanation for the lack of consistent relation is that mechanisms underlying time estimation fundamentally differ at time scales using seconds compared to those using months (Wittmann & Paulus, 2009). Another explanation is that time estimation between even sub and suprasecond time-scales may involve unique behavioral and neurological mechanisms (Buonomano, Bramen, & Khodadadifar, 2009; Wittmann & Paulus, 2009). Further disproportionate changes in discount rates shortly before and after 1 year delays may also be a product of unique time scales (Wittmann & Paulus, 2009). Another limitation to the literature attempting to connect delay discounting to time limitation is the logistical difficulties involved with measuring time estimation at time intervals greater than a one-session experimental session. Further, even if one had participants estimate time that had passed over times greater than 1 or 2 hours, use of clocks, calendars and other temporal cues would provide significant barriers. The degree to which delay discounting and time estimation relate remains unknown because of the dearth of research evaluating both phenomena at longer intervals, potential fundamental difference in time estimation at parametrically removed time scales, and the inconsistent or weak findings between the two measures.

Time perception and temporal attention. Subjective time perception tasks probe one's subjective judgement of the passage of time as it relates to longer time intervals into the past or the future (e.g., minutes, hours, days, weeks, months, and years; Lejeune, Richelle, & Wearden, 2006). In contrast to time estimation, time perception is usually measured by explicitly asking participants to provide their subjective interpretation or perception of durations of time (Kim & Zauberman, 2009). Although used less frequently than time perspective and time estimation measures, subjective time perception tends to consistently relate to delay discounting (Kim & Zauberman, 2009, 2013; Zauberman, Kim, Malkoc, & Bettman, 2009). Relatedly, orienting attention to the duration between present and temporally distant events, or towards one's perception of the passage of time between events, decreases rates of delay discounting (Radu et al., 2011; Zauberman et al., 2009). Zauberman et al. (2009), for example, found that those participants who estimated how long it would take to complete certain activities discounted at lower rates than those who guessed the caloric content of certain foods. Zauberman et al. (2009) asked participants to imagine a day *x* time from now, and then indicate how long the given duration on a 180 mm line with "very short" on the left end and "very long" on the right end. The authors found that the greater the difference observed between perceptions of short time durations relative to long time durations (i.e., sensitivity), the lower the rate of delay discounting. Further, subjective time perception measures appear to covary consistently with changes in delay discounting (Kim & Zauberman, 2013; Zauberman et al., 2009). In a study by Kim & Zauberman (2013), for example, sexual cues lengthened the same measure of future time perception, which corresponded with increased rates of delay discounting. Such findings are further supported by evidence that chronic smokers report the time until smoking is permitted to be longer when they are craving than when they are not (Sayette, Loewenstein, Kirchner, & Travis, 2005) and discounting rates are lowered when made in shorter temporal windows compared to longer ones.

Although there are no studies to my knowledge evaluating both subjective past time perception and delay discounting, there is considerable evidence suggesting that subjective time perception of past and future events are related and are facilitated by overlapping neural systems (Addis, Wong, & Schacter, 2007; Buckner & Carroll, 2007; Nyberg, Kim, Habib, Levine, & Tulving, 2010; Okuda et al., 2003). Importantly, however, researchers arguing for the role of temporal attention have posited that two unique but related temporal constructs are prerequisites for temporal attention to occur. The first of these is subjective time perception, which is highly related to one's temporal window. In other words, the degree to which one perceives objective temporal markers (e.g., exactly two months in the future from now) as subjectively close to the present, the more expansive their temporal window. The second of these temporal constructs is one's temporal focus, which is hypothesized to relate to one's temporal window and time perception of distant events. In Radu et al. (2011), for example, the authors posited that they may have observed individual differences in participant's ability to draw attentional resources towards distant past versus distant future events. In other words, the perception that temporally distant events are close to the present may be a necessary prerequisite for attributing attentional resources to future events, thereby valuing them (Bickel et al., 2016b). One measure that might perform such a role is the Temporal Focus Scale (Shipp, Edwards, & Schurer Lambert, 2009). The Temporal Focus Scale is 12-item psychometric scale designed to measure one's relative attention allocated towards future, past, and current events (Shipp et al., 2009). The well validated scale (Shipp et al., 2009) has 12 items (four past, four present, four future) rated on a 7-point scale (1= never; 3 = sometimes; 5 = frequently; 7 = constantly). The scale provides two notable advantages to other temporal scales measuring trait-like perceptions of time. First, none of the items present any assumed maladaptive or adaptive characteristics and none of the temporal directions (i.e., past, present, future) were assumed apriori to be adaptive or maladaptive. Second, Shipp et al. (2009) designed the scale with the assumption that attention is dynamic. Namely, attention can shift between time periods and that a propensity to focus on the future does not preclude a heightened focus on the past or present. Although there are no studies to my knowledge incorporating the temporal focus scale and delay discounting, future research on temporal attention may benefit from its inclusion.

Integrating the Sunk Cost Effect, Delay Discounting, and Temporal Attention

The sunk cost effect may be an ideal candidate for studying how temporally distant past events impact current behavior. First, like delay discounting, sunk cost procedures present intertemporal decisions juxtaposing present events with temporally distant ones, therefore providing strong potential for conceptual overlap. In delay discounting tasks, either reward amounts or delays are titrated across choice trials depending on participant choices between smaller sooner and larger later rewards (Rachlin et al., 1991; Richards, Zhang, Mitchell, & de Wit, 1999). The point at which participants are indifferent between reward amounts are plotted for each delay condition, providing the data for the discounting curve. Similarly, the sunk cost effect is typically studied by manipulating a characteristic of the initial link investment (e.g., temporal gap between initial and terminal link) across experimental groups to observe the differential effects on terminal link behavior (Arkes & Blumer, 1985). Therefore, both delay discounting and sunk cost paradigms entail choices that are hypothetically separated, but related, in time.

Second, the sunk cost effect may be an approach to understanding commitment responses that are made in anticipation of potential preference reversals (Berns, Laibson, & Loewenstein, 2007). Purchasing a year-long gym membership, for example, has been hypothesized to help in persisting towards long-term health goals such as persisting in an exercise regimen (Rachlin, 2000). Further, Radu et al. (2011) temporally primed past positive experiences in Experiment 4 and the authors suggested that increased salience of positive past experiences may increase future valuation (i.e., exemplified lower rates of future delay discounting).

Relatedly, in a series of delay of gratification tasks that acknowledge that the anticipated timing of future rewards are often uncertain, McGuire & Kable (2012, 2013) found that participant predictions of the delay length remaining until the larger later reward increased as a function of already elapsed time. Specifically, in a study with human participants by McGuire and Kable (2012), randomly timed deliveries of delayed rewards were given according to either a uniform or a rapidly declining probability distribution of waiting time. Participants could opt out at any point to obtain a smaller sooner reward. The reward maximizing strategies across the two groups were to always persist, and to persist for roughly two seconds, respectively. Based on their respective experiences across repeated trials, those participants assigned to the uniform distribution condition adjusted their tolerance to wait (i.e., persisted) better than those with rapidly declining delivery schedules. Specifically, those in the rapidly declining group frequently passed on trials too soon. The authors concluded that high or low levels of persistence are not necessarily adaptive or maladaptive, but that adaptive persistence is exemplified by fluctuations that are sensitive to the environment. These findings suggest two important implications for temporal attention as it relates to the sunk cost effect and delay discounting. First, individual differences in joint past and future time perception are shaped by ones history of reinforcement (McGuire & Kable, 2012, 2013). Second, bidirectionally linked subjective time perception may influence both the sunk cost effect (i.e., persistence under the stimulus control of an initial investment) and delay discounting at a longitudinal and moment-to-moment basis. In other words, one's general propensity to exhibit expansive (or restrictive) time perception may be related to, but unique from, time perception at a state-level. A first step may therefore be to better understand how a subjective time perception measure, used as a proxy for temporal attention processes, relates to the sunk cost effect and delay discounting.

Pilot evidence of the sunk cost and delay discounting overlap. Further evidence for the potential overlap between the sunk cost and delay discounting comes from a recent pilot study by Sofis, Lemley, & Jarmolowicz (under revision). Participants completed an adjusting amount delay discounting procedure (Richards et al., 1999), a novel temporal sunk cost task, and a subjective time perception task (Zauberman et al., 2009). A total of 55 subjects' data were retained from an initial sample of 83 participants. Specifically, based on recommendations from Johnson and Bickel (2008), 22 participants were excluded for inconsistent indifference points across delays. An additional six participants were excluded for reporting one or more inconsistencies in time perception (e.g., reported that 12 months was closer to the present than 3 months). One participant was excluded for always investing in all trials of the sunk cost task. Therefore, the final sample was 55 subjects.

Subjective time perception was measured by instructing participants to, "Slide the tab to show how soon or far away x is from now" on a computer screen (x = 3 months, 1 year, and 3 years). A visual analogue scale with a sliding tab was located below the instructions and had labels of "really soon" (far left) "really far" (far right). After sliding the tab to indicate how subjectively close or far the objective time was from the present, participants clicked on a large button at the bottom of the screen that was labeled "Accept" to move to the next task. A single measure of subjective time perception was calculated for each participant by deriving k values using the hyperbolic model often used to model delay discounting (Mazur, 1987). The natural log of the k values was then calculated, which altered the Kolmogorov-Smirnov test from 0.30 ($p < .01$) to 0.07 ($p > .20$). Further, high and low time perception groups were created by performing a median split based on subjective time perception (Ln (k)).

For the temporal sunk cost task, the authors replicated the procedures used in Sofis et al. (2015) by using $5 and $35 forced choice initial link investments and $5, $20, $80, and $95 free-choice terminal link investments (with option to pass a begin a new trial). Besides not using $20 as one of the initial link amounts, the only addition to the methods was the addition of hypothetical temporal gaps between initial and terminal links. Specifically, participants were exposed to conditions with a range of hypothetical temporal gaps (i.e., 0, 3, 12, or 36 months) between initial and terminal links. Within each temporal condition, for example, participants were told to imagine that they had made the initial investment 0, 3, 12, or 36 months ago and were presented with one of the two initial link monetary amounts. After clicking invest (forced-choice), they were then provided with one of the four terminal link investments amounts on the left-hand side of the screen and a pass on the bottom-right-hand side.

Within each series of eight trials (i.e., two initial link amounts and four terminal link amounts), referred to as a round, there were three important dependent measures. First, any completed terminal investment of $80 or $95 was counted as an *escalation instance*, because both $80 and $95 are greater than the average initial and terminal link amounts for a given trial (i.e., $70). Specifically, the mean of $5 and $35 (initial links) is $20 and the mean of $5, $20, $80, and $95 is $50 (i.e., $20 + $50 = $70). Second, a *sunk cost instance* was a joint event wherein participants passed on a low initial-escalation trial (i.e., 5-80 or 5-95), and completed a high initial-escalation trial with the same escalation amount [(i.e. 35-80 or 35-95, respectively) (See Figure 3 for a demonstration of a sunk cost instance across two trials with $80 as the terminal investment option in both trials)]. Lastly, *sunk cost proportion* was an index measure calculated by taking the number of sunk cost instances plus one, divided by the number of sunk cost and escalation instances plus one. The natural log of each sunk cost proportion measure at each time point was calculated to improve the distributions of data and to allow for the data to be plotted symmetrically to the discounting data. [1]

Figure 4 shows mean Ln (sunk cost proportion (left y-axis)) and mean indifference points (right y-axis) as a function of days since initial investment (left panel x-axis) and days from now (right panel x-axis), whether individuals were in the high (open circles) or low (closed circles) subjective time perception groups. Curves were fit to group discounting data using Rachlin's (2006) hyperboloid discounting model (see Equation 2), with the *s* parameter shared across groups of high and low time perception. The area under the curve (AUC) method was used to calculate an individual measure of delay discounting for each participant. Specifically, the areas under successive trapezoids formed by consecutive indifference points were calculated using the

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[1] Although sunk cost proportion is derived here by dividing sunk cost instances by escalation instances, recent evidence from fMRI research provides empirical support for this decision. During terminal link decisions, greater dorsal lateral prefrontal cortex (dlPFC) activation, and reduced ventral medial prefrontal cortex activation (vmPFC), occurred after greater initial investments (Haller & Schwabe, 2014). Greater dlPFC activation during initial link responding negatively correlated with vmPFC activation in terminal link choices and in the sunk cost effect. The authors concluded that initial link dlPFC activation "overrides" vmPFC activation during terminal link responding that completes an instance of the sunk cost effect. Interestingly, the vmPFC is differentially activated during smaller sooner rewards and the dlPFC larger later rewards during delay discounting choices (McClure, Laibson, Loewenstein, & Cohen, 2004). In sum, dividing the sunk cost by escalation may control potential overlap between escalation and sunk cost and therefore may provide a more accurate representation of the sunk cost effect

summed trapezoid method (Myerson, Green, & Warusawitharana, 2001). Rachlin's (2006) hyperboloid equation was not fit to the sunk cost proportion data because the data from individual participants did not always systematically decline as a function of temporal gaps. Mean sunk cost proportion at each temporal gap, however, was calculated for each participant.

A t-test used to compare mean delay discounting (AUC) of participants in the low and high time perception groups revealed a significant difference in delay discounting between the low and high subjective time perception groups (t = -2.10, p = .04). Specifically, participants with lower time perception group (i.e., perceived distant events as subjectively further from the present than their counterparts) discounted at higher rates than those in the high time perception group. For the sunk cost data, a two-way repeated measures ANOVA was used wherein differences in sunk cost proportion was evaluated across subjective time perception groups (across subject) and temporal gaps (within subject). A main effect of temporal gap (F (3, 159) =8.73, p < .001) and subjective time perception group was found (F (1, 53) = 4.30, p = .04), however; there was not a significant interaction effect (F (3, 159) = 0.77, p = .51). Specifically, those in the low time perception group exhibited less sunk cost proportion compared to those in the high time perception group. Further, the main effect of temporal gap was such that sunk cost proportion typically declined as a function of increasing temporal gaps.

The pilot study from Sofis and colleagues (under revision) provided three initial findings suggesting that the sunk cost and delay discounting may relate due to shared processes underlying subjective time perception. 1) First, sunk cost proportion generally decreased as a function of the time between the initial and terminal link. 2) Second, and more importantly, the sunk cost increased and delay discounting decreased in those who demonstrate greater levels of subjective time perception. In other words, those who perceived distant events as subjectively closer to the present relative to others showed a greater propensity to exhibit the sunk cost effect and demonstrated lower rates of delay discounting. 3) Third, delay discounting did not directly correlate with any measure of the sunk cost (e.g., instances, proportion), suggesting that time perception may be critical process shared by delay discounting and the sunk cost.

Verbal Behavior and Cross-Species Implication in Temporal Decision-Making

Many psychologists argue that human's alone demonstrate verbal behavior (Catania, 1995; Hayes, Barnes-Holmes, & Roche, 2001). Regardless of whether nonhuman animals exhibit verbal behavior, it is well established that humans demonstrate significantly more sophisticated patterns of verbal behavior (Catania, 1995, 2006). Further, the ability of humans to arbitrarily relate events has been proposed as a fundamental framework of verbal skills unique to humans (Hayes et al., 2001). As it relates to time, the ability of humans to make temporal discriminations such as Now-Then relations facilitates processes underlying human conceptualization of time (Biglan & Barnes-Holmes, 2015). The development of temporal verbal relations may even be fundamental to how humans make complex discriminations between past, present, and future (Friedman, 2000). Such distinctions are thought to contribute to a more complex repertoire underlying one's ability to act in anticipation of possible future events and in reference to past events (Biglan & Barnes-Holmes, 2015). This differential verbal repertoire between humans and nonhuman animals has arguably been the most referenced explanation for differences observed in the level of delay discounting (Critchfield & Kollins, 2001) and sunk cost effect (Arkes & Ayton, 1999). The next two sections will discuss the implications of verbal behavior across human and nonhuman species for delay discounting and the sunk cost effect in turn.

Verbal behavior and delay discounting. Despite several notable methodological differences between human and animal delay discounting paradigms, non-human animals tend to discount at higher rates than humans (Jimura, Myerson, Hilgard, Braver, & Green, 2009). One methodological difference is that most discounting studies with human participants do not use real rewards and animal studies do so exclusively (Johnson & Bickel, 2002). In human delay discounting paradigms, experimenters typically rely on the verbal repertoires of human participants to provide a proxy of actual circumstances wherein delays and reward values are not fully experienced (Critchfield & Kollins, 2001; Dixon, Lik, Green, & Myerson, 2013; Lagorio & Madden, 2005). Indirect evidence for a species-specific role of verbal behavior comes from delay discounting studies wherein small changes to the verbal stimuli that make up the discounting result in altered rates of discounting (Magen et al., 2008a; Read, Frederick, Orsel, & Rahman, 2005). Delay discounting studies with human participants also tend to show similar responding between real and hypothetical rewards (cf. Johnson & Bickel, 2002; Madden, Begotka, Raiff, & Kastern, 2003). Further, human participants tend to discount real versus hypothetical rewards similarly regardless of whether procedures are trial-based, include steady state responding, or include high versus low proportions of real vs. hypothetical rewards (Madden et al., 2007). Although verbal stimuli can impact rates of discounting (Magen et al., 2008a; Read et al., 2005), the verbal stimuli appear to provide fairly close approximations to actual conditions to which they refer (Johnson & Bickel, 2002; Madden et al., 2003).

Verbal behavior and the sunk cost effect. Whether the sunk cost effect can only occur in humans also continues to be widely debated (Arkes & Ayton, 1999; Navarro & Fantino, 2005). The ability of humans to discriminate compound verbal stimuli and rules has been hypothesized as one factor that contributes to the sunk cost effect in humans (Fantino, 1998). Research on the conjunction effect, typically considered a phenomenon specific to humans (Fantino, 1998), suggests that participants often indicate that the conjunction of two events are more likely than just one of the events (Stolarz-Fantino, Fantino, & Kulik, 1996). Although few disagree that human capacity for verbal behavior influences the effect in humans, some have argued that this discrepancy is why the effect may not be possible in non-human animals (Arkes & Ayton, 1999). Although several operant researchers have reported demonstrating the effect, the procedures used leave notable room for debate as to whether all of the criteria of the sunk cost effect are met (Macaskill & Hackenberg, 2012; Navarro & Fantino, 2005). As discussed previously in the case of Navarro and Fantino (2005), researchers often do not differentiate between escalation and sunk cost. In other words, there is not sufficient experimental manipulation such that a differential effect of initial investment can be attributed to the likelihood of continued responding. Other studies have implemented procedures wherein multiple free-choice links are present, making unclear whether the initial link investment is clearly related to the propensity to complete terminal investments (White & Magalhaes, 2015). Further, Clement, Feltus, Kaiser, and Zentall (1999) provided simultaneous discrimination training in which stimuli paired with high versus low effort conditions were used to establish conditional discriminations of the effort conditions (i.e., the justification effect). During probe trials with non-differential reinforcement and both stimuli presented, the pigeons preferred the stimulus corresponding to the high effort condition. Interestingly, however, the findings observed in Clement et al. (2001) could not be replicated by a series of six studies by Vasconcelos, Urcuioli, and Lionello-DeNolf (2007). Despite inconsistent evidence for the justification effect in non-human animals, there is considerable evidence that the effect occurs in humans (Aronson & Mills, 1959; Takemura, 1993). Further, traditional definitions of justification effect are explicitly a function of complex social contexts in which verbal behavior is pervasive (Staw, 1976). In sum, there is insufficient current evidence suggesting that animals are reliably capable of committing the sunk cost effect. At the very least, it appears clear that the sunk cost effect may not be as easily observable in non-human animals as it is in humans.

Most hypothesized explanations for the differential ease at which the sunk cost occurs in humans versus animals reference human sensitivity to verbal rules (Biglan & Barnes-Holmes, 2015). Verbal rules, for example, have been shown to induce the sunk cost effect by emphasizing not wasting resources (Arkes & Blumer, 1985) or through justifying past bad decisions (Bragger et al., 1998; 2003). Further, verbal stimuli manipulating social-context, and relative presence of heuristics (e.g., "avoid wasting resources") have all been shown to influence the relative likelihood of the sunk cost effect (Arkes, 1996). Further, the tendency for human subjects to prefer compound verbal stimuli to constituent stimuli has been shown to be a hallmark feature of reasoning and indicative of the sunk cost effect (Fantino, 1998). In other words, the general tendency for humans to display summation of stimuli may interact with verbal repertoires to differentially increase the likelihood of the sunk cost effect in humans.

Competing Neurobehavioral Decision Systems. The Competing Neurobehavioral Decision Systems hypothesis (CNDS) holds that the relative balance between the impulsive (reward-driven, automatic) and executive (future-oriented, deliberate) systems strongly underpins maladaptive and adaptive decision-making (Bickel, Jarmolowicz, Mueller, Gatchalian, & McClure, 2012; Bickel et al., 2007; Bickel, Stein, et al., 2017a; Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013; McClure et al., 2004). The CNDS hypothesis is derived in part from data showing that larger later choices during delay discounting tasks result in higher relative activation in the dorsal-lateral prefrontal cortex (dlPFC), while smaller sooner choices result in greater relative activation in the medial prefrontal cortex [(mPFC) (Bickel, Pitcock, Yi, & Angtuaco, 2009a; Bickel, Pitcock, Yi, & Angtuaco, 2009b; McClure et al., 2004; Tanaka et al., 2004)]. Differential activation of these two regions corresponds strongly with planning and reward-driven behavior, respectively. Although the CNDS hypothesis is intricately linked to neural events observed during delay discounting tasks, there are several two-system theories of decision-making that resemble the CNDS model (see Bickel, Mellis, et al., 2017 for a review). A large body of evidence suggests that delay discounting and the neural substrates that facilitate it undergird treatment outcomes such as relapse (Stanger, Ryan, Fu, Landes, & Jones, 2012), treatment response (MacKillop & Kahler, 2009; Washio et al., 2011), and prospective prediction of drug use (Brody et al., 2014). As such, delay discounting is often discussed as a treatment target for interventions in applied or translational contexts (Koffarnus et al., 2013; Sheffer et al., 2014).

Interestingly, evidence from neuroimaging studies suggest that the sunk cost effect and escalation may also fit neatly within the existing framework of the CNDS theory. Specifically, during the sunk cost effect, initial link responding elicits dlPFC activity, the same region activated during larger later choices in delay discounting (Haller & Schwabe, 2014; Zeng, Zhang, Chen, Yuc, & Gong, 2013). Terminal link responding, however, elicits differential mPFC activity as a function of escalation amount, the same region activated during smaller, sooner choices in delay discounting (Haller & Schwabe, 2014; Zeng et al., 2013). These data not only provide supplemental evidence of the overlap between delay discounting and the sunk cost effect, but also suggest that the sunk cost effect can be incorporated into the CNDS framework.

Narrative theory. One method of altering rates of delay discounting is with verbal framing designed to reduce impulsive system activation or increase executive system activation through altering corresponding changes in preference for immediate and delayed rewards, respectively. A growing body of literature suggests that verbal framing manipulations can alter rates of temporal decision-making such as delay discounting (Bickel et al., 2016b; Magen, Dweck, & Gross, 2008b; Peters & Buchel, 2009; Radu et al., 2011; Read et al., 2005). Within the CNDS framework, such verbal frames can be categorized by four dimensions (see Bickel, Stein, et al., 2017b for a reivew). Specifically, the dimensions refer to who creates the narrative (i.e., experimenter or participant), who the narrative refers to (i.e., self or others), time (i.e., past, present, future), and valence [(positive or negative) (Bickel, Stein, et al., 2017a)]. Often, positive narratives about multiple future events are presented as cues during tasks such as delay discounting (Bickel, Stein, et al., 2017a; Daniel, Stanton, & Epstein, 2013; Stein et al., 2016). Researchers have shown that positively valenced episodic future thinking reduces delay discounting (Stein et al., 2016; Sze, Stein, Bickel, Paluch, & Epstein, 2017).

A second verbal manipulation is the use of income narrative prompts designed to induce the perception of immediate scarcity or abundance conditions. Haushofer, Schunk, and Fehr (2013), for example, split participants into "rich" and "poor" groups, wherein participants were given low or high amounts of experimental cash that was later exchanged for actual money. After an effort-based task wherein participants earned extra experimental money, participants received either a positive, negative, or control income narrative. In other words, with the exception of the control income narrative group, participants were told that they either lost or gained a large amount of their experimental income. These statements corresponded with the participants actually losing or gaining that amount of experimental money. After being informed of their change in financial status, participants then played multiple additional rounds of the effort-task prior to completing a delay discounting procedure. The authors found that negative income shocks increased rates of discounting and to a lesser extent, positive income shocks decreased rates of discounting. Although Haushofer et al. (2013) used income narratives to inform participants of the change in conditions, they also provided actual income shocks that corresponded with real monetary outcomes. Therefore, it is difficult to determine to what degree the income narratives alone contributed to discounting differences between the groups. To that end, Bickel, Wilson, Chen, Koffarnus, and Franck (2016a) investigated the effects of negative, neutral, and positively valenced hypothetical income narratives without actual income shocks on delay discounting. The authors found that negative and positive income narrative groups showed higher and lower rates of discounting, respectively. Further, similar to the effects reported by Haushofer et al. (2013), the negative income narrative induced a greater effect on discounting than the positive income narrative. Additionally, in a factorial design, Sze et al. (2017) had groups of participants experience future, recent, or no episodic thinking conditions and either neutral or negative income narrative prior to completing a delay discounting task. Sze et al. (2017) replicated the previously described effects observed with episodic future thinking and negative income narratives (i.e., high rates of discounting with negative compared to neutral narratives). Additionally, participants who received episodic future thinking in the negative income narrative group showed decreased discounting rates compared to other participants in the negative income narrative group who received the recent or no episodic thinking manipulation.

One potential process underlying effects of income narratives on discounting rates is a constriction of the temporal window in which events can be valued (Bickel et al., 2016b). Temporal window, however, is merely a byproduct of the rate at which one subjectively perceives objective time points as close to the present (Zauberman et al., 2009). In other words, temporal window can be conceptualized as the furthest point in time that one is capable of perceiving. Despite individual differences observed, the temporal attention hypothesis holds that subjective time perception and attention towards specific points in time are generally symmetrical across future and past events (Radu et al., 2011). Additionally, attention directed towards specific points in time and subjective time perception are related but independent constructs (Bickel et al., 2016b; Rader, McCauley, & Callen, 2009; Stein et al., 2016). In other words, improvements in temporal window and subjective time perception are thought to shift temporal focus, and as a result, valuation towards temporally distant consequences (Kim & Zauberman, 2013; Rader et al., 2009; Radu et al., 2011; Stein et al., 2016; Zauberman et al., 2009). The existing evidence, however, has only shown that larger temporal windows (i.e., perceiving distant events as subjectively closer to the present) correspond with lower rates of delay discounting (Kim & Zauberman, 2013; Sofis et al.; Zauberman et al., 2009) and greater levels of sunk cost (Sofis et al., under review).

Those with a small temporal window (e.g., consider two weeks from now to be the "future"; Petry, Bickel, and Arnett (1998)) may not be capable of considering events past a given objective point in time. Such a deficit may result in a reduced sensitivity to long-term consequences. The ability to consider greater temporal windows, however, does not necessarily guarantee temporal attention towards distant events (Kim & Zauberman, 2013; Rader et al., 2009). In Kim and Zauberman (2013), for example, immediate and delayed reward choices were presented independently and happiness scores were used in lieu of a binary choices between smaller sooner and larger later rewards. Notably, sexual arousal worsened subjective time perception (i.e. objective time points perceived as further away from the present), which corresponded with fewer reduced happiness scores only for the delayed rewards. The authors hypothesized that arousal may have shifted temporal attention, as evidenced by the concurrent changes in discounting and subjective time perception measures.

Unfortunately, however, little is known about which aspects or measures of time best characterize temporal window and subjective time perception of distant future and past events. Further, there is limited evidence evaluating how subjective time perception might relate delay to discounting. Additionally, the attention factor in temporal attention has generally been inferred by evaluating how given interventions alter delay discounting in comparison to control manipulations (Kim & Zauberman, 2013; Radu et al., 2011; Yi et al., 2006). One method of avoiding this limitation is to evaluate concurrent effects of a measure of temporal focus (i.e. orientation) and subjective time perception. As previously discussed, the Temporal Focus Scale (Shipp et al., 2009) may be ideal because it does not assume adaptive or maladaptive patterns apriori and the scale was created with the assumption that temporal attention is a dynamic and non-mutually exclusive. Finally, the subjective time perception and sunk cost effect paradigms reported by Sofis and colleagues (under revision) already demonstrate overlap with each other and delay discounting.

Statement of Problem

There were three primary questions related to the current study. First, would valenced income narrative prompts concurrently alter subjective time perception, sunk cost, and delay discounting,? In other words, would positive income narratives improve subjective time perception, resulting in decreased discounting and increased sunk cost? Similarly, would negative income narratives worsen subjective time perception, resulting in increased discounting and decreased sunk cost? Such findings would provide further support for the temporal attention hypothesis and were anticipated based on the findings reported by Sofis et al. (under revision), Sze et al. (2017), and Bickel et al. (2016b). Second, would the sunk cost decrease as a function of temporal gaps in a manner similar to the data observed in the pilot study by Sofis and colleagues (under revision)? If the sunk cost effect is indeed a manifestation of temporal attention, then the general trend of decreasing sunk cost as a function of temporal gaps should be observed. Third, would delay discounting directly correlate with the sunk cost effect? Further, would the terminal amount of sunk costs differentially correlate with delay discounting? Would lower rates of discounting, for example, correlate with sunk cost instances of higher terminal link values, but not those of lower terminal link values? Unlike the pilot study from Sofis and colleagues (under revision), the current study used the terminal link values of $5, $30, $50, $75, and $105 to provide amounts more proximal (i.e., $50 and $75) and more distant (i.e., $105) from the trial mean ($73). Based on these goals, the proposed experiment investigated the effects of valenced income narratives (independent groups of positive, negative, or neutral narrative) and on subjective time perception (future and past), temporal focus, delay discounting, and the sunk cost effect.

Methods

Subjects

A total of 205 participants were recruited from Amazon Mechanical Turk (mTurk). Mturk is an online crowdsourcing marketplace wherein human intelligence tasks (HITs) are posted for mTurk workers to complete. Only workers who had records of at least 95% of their HITs accepted by requesters were used for the current study. A statistical power analysis was performed using GPower 3.1.9.2 to estimate the necessary sample size. Existing literature investigating the effects of income narratives on delay discounting was used to determine effect sizes because there is no available evidence to my knowledge evaluating the effects of income narratives on the sunk cost. The means and standard deviations of delay discounting rates reported in Haushofer & Fehr (2013) were used to calculate effect sizes for positive (η^2= 0.107) and negative ($ŋ^2$= 0.153) income shock (i.e., Ratio of positive to negative income shock = 70%; see Appendix A). Unfortunately, the addition of independent variable components (high and low experimental endowment groups) besides the income narratives in Haushofer & Fehr (2013) limited the generality of their effect sizes. Sze et al. (2017) reported partial eta-squared, but only used negative and neutral income narrative groups. The partial eta-squared from Sze et al. (2017) was translated to an effect size (Appendix B). Then, the 70% proportional difference in effect size between positive and negative narratives from Haushofer & Fehr (2013) was multiplied by the Sze et al. (2017) negative income shock partial eta-squared of .14 to arrive at an adjusted estimated partial eta-squared of .098 for the positive income condition (Appendix C). This was done to adjust the power appropriately to the lower relative effect of the positive income narrative on delay discounting. The estimated effect size of the positive income condition (i.e., $ŋ^2$ =.098, Cohen’s d = 0.33) was then used to estimate the necessary sample size because greater statistical power was assumed to be necessary to observe the effect of the positive income narrative compared to the negative narrative. With an alpha of 0.5 and power of 0.95, the sample size necessary to observe a significant effect of income narrative group on discount rate using a One-Way ANOVA was N =147.

Participants were compensated $0.75 for completing all experimental procedures. Participants also received a bonus of $0.75 for passing at least once on terminal links. Participants were instructed in the informed consent and prior to completing the sunk cost task that they could receive $0.75 for attending to the sunk cost task. Specifically, they were told:

> Please note that you can earn an extra 75 cents (totaling $1.50) if you honestly and realistically answer during the task labeled, 'financial decision-making.' Based on our experience administering this task, we can identify if you are not attending. There are no

right or wrong answers, and if you are carefully attending to the questions, you will earn the bonus of 75 cents. We will remind you of these criteria prior to the “financial decision-making task."

Following completion of the experimental tasks, participants were provided with a code that they used to acquire their compensation. Bonuses were provided within 24 hours of the completion of the experiment.

Procedure

Participants completed all experimental tasks online using Qualtrics survey software™. The university’s institutional review board approved all procedures used in the present experiment. Participants were provided with an information statement and then reported demographic information including age, height and weight, gender, race and ethnicity, income, education, and parent’s education during childhood. Participants were then provided with instructions regarding the $0.75 bonus, and the following summary:

In this experiment, you will be asked to first read and envision yourself experiencing a hypothetical income-based scenario for 15 seconds. You will then be asked to write very briefly about how this hypothetical scenario might change your current financial situation. You will then be given four tasks and three surveys to complete.

Following completion of the experimental tasks, participants were provided with a code to enter on the Amazon mTurk website to acquire their compensation.

Income narrative conditions. Immediately after being presented with the instructions for the experiment, participants were randomly assigned to either a positive, negative, or neutral income narrative condition. The income narratives were based off of those used by Sze et al. (2017) with minor modifications. Specifically, there was no reference to changes in living situation in the income narratives. These were omitted so that the effects resulting from the hypothetical change in income would not be confused with those related to changes in living situation. In addition, the negative income narrative did not reference losing one's job, but instead, oriented participants to a situation wherein their pay was lowered to a third of their current pay. This was to create more subjectively equivalent circumstances amongst those in the negative and positive income narrative groups. Lastly, the positive income narrative alluded to a threefold increase in pay, which was larger than the increase used in Sze et al. (2017), and was an equivalent change to the lowered payment used in the present experiment's negative income narrative. Participants saw the following narratives based on their condition:

- Positive: At your job you have just been promoted. You will be making three times more money than you previously were.
- Negative: At your job, you have just been demoted. You will be making 1/3 of what you were making previously.
- Neutral: At your job, you have just been transferred to a different department, but will make the same amount of money.

After the initial presentation of the income narrative, participants responded to two questions regarding the narrative that were designed to individualize each participant's narrative experience. The individualization of the income narrative responses was further designed to help enhance the effectiveness of the narratives on subsequent tasks (Sze et al., 2017). Participants were shown the income narrative again and responded to the following prompt: "Describe how your financial situation has changed based on this narrative. Write approximately 2-4 sentences." Qualtrics response criteria were set such required that responses had to be at least 30 characters before the participant could proceed. Participants' written responses to the income narratives were then presented and participants were asked to rate their mood using a five-point scale featuring a face showing sad to happy, and participants were instructed, “Rate your current mood. All the way to the left is very sad, and all the way to the right is very happy.”

The participants’ written responses to the income narrative were presented prior to the delay discounting, sunk cost effect, subjective time perception tasks, and temporal focus tasks. In addition, participants rated their mood prior to completing each of these tasks as a manipulation check. Participants completed subjective time perception and temporal focus tasks in order, respectively, prior to the delay discounting and sunk cost tasks, to potentially reduce the likelihood that the effect of the income narratives would have lost sensitivity prior to the time perception measures. The order of the delay discounting and sunk cost tasks were counterbalanced across participants.

Temporal focus scale. The temporal focus scale (TFS) is a 12-item scale designed to measure the relative degree to which participants attend to toward future, past, and current events (Shipp et al., 2009). All 12 items (four past, four present, four future) are rated using a 7-point scale (1= never; 3 = sometimes; 5 = frequently; 7 = constantly). Means of all items within past, present, and future factors are used as the primary dependent measures (Shipp et al., 2009). As reported by Shipp et al. (2009), the chi-squared test for a confirmatory factor analysis model was significant ($p < .01$). In addition, the authors reported that the comparative fit index (CFI) was .96, which is above the recommended criteria of .95 (Hu & Bentler, 1999). All factor loadings for were statistically significant with a median factor loading of .78, and the factor structure was replicated three times in Shipp et al. (2009). The authors established convergent validity with moderate to high correlations between each factor of the TFS (i.e., past, present, and future), and the corresponding factors of the ZTPI (Zimbardo & Boyd, 1999), and the Temporal Orientation

Scale (Holman & Silver, 1998). Test-retest validity was established by the authors by reassessing the scale with the same participants six weeks after the initial assessment, and strong positive correlations were found for past (r = .73), current (r = .66), and future (r = .72) mean scores.

Predictive validity was established in study four, wherein temporal focus factors and past, present, and future measures of autonomy, pay, opportunities for advancement, and recognition at time point one. The current, present, and anticipated job characteristics and the temporal focus factors derived at time point one were then used to prospectively predict the outcomes of job satisfaction, organizational commitment, and turnover intent at time point two (i.e., predictive validity). High future temporal focus interacted with several anticipated job characteristics at time point one to predict job satisfaction at time point two. Similarly, high past temporal focus interacted with each of the four job characteristics to negatively predict turnover intent at participant's current job. Importantly, there were no interactions amongst the temporal focus measures, providing additional confidence that the temporal focus factors should be considered as three separate main effects (Shipp et al., 2009). Additional construct validity was provided in study two of Shipp et al. (2009), wherein past temporal focus was found to be negatively correlated with optimism and conscientiousness, and positively correlated with neuroticism. In contrast, future temporal focus was positively correlated with extraversion, conscientiousness, optimism, and risk-taking. The generality of the scale was furthered by replicating the factor structure across a range of ages, occupational status (student or working), and educational levels.

Subjective time perception task. The subjective time perception task used in the current experiment was based off of the procedure described in Zauberman et al. (2009). The authors did not validate their measure of subjective time perception. In the current study, participants were asked to slide a tab along a visual analog scale to report how soon or how far away *X* time is from now for both past and future temporal conditions (Appendix A). Participants were instructed:

> We are going to ask you a series of questions about how close or far certain times are from the present. We will ask you about time points in the past and the future (i.e., 1 day, 1 week, 1 month, 6 months, 1 year, and 5 years). Please click okay if you understand these instructions.

The temporal conditions probed in the subjective time perception tasked matched the five time periods used in the delay discounting task (1 day, 1 week, 1 month, 6 months, 1 year, and 5 years). Therefore, there was a total of 10 temporal conditions probed (5 for future and 5 for past temporal direction).

Delay discounting task. Participants completed a version of a titrating amounts delay discounting task in which participants made choices between rewards to be received immediately and delayed rewards. Six delay conditions were used that matched the temporal distances used in the temporal sunk cost task and the subjective time perception task (i.e., 1 day, 1 week, 1 month, 6 months, 1 year, and 5 years). For each delay condition, participants made six choices between an immediate and delayed amount. First, they chose to receive either $500 now, or $1000 at the given delay. Within each delay condition, the delayed choice is always fixed and the immediate amount is changed based on the participant last choice. Specifically, if the participant chose the immediate reward option, then the immediate reward was reduced by half of the previous difference between the immediate and delayed options for the next trial (i.e. 50% of $1000-$500 is $250). Therefore, the participant chose between $250 now and $1000 after a given delay. When the participant chose the delayed option, the immediate reward was increased by half of the previous difference. Therefore, the participant chose between $750 now and $1000 after the same delay. The immediate reward amount was titrated for six consecutive trials, including the first choice between $500 now and $1000 after a delay. This process was then repeated for each of the six delays in ascending order. The subjective value of the delayed $1000 amount was calculated by taking the midpoint of the final immediate reward chosen and the last amount of the immediate reward that had been forgone (Du, Green, & Myerson, 2002).

Temporal sunk cost task. The temporal sunk cost task (similar to that described by Sofis, Lemley, and Jarmolowicz (under revision), featured a series of two-link decision-making trials. The program first presented the following written instructions:

> Imagine that your job entails completing work projects and that you do not get any significant amount of income from any other source. Your department has been given a budget of $4,330 dollars. It is your responsibility to best allocate the budget to complete projects. Your goal is to efficiently complete 50 projects while saving the company money.
>
> Your work projects entail investing money from your project budget (seen in the upper right corner of your screen) to complete individual projects. The costs will vary from project to project. You must pay the cost to start each project, but then you will have the choice to either complete the investment or opt out of completing that investment.
>
> When you are working on projects, you will be told to think about how long ago you began each project. For some projects, you will assume that you have just begun them. For others, you will be instructed to imagine that you began the project some time ago. Please consider these instructions when choosing whether to complete projects.
> If you understand these instructions, please click okay.

The two-link decision-making trials were identical to those used in the pilot study by Sofis, et al. (under revision), except for changes to the temporal conditions and terminal link amounts. Specifically, unlike the pilot study, the hypothetical temporal gaps between initial and terminal links matched four of the temporal distances used in the delay discounting and subjective time perception tasks (i.e., 1 week, 1 month 1 year, and 5 years). Further, a $50 terminal investment was added and the $20 terminal investment was increased to $30 to potentially create more challenging decisions as to whether or not to persist. In other words, almost all $5 and $20 terminal investments in the pilot study were completed, suggesting that those terminal investment amounts were not inducing passing. For the sunk cost effect to occur, participants must pass on LI links. Therefore, the addition of the $50 and the change from $20 to $30 was designed to induce decisions that are more difficult and ideally, sunk cost instances at lower terminal values. Lastly, the $80 terminal investment and the $95 terminal investment were changed to $75 and $105, respectively. These alterations were made to increase the likelihood that differences between sunk cost instances at low ($75) and high ($105) terminal values would be observed. In other words, the changes in terminal link amounts resulted in a new trial mean of $73 (initial link = $20, terminal link = $53), which is only $2 lower than the lower of the two escalation amounts (i.e. $75) and $32 removed from the higher of the two escalation amounts (i.e. $105). Due to the anticipated increase in sunk cost instances at lower terminal link values, the sunk cost proportion measure used in the current study included completed investments at all terminal link amounts, instead of only escalation instances in the denominator. Each set of five rounds is a block (i.e., 50 trials).

Text describing the two-link decision-making trials was shown in the center of the screen (Appendix B). Text in the upper left-hand corner depicted the number of projects the participant has completed, and text in the upper right-hand corner displayed funds the participant could invest in projects ($4,330 to start). As an attempt to incentivize participants passing on some projects, a total budget of $4,330 was chosen because if a participant invested in 66.67% of trials, then they had to complete 84 initial investments (84 x 20 = x) to complete 50 projects (50 x 53 = x).

All possible combinations of initial ($5 or $35; average initial investment = $20) and terminal ($5, $30, $50, $75, or $105; average terminal investment = $53) investments constituted a round of two-link decision-making trials (ten trials total); the order of combinations of initial and terminal investments within each round was presented randomly.

Prior to starting each round, text informed the participant "Now imagine you started these projects *X*." The value of *X* changed in ascending order across rounds: now, 1 week, 1 month, 1 year, and 5 years. Additionally, prior to starting each time condition, participants were asked "When did you start these projects?" Participants had to select the correct answer from a list in order to proceed to the decision-making trials for that round. Further, text in the terminal link of each trial prompted, "You started this project *X*" to remind participants of the time condition in which they were responding.

In the initial link of each trial, the Qualtrics program presented a hypothetical investment amount, and participants pressed a button immediately below this amount labeled "Invest" followed by an arrow button to advance the terminal link. Advancing to the terminal link subtracted initial link costs from the participant's funds. The terminal link showed the amount of additional investment (and buttons with the option to "Pass" (lower right-hand corner) or "Invest" (lower left-hand corner). If a participant invested in the terminal link, the costs were subtracted from their funds and the number of projects was incremented by one. After a choice to invest or pass, text appeared informing the participant of the number of projects completed with an arrow button; clicking this button advanced the participant to the next two-link decision-making trial. Participants completed at least two sets of two-link decision-making trials for every time period (i.e., 50 two-link trials, eight each for now, 1 week, 1 month, 1 year, and 5 years), and continued investing until they completed 50 projects.

Data Analysis

Curves were fit using GraphPad Prism version 7. All statistical analyses were performed using SPSS version 25 or GraphPad Prism version 7.

Delay discounting task. The hyperbolic (Equation 1) and Rachlin's hyperboloid model (Equation 2) were fit to the median indifference data for each income narrative group using the Discounting Tool Selector (Gilroy, Franck, & Hantula, 2017). The Discounting Tool Selector ranks discounting models based on the respective probability that each model provides the best fit to the data. The Discounting Tool Selector compares model fits using Bayesian Information Criterion (Schwarz, 1978) to estimate the likelihood that the each of the various models are the best fit to the discounting data (Gilroy et al., 2017). The best fit model to the group indifference data was then used to determine *k* values for all participants. If the hyperboloid model provided the best fit to the data, then the *s* parameter for each participant was shared across the entire sample so that only the *k* parameter was free to vary. Additionally, the best fit curves for the income narrative groups were further compared using extra-sum-of-squares F tests to determine whether individual curves or one curve was a better fit to the group data. To avoid confusing Ln (*k*) parameters for individual participant delay discounting, past subjective time perception, and future subjective time perception, delay discounting rate will be abbreviated by Ln (k_{disc}), past subjective time perception by Ln (k_{past}), and future subjective time perception by Ln (k_{fut}).

Subjective time perception. For each temporal distance (1 day, 1 week, 1 month, 6 months, 1 year, 5 years), and temporal direction (i.e., future and past), participants' reported how close or far the objective time points were on a scale of 0-1000. Data from the visual analogue scale was then reverse scored (1000 = very close and 0 = very far). Data were reverse scored to permit fitting a hyperbolic curve using Mazur's (1987) hyperbolic model (Equation 1), where *A* will be 1000, which corresponds to the maximal valuation, *d* will be the temporal distance (x-axis), and *v* was each participant's subjective time perception (y-axis). Because researchers have found that time perception directly underlies the shape of hyperbolic discounting curves (Kim & Zauberman, 2009; Zauberman et al., 2009), a separate measures of time perception were derived for future (Ln (k_{fut})) and past (Ln (k_{past})) subjective time perception for each participant. Hyperbolic discounting of mean temporal distances for each income narrative group were also calculated.

Temporal sunk cost task. Mean investment percentage for each initial-terminal link combination on escalation trials were determined for each of the five time conditions (now, 1 week, 1 month, 1 year, and 5 years). Sunk cost instances were defined in an identical fashion to Sofis and colleagues (under revision), except the terminal amount of a sunk cost instance could be any of the terminal link values (i.e., $5, $30, $50, $75, $105). In other words, a pass on a trial with a $5 initial link and $30 terminal link, followed by a completed investment of a trial with a $35 initial link and a $30 terminal link, would count as an instance of the sunk cost effect.

Sunk cost proportion was calculated by dividing sunk cost instances plus one by the number of terminal investments plus one. Unlike the sunk cost proportion measure used in the pilot study by Sofis and colleagues (under revision), investments at all terminal link values, instead of only escalation values, were used in the denominator of this measure. This adjustment was made in anticipation of observing a broader continuum of sunk cost instances across terminal link amounts. Mean sunk cost instances and sunk cost proportion across temporal gaps were both measured to calculate a curve for each income narrative group if each group showed a consistent declining pattern across temporal gaps.

If either sunk cost instances or sunk cost proportion did show a consistent declining pattern across temporal gaps, then mean sunk cost instances and sunk cost proportion collapsed across temporal gaps was calculated. In addition, sunk cost instances and sunk cost proportion across temporal gaps for each participant were calculated using the area under the curve (AUC) approach. The areas under successive trapezoids formed by consecutive sunk cost data points across temporal gaps were calculated for each participant using an adjusted version of the summed trapezoid method (Myerson, Green, & Warusawitharana, 2001). Due the presence of a sunk cost value at the "now" temporal gap, the first x-y coordinate was the sunk cost value in the "now" temporal gap condition. The x coordinates for the remaining conditions were the actual temporal gaps (days). If a consistent declining pattern was demonstrated across temporal gaps, then the fits of the hyperbolic model (Equation 1) and Rachlin's (2006) hyperboloid model (Equation 2) were compared using Graph Pad Prism. Akaike's information criteria corrected (AICc) was used to determine the best fitting model. For each income narrative group, the *A* parameter was set to the mean sunk cost in the now condition, and the *d* parameter represented the temporal gaps. The best fit model to the group sunk cost data across temporal gaps was then used to determine *k* values for individual participant curves. If the hyperboloid model (Rachlin, 2006) was the better model, then *s* parameter would be shared across all participants so that the *k* parameter would be free to vary. Additionally, the best-fit curves were compared across income narrative groups for mean sunk cost instance data using extra-sum-of-squares F tests to determine whether individual curves or one curve fit to the group data was a better fit.

Comparisons. Temporal distance, sunk cost instance, and indifference data were aggregated across each of their respective time points for each income narrative group. The model (i.e., hyperbolic or hyperboloid) that best fit the data or could be fit to the data, was used for each measure. Then Ln (*k*) values from each measure were derived from curves corresponding to each of the income narrative groups. Extra sum-of-squares F tests were then used to determine whether a single curve or separate curves for each income narrative group better fit the data for each measure.

Natural log-transformed *k* values were derived for individual participant delay discounting (Ln (k_{disc}), past subjective time perception (Ln (k_{past})), future subjective time perception (Ln (k_{fut})) and sunk cost instances to correct for distribution and Kolmogorov-Smirnov tests were re-run to test for normality. Kolmogorov-Smirnov tests were used to test for normality; non-parametric statistical alternatives (e.g., Spearman's rank order correlation, Mann-Whitney U, Kruskal Wallis H, Quade ANCOVA) were used for non-normally distributed variables. Chi-square and non-parametric one-way ANOVA (i.e., Kruskal Wallis H) tests were performed to test for differences in demographic variables across income narrative groups. Any demographic variables that were significantly different across income narrative groups were used as covariates in any of the ANCOVAs used to evaluate for effects of income narrative group on subjective time perception, temporal focus, delay discounting, sunk cost instances, and sunk cost proportion. Specifically, there was one independent factor (i.e., income narrative group), and a main effect of income group is expected for each dependent measure. Post-hoc comparisons were used to evaluate differences between income narrative groups of time perception, temporal focus, delay discounting, and sunk cost.

Existing research suggests that education (de Wit, Flory, Acheson, McCloskey, & Manuck, 2007), income (Green, Myerson, Lichtman, Rosen, & Fry, 1996), age (Steinberg et al., 2009), BMI (Jarmolowicz et al., 2014), and ethnicity (Andrade & Petry, 2014) may relate to delay discounting such that less education, lower incomes, younger ages, and minority ethnicities have been linked to higher rates of discounting. Regardless of whether statistically significant relations were observed with delay discounting, the covariates of education (no 4-year degree, 4-year degree), personal income (below, above U.S. median), age (continuous), BMI (continuous), and ethnicity (non-minority, minority) were used as covariates in a one-way ANCOVA with delay discounting rate (Ln (k_{disc})) as the dependent measure and income narrative group as the fixed factor. Similar ANCOVA tests were run for the other dependent variables of interest (i.e., future and past subjective time perception, temporal focus, and sunk cost). Covariates were not added, however, to the ANCOVA models testing the other primary dependent measures unless statistically significant effects were demonstrated between the covariate and the dependent measure of interest.

Results

A total of 205 participants completed the experiment on Amazon mTurk. Of those 205 initial participants, 48 participants were excluded, leaving a final total of 157 participants. A power analysis revealed at least 147 participants were necessary to have sufficient statistical power. Specifically, based on the exclusionary criteria from Johnson and Bickel (2002), 25 participants were excluded for inconsistent indifference points on the delay discounting procedure. Of those exclusions, nine of those participants always picked the larger later reward and 16 of those participants reported an indifference point that was at least $200 greater than the indifference point at the previous delay. An additional eight participants were excluded for always choosing to invest in terminal links during the sunk cost task. Lastly, 15 participants were excluded for reporting a temporal distance on the future or past time perception task that was 5% or more than the previous temporal point (e.g., reporting that one year is closer to the present than one month). The 15 excluded participants for time perception also included those who always indicated 0 (proximal anchor) or 100 (distal anchor) for all time points for either future or past time perception.

Normality and income narrative group covariates. All variables except future time perception (Ln (k_{fut})) and future temporal focus were non-normally distributed. Non-parametric tests were used for all analyses involving non-normally distributed data. One-way non-parametric Quade ANCOVAs were performed to compare means of individual participant delay discounting, sunk cost, future and past time perception, and temporal focus factors across income narrative conditions. Mann-Whitney U tests were used to determine potential differences in discounting, sunk cost, future or past time perception, and temporal focus factors across the dichotomous variables of demographic variables of income, education, and ethnicity. Non-parametric Spearman's rank order coefficients were used to determine potentially significant correlations between BMI or age and discounting, sunk cost, future or past time perception, and temporal focus factors.

Demographics..Table 2 shows means, standard deviations, and significance values derived from a series of Kruskal-Wallis H tests investigating potential differences in BMI, age, and time to complete experiment across income narrative groups. There were no significant differences in age (H (2, 156) = 0.37, p = .83) or completion time of the experiment (H (2, 156)

= 1.17, p = .56) across income narrative groups. There were, however, significant differences in BMI (H = (2, 156) = 6.10, p = .047). Post-hoc comparisons using Mann-Whitney U tests showed no significant differences in BMI between neutral and positive income narrative groups (U = 1346, p = .62), or between neutral and negative income narrative groups (U = 982.5, p = .07), however, there was a significant difference in BMI between those in the negative and those in the positive group (U = 1049.5, p = .02). Specifically, those in the positive income narrative group had higher BMIs on average than those in the negative income narrative group. BMI was therefore used as a covariate in all tests comparing means of any dependent variable across income narrative groups.

The demographic variables of education (no 4-year degree, 4-year degree), personal income (below, above U.S. median), ethnicity (non-minority, minority), and work-status (full-time, not full-time) were coded in a dichotomous fashion consistent with previous established qualitative cut-offs (e.g., Andrade & Petry, 2014). Table 3 shows sample sizes, relative percentages of the sample for the overall sample and for each income narrative group. In addition, significance values derived from Pearson's chi-squared tests of potential differences in gender, ethnicity, education, income, and employment status across the income narrative groups are shown in the far right column of Table 3. For categorical variables, Pearson's chi-squared tests showed no significant differences across income narrative groups in education (X^2 (2, 156) = 1.58, p = .45), income (below or above the nationwide median income (X^2 (2, 156) = 2.15, p = .34)), employment status (X^2 (2, 154) = 0.93, p = .63), gender (X^2 (2, 156) = 0.00, p = .99), or minority status (X^2 (2, 154) = 2.79, p = .25).

Model fitting and dependent measures.

Delay discounting. Rachlin's (2006) hyperboloid model was selected as the model with highest probability to be the best fit for the median indifference data for the negative (99%; AIC = -29.73, R^2 = .99), neutral (99%; AIC = -28.91, R^2 = .99), and the positive group (71%; AIC = -30.77, R^2 = .99), respectively. Rachlin's (2006) hyperboloid model was therefore used to model the median indifference points for each income narrative group and to determine discounting rates for each individual participant. To calculate individual discounting curves, the *s* parameter was shared across all participants and the *k* parameter was left unconstrained. The *s* parameter was shared across all participants so that comparisons of the mean of individual *k* parameters for each income group could be made in isolation. The shared *s* parameter was 0.901.

Subjective time perception. Mean and median temporal distances for future and past time perception were calculated for each income narrative group across the time points of one day, one week, one month, one months, one year, and five years. Hyperbolic models were used for each of the income narrative groups. For median values, the hyperbolic model fit the data well for the negative income narrative group in the future (RMSE = 8.96, R^2 = .92) and past (RMSE = 6.63, R^2 = .96). Median values in the neutral income group were well fit to the future (RMSE = 10.62, R^2 = .86) and past (RMSE = 6.65, R^2 = .96) time perception. The hyperbolic model fit the positive income narrative group data well in the future (RMSE = 9.31, R^2 = .89) and past (RMSE = 5.62, R^2 = .97). The hyperbolic discounting model also fit individual participants' temporal distance data well for future (Mean RMSE = 8.86, SD = 3.74, Mean R^2 = .76, SD = 0.40) and past temporal directions (Mean RMSE = 9.70, SD = 4.38, Mean R^2 = .81, SD = 0.46).

Sunk cost instances. Mean sunk cost instances at each temporal condition and across income narrative groups were calculated prior to using an AIC test to compare whether the hyperboloid or hyperbolic model was the superior fit. The hyperboloid model was the superior fit for the negative (p = 99.99%, RMSE = 0.01, R^2 = .99), neutral (p = 99.99%, RMSE = 0.04, R^2 = .99), and positive (p = 99.99%, RMSE= 0.06, R^2 = .95) income narrative groups. Rachlin's (2006) hyperboloid model was therefore used to evaluate mean sunk cost instances across the income narrative groups. For each hyperboloid curve for each income narrative group, the *A* parameter was set to the mean sunk cost in the now condition for that group, and the *d* parameter represented the temporal gaps (x-axis) that corresponded with mean sunk cost (y-axis) at each time point.

Sunk cost instances and sunk cost proportion was calculated for each of the terminal link amounts (i.e., $5, $30, $50, $75, and $105), temporal gaps (i.e., now, one week ago, one month ago, one year ago, and five years ago) and income narrative groups (i.e., negative, neutral, and positive). Sunk cost proportion was calculated in identical fashion to the method used in the pilot study. Specifically, sunk cost instances plus a constant of one was divided by escalation instances divided by a constant of one. Similar to the pilot study, the total number of sunk cost instances and an total sunk cost proportion measure were calculated for each participant's sunk cost data. Many participants showed irregular or non-declining sunk cost data across temporal gaps, preventing fits of hyperbolic and hyperboloid models. Therefore, the area under the curve (AUC) approach was used to assess the combined sunk cost totals across the temporal gaps for each participant. This approach was used for the dependent measures of sunk cost instance and sunk cost proportion.

Pre-task mood scores. Figure 5 shows mood scores taken prior to temporal focus, time perception, delay discounting, and sunk cost measures. Mean mood scores (y-axis) are shown as a function of income narrative group (x-axis) for the measures of temporal focus (white bars), time perception (light grey bars), delay discounting (medium grey bars), and sunk cost (dark grey bars). Quade ANCOVA tests with BMI as a covariate and income narrative group as the fixed factor were used to evaluate potential differences in mood scores reported prior to time perception, temporal focus, sunk cost, and delay discounting. Significant main effects were found for mood prior to time perception (F (2, 153) = 327, $p < .0001$), temporal focus (F (2, 151) = 356, $p < .0001$), sunk cost (F (2, 152) = 293, $p < .0001$), and delay discounting (F (2, 150) = 295, $p < .0001$) tasks. Bonferroni post-hoc comparisons showed that for each measure, mood scores were greater for the neutral group than the negative income narrative group ($p < .0001$), greater for the positive group compared to the neutral group ($p < .0001$), and greater for the positive group compared to the negative group ($p < .0001$).

Mood scores prior to the delay discounting task negatively correlated with delay discounting rate ($r_s = -.18$, $p = .03$). Mood prior to the temporal focus task was negatively correlated with current temporal focus ($r_s = -.17$, $p = .03$), but not future ($r_s = .00$, $p = .98$) or past ($r_s = -.10$, $p = .23$) temporal focus. Mood scores prior to the sunk cost task did not correlate with any of the sunk cost measures ($r_s > |-.14|$, $p > .08$). Finally, mood scores prior to the subjective time perception tasks did not correlate with either future ($r_s = -.06$, $p = .49$) or past subjective time perception ($r_s = -.12$, $p = .15$).

The sunk cost effect across narrative groups. The left panel of Figure 6 shows mean sunk cost instances (y-axis) across temporal gaps (x-axis) and the income narrative groups of negative (open circles with heavily dotted line), neutral (open squares with solid line), and positive (open triangles with lightly dotted line) conditions. The hyperboloid curve (Rachlin, 2006) was fit to the data by sharing the *s* parameter across groups and comparing for differences in the *k* parameter. An extra sum-of-squares F test showed that one hyperboloid curve did not fit as well as three independent curves for the three respective income narrative groups (F (2, 11) =

14.17, p < .001). For post-hoc comparisons of hyperboloid fits, the same s parameter value (i.e., 0.25) from the first analysis was used as the shared s parameter to isolate potential differences observed in k values. Post-hoc extra sum-of-squares F tests showed that the negative and neutral groups' sunk cost fits were better fit by one curve (F (1, 8) = 0.30, p = .60), however; two curves were more appropriate than one when comparing positive and negative groups (F (1, 8) = 20.68, p = .002) and positive and neutral income groups (F (1, 8) = 17.00, p = .003).

Non-parametric Quade ANCOVA models were used to test for significant differences in sunk cost instances and sunk cost proportion, and mean terminal investment. There was not a significant main effect for sunk cost instances (F (2, 154) = 0.39, p = .68), sunk cost proportion (F (2, 154) = 0.32, p = .73), or mean terminal investment percentage (F (2, 154) = 0.35, p = .71). When using the AUC as the dependent measure of individual participant data, a non-parametric Quade ANCOVA model failed to demonstrate a significant effect of condition on sunk cost instances (AUC) (F (2, 154) = 0.62, p = .54) and sunk cost proportion (AUC) (F (2, 154) = 2.65, p = .07).

None of the sunk cost related measures were normally distributed before or after natural log transformation or square root transformation of the data. None of the sunk cost measures were significantly correlated with age or BMI (r < |.12|, p > .15). Categorical demographic covariates were determined by using Mann-Whitney U tests were used to compare sunk cost instances, sunk cost proportion, and mean terminal investment percentage across the potential covariates of education (no 4-year degree, 4-year degree), personal income (below, above U.S. median), and ethnicity (non-minority, minority). In addition, due to the specific work-related context of the task, employment status (full-time work, not full-time) a series of Mann-Whitney U tests were used to evaluate work status as a potential covariate for each of the sunk cost measures. Significant covariates were the effect of education on sunk cost instances (U = 2298, $p = .049$), sunk cost proportion (U = 2289.5, $p = .046$), sunk cost instances (AUC) (U = 2218, $p = .03$), and the effect of minority status on sunk cost proportion (AUC) (U= 1285.5, $p = .04$). Therefore, education was added as a covariate only when sunk instances, sunk cost instances (AUC), sunk cost proportion, and sunk cost proportion (AUC) were the dependent variables.

Figure 7 shows mean number of sunk cost instances (y-axis) as a function of temporal gap (x-axis) and negative (open circles with light dashed lines), neutral (open squares with solid lines), and positive (open triangles with heavy dashed lines) income narrative groups. A two-way repeated measures ANOVA resulted in a significant main effect of temporal gap (F (4, 616) = 32.77, $p < .0001$), but not across income narrative groups (F (2, 154) = 0.14, $p = .87$).

Delay discounting across narrative groups. The right panel of Figure 6 shows median indifference points across (y-axis) across delays (1 day, 1 week, 1 month, 1 year, 5 years) and income groups of negative (open circles with heavily dotted line), neutral (open squares with solid line), and positive (open triangles with lightly dotted line) conditions. The analyses were identical to that of the mean sunk cost data in the left panel. The hyperboloid curve (Rachlin, 2006) was fit to the data by sharing the *s* parameter across groups and comparing for differences in the *k* parameter. An extra sum-of-squares F test showed a significant main effect suggesting that three curves fit the group discounting data better than one curve (F (2, 14) = 11.85, $p = .001$). The shared *s* parameter value (0.82) was then used as the shared *s* parameter for the post-hoc comparisons between income narrative conditions. Post-hoc extra sum-of-squares F tests revealed a significant difference between negative and neutral groups discounting fits (F (1, 10) = 8.03, $p = .02$), positive and negative groups (F (1, 10) = 26.19, $p < .001$), but not positive and neutral income groups (F (1, 10) = 4.75, $p = .054$).

Individual participant delay discounting rates (Ln (k_{disc}) were not normally distributed. Discounting rate (Ln (k_{disc})) did not correlate with any of the continuous demographic variables (all $r < |.11|$, all $p > .18$) or show any differences across categorical demographic variables when using Mann-Whitney U tests (all U < 2820, all $p > .36$). A non-parametric ANOVA Kruskal-Wallis test failed to demonstrate a main effect of income narrative group on delay discounting (H (2) = 3.16, $p = .21$). Income, education, age, BMI and ethnicity were added as covariates to a second Quade non-parametric ANCOVA model with delay discounting rate as the dependent variable and income narrative group as the group factor. The overall model was also not statistically significant (F (2, 152) = 2.41, $p = .09$).

Subjective time perception across narrative groups. Figure 8 shows mean (top row) and median (bottom row) temporal distances for both future (left column) and past (right column) time points. When using an extra sum-of-squares F test to compare the k parameters of time perception across the three income narrative groups, there were no significant differences for future means (F (2, 15) = 0.13, $p = .88$), past means (F (2, 15) = 0.59, $p = .56$), future medians (F (2, 15) = 0.33, $p = .72$), or past medians (F (2, 15) = 0.66, $p = .53$), thus they are better fit by one curve than by separate ones. Further, there were no significant differences between future and past means (F (1, 10) = 0.22, $p = .65$) and future and past medians (F (1, 10) = 0.36, $p = .56$). Lower temporal distances (e.g., 15 on the visual analogue scale of 0-100) correspond to a perception that the given time point is relatively close to the present, whereas higher raw temporal distances (e.g., 85) correspond to a perception that the given time point is far removed from the present. Temporal distances were reverse scored to facilitate the plotting hyperbolic functions. With the reverse scoring, greater temporal distances correspond to perceptions that the given time point is relatively close to the present whereas lower temporal distances correspond to perceptions that the given time point is relatively far from the present. In other words, greater temporal distances correspond to what has previously been discussed as greater temporal attention (Zauberman et al., 2009). The reverse scoring of temporal distances also allows hyperbolic fits to be used derive *k* parameters in a similar direction as delay discounting, such that lower *k* values correspond to lower rates of discounting. Hyperbolic fits were used to fit the mean and median temporal distances as the hyperbolic function fit the data better than the hyperboloid model. For future time perception (Ln (k_{fut})), a one-way ANCOVA failed to demonstrate a significant effect of income narrative group (F (2, 154) = 1.03, p = .36). For past time perception (Ln (k_{past}), a non-parametric one-way Quade ANCOVA also failed to demonstrate a significant effect (F (2, 150) = 1.01, p = .37). Categorical demographic covariates were determined by using Mann-Whitney U tests were to compare past subjective time perception (Ln (k_{past})) across the potential covariates of education (no 4-year degree, 4-year degree), personal income (below, above U.S. median), ethnicity (non-minority, minority), and employment status (full-time work, not currently working). For past subjective time perception (Ln (k_{past})), there were significant effects of full/not-full timework status (U = 2283.5, p = .04), education (U = 2267.5, p = .04), and ethnicity (U = 1132, p = .01). Specifically, those working full-time, of minority status, and with lower levels of education viewed objective time points in the past as further removed (subjectively) than non-minorities. For future subjective time perception (Ln (k_{fut})), t-tests were used to evaluate the effects of potential covariates on future time perception. There were no significant differences in future subjective time perception (Ln (k_{fut})) as a function of education, income, or full-time work status (p > .28), however; there were significant differences based on ethnicity (t = -2.51, p = .02). Specifically, those with minority status viewed objective time points in the future as further removed (subjectively) than non-minorities. For the continuous variables of age and BMI, spearman's rank order correlations showed that past subjective time perception (Ln (k_{past})) was not related to BMI (r_s = -.01, p = .95), or age (r_s = -.15, p = .06). Future time perception (Ln (k_{fut})) did not significantly correlate with BMI (r_s = .05, p = .56), but showed a significant negative relation to age (r_s = -.21, p = .01). For future subjective time perception (Ln (k_{fut})), the negative relation to age was such that younger individuals perceived objective time points as being further from the present than their older counterparts.

Temporal focus across narrative groups.A one-way non-parametric Quade ANCOVA did not result in a significant main effect for past (F (2, 154) = 1.37, p = .26) or current temporal focus (F (2, 154) = 3.03, p = .051). A one-way ANCOVA F test for future temporal focus also failed to show a significant effect of income narrative (F (2, 156) = 0.12, p = .89). Categorical demographic covariates were determined by using Mann-Whitney U tests to compare mean past and current temporal focus (non-normally distributed) across education (no 4-year degree, 4-year degree), personal income (below, above U.S. median), and ethnicity (non-minority, minority). T-tests were used to compare mean future temporal focus (normally distributed) across the same dichotomous variables. When comparing across the two education groups, significant differences were observed for future (t = -2.04, p = .043), but not current (U = 2308.5, p = .06) or past focus (U= 2641.5, p = .49). There were no significant differences observed when comparing any temporal focus measures across income groups (p > .15) or ethnicity (p > .12). Spearman rank-order correlations were used to compare past, current, and future temporal focus to age and BMI. Age was significantly negatively correlated with future (r_s = -0.23, p = .004) and past (r_s = -.22, p = .005) temporal focus, but not current temporal focus (r_s = .14, p = .086). There were no significant correlations between BMI and the temporal focus scores ($p > .11$), however; BMI was still included due the significant differences in BMI observed across income narrative groups.

Subjective time perception and temporal focus. Collapsed across all participants, Table 4 shows correlation coefficients amongst past, current, and future temporal focus, future and past subjective time perception (Ln (k_{past})). Past and future temporal focus were significantly positively correlated ($r = .41$, $p < .001$) and past and future subjective time perception were significantly positively correlated ($r = .74$, $p < .001$). There were statistically significant correlations between temporal focus and subjective time perception measures.

Figure 9 shows future time perception (Ln (k_{fut})) on the x-axis and past time perception (Ln (k_{past})) on the y-axis. A spearman's rank order correlation resulted in a statistically significant positive correlation between the two measures ($r_s = .73$, $p < .0001$). A linear regression line is plotted as well to illustrate the correlation ($r_s = .62$, $p < .0001$).

Aggregate sunk cost. No significant differences were observed across income narratives groups for any measure of sunk cost. Due to the lack of significant differences, the effects of temporal gap conditions and terminal link amounts on sunk cost instances, sunk cost proportion, and meant terminal investment percentage were collapsed across income narrative groups. To evaluate the effects of temporal gaps and terminal link amounts on each of the sunk cost measures, two sets of analyses were performed. First, a series of two-way repeated measures ANOVAs were performed despite the non-parametric nature of the sunk cost measures. The two-way ANOVAs were performed to reduce the likelihood of type I error that could be observed by using separate one-way non-parametric ANOVAs to test for main effects of temporal gaps and terminal link amounts. Second, because two-way repeated measures ANOVA tests are not robust to deviations from normality, separate Friedman's tests were performed (i.e., one-way non-parametric ANOVA equivalent) to supplement the findings.

Figure 10 shows mean investment percentage of $5 (low) initial link investments subtracted from $35 (high) initial link investments (y-axis) at each terminal link investment amount (x-axis) in the now (open circles), one week (open squares), one month (open triangles), one year (open diamond), and five years (Xs) conditions, collapsed across income narrative groups. A two-way repeated measure ANOVA did not result in a significant effect of terminal investment amount (F (4, 624) = 2.26, p = .06), temporal gap (F (4, 624) = 2.27, p = .06), or the interaction of terminal investment amount and temporal gap (F (16, 2496) = 0.87, p = .61). A non-parametric Friedman's test of differences among repeated measures of terminal link amount rendered a X^2 of 17.5 (p = .002), however, the same test with temporal gap as the repeated measure rendered a X^2 of 8.41, which was not significant (p = .08).

Relatedly, Table 5 shows consolidated mean investment percentages of initial and terminal investment amounts (rows) across temporal gaps (columns). The majority of terminal investment percentages are greater when the initial investment amount is $5, however; several terminal investment amounts share a similar average across initial and terminal link investment amounts (e.g., $30 terminal investments across 30, 365, and 1825 days). Notably, for the $105 terminal investment amount in the 0 day condition, the sample averages completing the terminal investment 5% more often when the initial investment is $35 compared to $5.

Also collapsed across income narrative conditions, Figure 11 shows mean sunk cost instances (y-axis) across temporal gaps (x-axis) and terminal link amounts represented by white ($5), light grey ($30), medium grey ($50), dark grey ($75), and black ($105) vertical bars. A two-way repeated measure ANOVA resulted in a significant main effect of temporal gap (F (4,

624) = 32.62, $p < .0001$), terminal investment amount (F (4, 624) = 24.78, $p < .0001$), and a significant interaction between terminal link amount and temporal gap (F (16, 2496) = 5.45, $p < .0001$). Specifically, sunk cost instances tended to increase in frequency as a function of increasing terminal investment amount and tended to decrease in frequency as a function of increasing temporal gaps. The interaction between terminal investment amount and temporal gaps was such that greater effects of temporal gap were shown at higher terminal link values (i.e., only at \$50, \$75, and \$105). A non-parametric Friedman's test of differences among repeated measures of temporal gap rendered a X^2 value of 114.6, which was statistically significant ($p < .0001$). The same test performed with terminal link amount as the repeated measure rendered a X^2 of 198, which was also significant ($p < .0001$).

Collapsed across income conditions, Figure 12 shows mean sunk cost proportion (y-axis) as a function of temporal gaps (x-axis) and terminal link amounts represented by white (\$5), light grey (\$30), medium grey (\$50), dark grey (\$75), and black (\$105) vertical bars. A two-way repeated measure ANOVA resulted in a significant main effect of temporal condition (F (4,624) = 22.60, $p < .0001$), terminal investment amount (F (4, 624) = 343.5, $p < 0.0001$), and a significant interaction of temporal condition and terminal investment amount (F (16, 2496) = 6.16, $p < .0001$). Specifically, the main effect of temporal condition corresponded to greater sunk cost proportion as a function of increasing temporal gaps, and the main effect of terminal investment amount corresponded with greater sunk cost proportion as a function of increasing terminal link amount. A non-parametric Friedman's test of sunk cost proportion differences among repeated measures of temporal gap rendered a X^2 value of 554.3, which was statistically significant ($p < .0001$). The same test performed with terminal link as the repeated measure rendered a X^2 of 1716, which was also significant ($p < .0001$).

Correlation coefficients. Table 6 shows spearman's rank order correlation coefficients, collapsed across income narrative groups, between the individual participant's delay discounting (Ln (k_{disc})), sunk cost instances, sunk cost proportion, mean terminal link investment percentage, future subjective time perception (Ln (k_{fut})), and past subjective time perception (Ln (k_{past})), future temporal focus, current temporal focus, and past temporal focus. Delay discounting was positively correlated with future subjective time perception (r_s = .25, p = .001) and past subjective time perception (r_s = .21, p= 0.01) such that lower rates of discounting corresponded to perceptions that distant events were relatively more proximal to the present. Future and past subjective time perception were also positively correlated (r_s = .74, p < .001). Frequency of sunk cost instances for each participant was positively correlated with sunk cost proportion (r_s = 0.98, p < .001) and negatively correlated with mean investment percentage (r_s = -.19, p = .02). Mean investment percentage was negatively correlated with sunk cost proportion (r_s = -.24, p= .003). Delay discounting was not significantly related to sunk cost instances (r_s = -.06, p= .45), sunk cost proportion (r_s = -.07, p= .40), or mean investment percentage (r_s = -.14, p= .07). There were no significant correlations between any measure of temporal focus and any measures of sunk cost or delay discounting (p > .32).

Due to the significant correlations between future (Ln (k_{fut})) and past (Ln (k_{past})) subjective time perception and future and past temporal focus, the same correlations were evaluated within each income narrative group. Within the negative income narrative group, future and past time perception were significantly correlated (r_s = .68, p < .0001) and future and past temporal focus were significantly correlated (r_s = .44, p= 0.001). For the neutral income narrative group, future and past time perception were significantly correlated (r_s = .81, p < .0001) and future and past temporal focus were significantly correlated (r_s = .44, p= 0.0001). For the positive income narrative group, future and past time perception were significantly correlated (r_s = .71, p < .0001) and future and past temporal focus were significantly correlated (r_s = .28, p = .03).

Supplemental Analyses.

Overall sunk cost. To provide a different level of analysis of the sunk cost effect, the natural log of the mean investment percentage for $35 initial investments was divided by mean investment percentage for $5 initial investments for each participant. In addition, this same calculation was performed at each temporal gap (i.e., now, 1 day, 1 week, 1 month, 1 year, and 5 years). Moving forward, this measure will be referred to as *Ln (overall sunk cost).*

Joint time perception. Three additional temporal measures were created. First, due to the significant correlations between past and future time perception and both time perception measures and delay discounting (Ln (k_{disc})), the areas under successive trapezoids formed by consecutive time perception data points were calculated using the summed trapezoid method for both the future and past time perception measures (Myerson, Green, & Warusawitharana, 2001). Temporal distances were located on the y-axis and time points on the x-axis (days). Then, these two area under the curve (AUC) values (r_s = .77, p < .0001) were added to form one measure of *joint time perception* (AUC). In other words, higher relative values of joint time perception (AUC) corresponded with a perception that distant events (future and past) were subjectively closer to the present.

Time perception and temporal focus indices. Second, future time perception (Ln (k_{past}) was divided by past time perception to create a proportion measure comparing the two temporal directions (i.e., *time perception index*). An identical measure was created with temporal focus by dividing mean past temporal focus by mean future temporal focus (i.e., *temporal focus index*).

For both the temporal index measures, positive scores indicated that, with the present time as the referent, the participant perceived future events as subjectively closer to the present than past events of equivalent objective temporal distance. Negative scores indicated that the participant perceived past events as subjectively closer to the present than future events of the same objective temporal distance. The degree to which either score deviated from one can be conceptualized as the strength of the perceptual bias.

Temporal attention and delay discounting. Correlation coefficients amongst delay discounting (Ln (k_{disc})), Ln (overall sunk cost), future time perception (Ln (k_{fut})), past time perception (Ln (k_{past}), joint time perception, and time perception index can be seen in Table 7. Notably, delay discounting rate was negatively related to Ln (overall sunk cost; r_s = -.18, p = .02), such that a greater propensity to exhibit the overall sunk cost corresponded with lower rates of delay discounting. Ln (overall sunk cost) failed to demonstrate significant correlations with delay discounting within the negative (r_s = -.23, p = .10), neutral (r_s = .01, p = .96), or positive groups (r_s = -.22, p = .10). Similar to the correlations observed between delay discounting and both Ln (k_{fut}) and Ln (k_{past}), delay discounting was positively correlated with both future (r_s = -.25, p = .001) and past (r_s = -.21, p = .01) subjective time perception (AUCs), such that the closer participants perceived distant events relative to others, the lower their respective rates of discounting. The positive correlation (r_s = .29, p = .001) between joint time perception and time perception index can be observed in Figure 13. The positive correlation between joint time perception and time perception index was such that the closer participants perceived the future relative to the past (i.e., high time perception index), the closer to the present participant's perceived of future and past objective temporal distances. Finally, delay discounting (Ln (k_{disc})) was positively correlated with joint time perception (r_s = -.24, p = .003), but not the time perception index (r_s = -.10, p = .21). By contrast, Ln (overall sunk cost) was negatively related to time perception index (r_s = -.20, p = .01), such that a greater propensity to exhibit the sunk cost corresponded with a perception that past events were closer to the present than future events of equivalent temporal distance. Ln (overall sunk cost) was not, however, significantly related to joint time perception (r_s = -.03, p = .75).

Table 8 shows spearman's rank order correlation coefficients amongst sunk cost instances, sunk cost proportion, mean terminal investment percentage, joint time perception, and time perception index. Lower terminal investment percentages corresponded with a greater propensity to commit the sunk cost effect (r_s= -.19, p = .02). None of the sunk cost related measures were related to joint time perception ($p > .43$). Time perception index was significantly related to sunk cost instances (r_s = -.20, p = .01) and sunk cost proportion (r_s = -.18, p = .02), however; time perception index was not significantly related to mean terminal investment percentage (r_s = .06, p = .46).

A non-parametric Quade ANCOVA was used to evaluate the effect of income narrative groups on Ln (overall sunk cost) with BMI and education as the covariates. The test was not significant (F (2, 154) = 2.18, p = .12). BMI was added due to the significant differences in BMI across income narrative groups reported earlier. The only significant difference in Ln (overall sunk cost) across demographic groups was education (p = .03). There were no significant correlations between Ln (overall sunk cost) and BMI or age ($p > .32$). Due to the correlation between time perception index (TP) and Ln (overall sunk cost), the previous non-parametric Quade ANCOVA was replicated with the additional covariate of time perception index. The effect remained non-significant (F (2, 154) = 2.37, p = .10).

A series of non-parametric Quade ANCOVAs with BMI as a covariate and income narrative as the grouping variable failed to demonstrate effects on joint time perception (F (2, 154) = 0.98, p = .38), time perception index (F (2, 154) = 0.03, p = .97), and temporal focus index (F (2, 154) = 0.42, p = .66).

Three final supplemental measures were created with the goal of adjusting the overall sunk cost measure by the number of trials each participant completed for both escalation-based trials and non-escalation-based trials. Specifically, *sunk cost propensity* was created by simply dividing overall sunk cost (without Ln) by the total number of trials experienced by the participant.

$$Sunk\ Cost\ Propensity = \frac{Overall\ Sunk\ Cost}{Trials} \tag{3}$$

For *sunk cost propensity (Esc)* the overall sunk cost measure (i.e., mean terminal investment percentage for $35 initial links divided by those with $5 initial links) was replicated, except that only terminal link amounts above the trial mean were used (i.e., $75, $105), and the natural log was not used because the measure was already normally distributed (D =.07, p =. 07)). Then, the resultant proportion was divided by the number of escalation trials experienced (i.e., $75 and $105 trials. The same process was used for *sunk cost propensity (nonEsc)*, except that non-escalation trial amounts (i.e., $5, $30, and $50) were used instead of escalation amounts. Importantly, the sunk cost propensity measure was normally distributed and the remaining sunk cost propensity measures were non-normally distributed.

Spearman's rank order correlation coefficients are shown in Table 9 amongst delay discounting (Ln (k_{disc})), sunk cost propensity, sunk cost propensity (NonEsc), sunk cost propensity (Esc), joint time perception, and time perception index. Notably, delay discounting was negatively correlated with sunk cost propensity (r_s = -.22, p = .005) and sunk cost propensity [(NonEsc) (r_s = -.20, p = .01)], but not sunk cost propensity [(Esc) (r_s = -.15, p = .07)]. In conjunction, this suggests that negative correlation between sunk cost propensity and delay discounting is more a function of the sunk cost effect occurring at lower terminal link amounts (i.e., $5, $30, and $50). Further, none of the sunk cost propensity measures were correlated with joint time perception or time perception index (p > .31).

For each income narrative group, Spearman's rank order correlation coefficients were performed between delay discounting (Ln (k_{disc})) and sunk cost propensity, sunk cost propensity (Esc), sunk cost propensity (NonEsc). For the negative income narrative group, delay discounting was significantly correlated with sunk cost propensity (r_s = -.35, p = .01), sunk cost propensity (Esc) (r_s = -.34, p = .02), and sunk cost propensity (NonEsc) (r_s = -0.31, p = .03). For the neutral income narrative group, none of the measures were significant (r_s > .08, p > .57). For the positive income narrative group, none of the measures were significant (r_s > -.20, p > .13). Within the negative income narrative group, the Pearson's correlation coefficients between delay discounting and sunk cost propensity were not significant in the low income group (r = -.04, p = .86), but were significantly related in the high income group (r = -.52, p = .01).

Finally, three non-parametric Quade ANCOVAs were run with income narrative as the grouping variable, BMI as a covariate, and each measure's respective mood score as an additional covariate. The dependent measures for the series of ANCOVAs were delay discounting, Ln (overall sunk cost), and joint time perception, respectively. There were no main effects observed for delay discounting (F (2, 150) = 0.21, p = .81), Ln (overall sunk cost) (F (2, 152) = 0.53, p = .59), joint time perception (F (2, 152) = 0.08, p = .92), or past (F (2, 151) = 0.69, p = .51), present (F (2, 151) = 0.85, p = .43), or future temporal focus (F (2, 151) = 0.21, p = .81).

General Discussion

There were three primary questions related to the current study. First, would valenced income narrative prompts concurrently alter sunk cost, delay discounting, and subjective time perception? In other words, would positive income narratives lower discounting and increase sunk cost, and negative narratives increase discounting and decrease sunk cost? These effects were anticipated due to findings reported by Sofis et al. (under revision), Sze et al. (2017), and Bickel et al. (2016b). The sunk cost effect and delay discounting were hypothesized to be a product of temporal attention. Subjective time perception was hypothesized to be the temporal process by which temporal attention altered choices in both the sunk cost and delay discounting tasks. The income narratives and their respective valences were hypothesized to affect future and past subjective time perception similarly, and thus, concurrently alter delay discounting and the sunk cost effect. The data from the current study failed to demonstrate any effect of the income narrative condition on subjective time perception, temporal focus, joint time perception, or time perception index. Aggregated within subject measures of sunk cost (e.g., AUC) and delay discounting (Ln (*k*)) failed to demonstrate significant differences across income narrative groups. Hyperboloid models of aggregated sunk cost data and indifference data across time points for each of the income narrative groups revealed that separate curves were better fit to the data than single curves for both sunk cost instances and delay discounting. Given that these findings were not replicated at the within-subject level, they should be interpreted with caution., if at all.

The second question of the current study was whether the sunk cost would decrease as a function of temporal gaps in a manner similar to the data observed in the pilot study by Sofis and colleagues (under revision)? If the sunk cost effect is indeed a manifestation of temporal attention, then the general trend of decreasing sunk cost as a function of temporal gaps should be observed. Within-subject trends of the sunk cost across temporal gaps did not show a clear decrease trend as a function of temporal gap, although a hyperboloid-shaped trend emerged when evaluating the aggregated data across temporal gaps for each of the income narrative groups.

The third question of the current study was whether delay discounting would directly correlate with the sunk cost effect. Further, would a specific type of sunk cost be correlated with delay discounting? With the addition of an extra terminal link amount below the trial mean (i.e., $50), for example, the current study provided an opportunity to investigate potential differences between sunk costs at lower terminal amounts and those at higher terminal amounts. Delay discounting showed a negative correlation with sunk cost propensity, however, only sunk cost propensity (Nonesc; $5, $30, and $50) showed a significant relation. The direction of this relation was such that lower rates of delay discounting corresponded with a greater propensity to commit the sunk cost effect. Despite mirroring the direction reflected in the pilot study by Sofis et al. (under revision), attempts to replicate the finding for each group were only successful in the negative income narrative group. The size of the negative correlation between delay discounting and sunk cost propensity in the negative income narrative group was moderate, and both escalation and non-escalation based sunk cost propensities were significantly related to delay discounting. Given the selective nature of this relation, the finding should also be interpreted with caution.

Based on these primary questions, the proposed experiment investigated effects of valenced income narratives (independent groups of positive, negative, or neutral narrative) on subjective time perception (future and past), temporal focus, delay discounting, and the sunk cost effect. Further discussion of the findings as they pertain to the primary questions and supplemental ones are discussed below.

Concurrent Effects of Income Narratives on Discounting, Sunk Cost, and Time Perception

Generally, the income narratives used in the current experiment did not affect subjective time perception, temporal focus, delay discounting, or the sunk cost effect. The primary hypothesis was that the positive income narrative would make participants perceive distant events as seem closer to the present, which would correspond with lower rates of discounting and higher levels of the sunk cost. The exact opposite effects were expected to be observed for those in the negative income narrative group. A series of non-parametric Quade ANCOVAs showed that there were no significant effects of income narrative group on any of the decision-making or temporal measures used in the current study. This finding also held when accounting for covariates and mood scores taken prior to each respective measure.

The income narrative manipulations did not affect any of the time perception or temporal focus measures used in the current study. The income narratives also did not consistently impact delay discounting or sunk cost. Although multiple researchers have argued that increased discounting rates following negative income shocks may be a product of a shift in temporal attention towards the present (Haushofer et al., 2013; Sze et al., 2017), the current data do not necessarily support this assertion. Such a shift in temporal attention is proposed to result in greater discounting of future events, thereby producing increased rates of discounting (Sze et al., 2017). Some have argued that such a shift in temporal attention is a function of worsening mood (Haushofer & Fehr, 2014; Kim & Zauberman, 2013), however, robust differences in mood were observed across the income narrative groups prior to subjective time perception, temporal focus measures, delay discounting, and the sunk cost. Further, when accounting for mood in a series of ANCOVA models, there was not a significant effect of income narrative group on joint time perception, all temporal focus measures, delay discounting, and all sunk cost measures.

Therefore, it appears that there was a strong effect of income narratives on mood, but that effect did not necessarily translate to time perception, temporal focus, or the other primary measures of interest.

Temporal focus and subjective time perception measures appeared to demonstrate symmetrical patterns across future and past measures. Indeed, past and future temporal focus measures were positive correlated and demonstrated a medium correlation (r_s = .41, p < .0001). Past (Ln (k_{past})) and future (Ln (k_{fut})) time perception were also positively correlated, but showed a stronger correlation (r_s = .74, p < .0001). The shapes of future and past time perception curves shown in Figure 8 were also well fit by hyperbolic models. Individual Ln (k) values were calculated for future and past time perception curves, suggesting that the particularly strong correlation further supports a symmetry pattern between future and past time perception. Further, the symmetrical correlations were replicated across each income narrative group, despite the reduced power available for those tests. Together, these findings support the notion that future and past time perception and future and past temporal focus are both likely to be symmetrical in nature. Such a findings falls in line well with previous interpretations of temporal attention as a symmetrical effect of perceived temporal distance from the present for both future and past events (Kim & Zauberman, 2013; Radu et al., 2011; Yi et al., 2006).

It also appears equally unlikely that the income narratives failed to alter time perception because of a lack of correlations between time perception measures, delay discounting, and the sunk cost. Specifically, the time perception index correlated with the sunk cost, and joint time perception with delay discounting. As would be expected, a greater relative focus on the past (i.e. lower time perception index) was related to greater levels of the sunk cost, and greater joint time perception (i.e. viewing distant past and future events as subjective closer to the present) was the related to lower rates of delay discounting. Adding joint time perception and time perception index to the ANCOVA models of delay discounting and sunk cost, however, did not result in a significant effect of income narrative group.

Participants tended to perceive past events as subjectively closer to the present than future events, but reported focusing on future events more than past events. As previously reported, however, temporal focus was positively correlated with time perception index, suggesting some overlap between the two measures. In addition, younger individuals showed worse joint time perception and lower past and future temporal focus scores than older adults. In other words, younger individuals perceived distant events as subjectively further from the present and reported focusing less on future and past events than their older counterparts. College-age students (i.e., 18-23) also tend to view the past as progressing more slowly compared to older adults (Friedman & Janssen, 2010; Wittmann & Lehnhoff, 2005). The current data from the temporal measures therefore seem to fall in line with previous reports suggesting that older adults view the past as progressing increasingly quickly (Friedman & Janssen, 2010; Wittmann & Lehnhoff, 2005). Additional research is needed to confirm the contrasting biases of subjective time perception and temporal focus observed in the present study, however; the combination of the contrasting biases and similar age-related trends observed here support the assertion that subjective time perception and temporal focus are likely unique but related constructs.

Data from the current study do not pinpoint why the income narratives did not alter any measure of subjective time perception or temporal focus. Future research might explore two possibilities. First, the mechanism by which income narratives affect discounting may be more complicated than simply a shift in temporal attention. In other words, temporal attention may only shift as a result of more robust physiological factors such as arousal (Kim & Zauberman, 2013), that may not have been sufficiently affected by the income narratives used in the present experiment. Significant differences in mood across income narrative groups did not translate to effects on delay discounting, the sunk cost, or any temporal measures, suggesting that mood may only be indirectly related to temporal attention, delay discounting, and the sunk cost effect. Future research might replicate the current experiment, but add a within-subject component wherein participants experience a neutral narrative and a positive or negative narrative (counterbalanced across participants). In addition, inducing fear or sexual arousal (see Kim & Zauberman, 2013) may induce greater physiological changes that alter temporal attention. Second, the components of which temporal attention is a function may be more complicated than previously asserted. Perhaps the "attending" and the "temporal" parts of temporal attention, for example, are related but independent constructs that must both be affected to successfully account for shifts in temporal attention. To this end, researchers might benefit from adding subjective time perception (future and past) and temporal sunk cost paradigms to studies using a delay discounting task. Further, specific components of independent variables manipulations such as time-estimation priming (Radu et al., 2011) and episodic future thinking (Daniel, Sawyer, Dong, Bickel, & Epstein, 2016) could be used to better isolate the particular conditions under which delay discounting, subjective time perception, and the sunk cost are affected. One approach would be to isolate the effects of episodic and temporal aspects of episodic thinking on subjective time perception, delay discounting, and the sunk cost effect. Does future episodic thinking (bias for temporally distant events), for example, result in lower rates of discounting and better subjective time perception than a "future thinking" control condition that only emphasizes temporal aspects? Similarly, would recent episodic thinking (present bias; low temporal attention) result in higher rates of discounting compared to a recent thinking condition that only prompts temporal characteristics? With the addition of future and past subjective time perception measures used in the present study, such investigations could provide valuable information on whether the temporal and attentional components of temporal attention can be isolated, and in turn how they might contribute to the sunk cost effect and delay discounting.

The Sunk Cost Effect

There was a decreasing propensity to exhibit any sunk cost measure as a function of the size of the temporal gap, which appears to mirror the general trend observed from the pilot study performed by Sofis and colleagues (under revision). There was significant support for separate hyperboloid curves for mean sunk cost instances across temporal gaps. This observed effect is consistent with the initial hypothesis that those in the positive income group would show lower rates of discounting and a greater propensity to exhibit the sunk cost effect. Importantly, however, the support for separate hyperboloid curves of mean sunk cost instances for the narrative groups should be interpreted cautiously. The sum-of-squares F test merely assesses differences between the fits of the hyperboloid curves by isolating the *k* parameter in the model (Rachlin, 2006). Although the curve of the mean sunk cost data for those in the positive group showed a unique *k* value compared to those in the negative group, the significant effect derived from the sum-of-squares F test may have been an artifact of minor differences in the quality of the model fits, not due to actual differences in sunk cost. Second, all non-parametric ANCOVA models with sunk cost related variables as the dependent measure were non-significant. It is not possible to isolate why the income narratives did not more robustly alter the sunk cost effect because of the null effect of income narrative group on subjective time perception and temporal focus. One barrier that also may have contributed to the null-effect was the incongruence between the shapes of sunk cost functions across temporal gaps for individual subject data. Specifically, although the shape of the aggregate sunk cost and delay discounting functions were hyperboloid; individual participants only demonstrated this function with the discounting data. Although 81% of subjects committed at least one instance of the sunk cost effect many participants did not specifically show a hyperboloid-like shape of declining sunk cost instances as a function of temporal gap. Specifically, many participants demonstrated flat or inconsistent sunk cost effects across temporal gaps. Similar to the results reported in the pilot study by Sofis and colleagues (under revision), individual participant patterns of sunk cost instances generally showed a declining, if not hyperbolic or hyperboloid, decline. These findings further suggest the significant differences observed in the aggregated data across income narrative groups should be interpreted with caution.

Interestingly, when collapsing across the sample, there was an interaction effect between terminal amount and temporal gap of sunk cost instances. In other words, the only significant post hoc tests were found to be at higher terminal amounts (i.e., $50, $75, and $105) and when comparing temporal gaps of greater distances (e.g., 0 vs. 365 days). In addition to the main effects of both terminal sunk cost amount and temporal gap, this finding suggests that both terminal investment amounts and temporal gaps likely contribute to the occurrence of the cost effect. The overall sunk cost and sunk cost propensity measures more explicitly compare terminal investment behavior when the initial link is $35, compared to when it is $5. The selective correlations between these measures and delay discounting, in conjunction with the main effects of temporal gap and terminal sunk cost amount, suggest that the sunk cost likely entails at least three relevant components. Specifically, the initial link, terminal link, and temporal gap are all aspects of the sunk cost that must be either controlled or manipulated in experimental settings. The fact that delay discounting only correlated with the sunk cost measures that weight initial link responding more heavily suggests that future research might benefit from targeting the experimental parameters of the initial link to better understand how discounting and the sunk cost relate.

Sunk Cost and Temporal Measures

Time perception index was negatively correlated with Ln (overall sunk cost) such that a greater emphasis on the past relative to the future corresponded with a greater propensity to commit the sunk cost. Time perception index was also negatively correlated with both sunk cost instances and sunk cost proportion, which further supports an underlying relation. Unlike delay discounting, none of the sunk cost measures or investment measures showed any relation to joint time perception. These findings suggest the possibility that the sunk cost and delay discounting may be undergirded by unique but related temporal constructs. Similarly, retrospection and prospection may be a product of unique but related processes (Daniel et al., 2016). Daniel et al. (2016), for example, investigated future and past delay discounting (within subject) across prospective thinking, retrospective thinking, and control groups (between subject). The authors found that the prospective group showed the lowest rates of discounting of future events and the retrospective group showed the lowest rates of discounting of past events compared to controls. Notably, those in the prospective thinking group showed lower rates of past discounting compared to controls and those in the retrospective thinking group showed lower rates of future discounting compared to controls. The authors argued that although past experiences may be used to simulate or prospect towards future events, the effects of retrospection and prospection might not act interchangeably to affect rates of delay discounting. Further, perhaps unique temporal constructs (e.g., joint time perception/time perception index, subjective time perception/temporal focus) may function in a similar fashion. Future research might benefit from replicating the Daniel et al. (2016) study with the temporal measures used in the present study to determine whether unique temporal constructs underlie particular discounting and sunk cost effects mediated by prospective and retrospective thinking. Ideally, future research would also compare the effects of a temporal and non-temporal manipulation on temporal measures, sunk cost, and delay discounting to better isolate the potential role of such temporal measures underlying delay discounting and the sunk cost.

Sunk cost and delay discounting. When collapsing across the sample, delay discounting was negatively related to Ln (overall sunk cost), sunk cost propensity, and sunk cost propensity (NonEsc). No such relations were observed between delay discounting and sunk cost instances, sunk cost proportion, or mean terminal investment percentage. Much of the weight behind the correlations between delay discounting and sunk cost propensities, however, was likely carried by the strength of the correlation observed in the negative income narrative group. Further, those in the high-income group who experienced the negative income narrative demonstrated a robust correlation between sunk cost propensity and delay discounting, while those with lower incomes did demonstrate the effect. These findings suggest that only those with higher personal incomes showed the relation of more sunk cost corresponding with lower rates of delay discounting. These selective effects should be taken with caution, however, because there was low statistical power available after splitting the groups on income narrative group and personal income. Roughly double the number of participants used in the current experiment may be needed to have sufficient power to evaluate combined effects of income narratives and personal income groups. The current study did not find main effects of income narrative group on delay discounting or sunk cost measures. The selective correlations of high-income individuals in the negative income narrative group, however, suggest that it may be prudent to replicate the current experimental arrangement with larger sample sizes to evaluate a potential interaction effect between personal income and income narratives.

Ln (overall sunk cost) and sunk cost propensity were both a product of dividing the averaging terminal investment percentages for $35 initial investments by that of terminal investment percentages of $5 initial investments. Interestingly, only sunk cost propensity (nonEsc), (not sunk cost propensity (Esc)), was significantly correlated with delay discounting. In other words, a higher overall propensity to commit the sunk cost with lower terminal investment amounts corresponded with lower rates of delay discounting. The correlations between delay discounting and the sunk cost propensity measures, however, were only significant in the negative income narrative group. Further, all of the sunk cost propensity measures showed a moderate effect size correlation ($r_s > -.31$, $p < .03$). The significant direct correlation between delay discounting and sunk cost propensity in the negative income group is a particularly interesting finding when considering that the two phenomena did not share any overlapping correlations with temporal focus or subjective time perception measures. Specifically, delay discounting directly correlated with future and past subjective time perception and joint time perception, and the sunk cost correlated with time perception index, a relative measure that divides past by future time perception. Taken together, these data suggest that temporal attention may be one of multiple underlying factors shared by the sunk cost and delay discounting.

Summary, limitations, and future directions. In conclusion, the current experiment suggests that temporal focus and subjective time perception measures did not directly relate, however; temporal focus and subjective time perception measures showed symmetrical effects such that greater future temporal focus related to greater past focus and perceiving distant future events as subjectively closer to the present related to perceiving distant past events as closer to the present. Regardless of income narrative group, participants tended to perceive the past as closer to the present than the future and the self-reported focusing on the future more than the past. The income narrative manipulation in the current experiment resulted in inconsistent effects with delay discounting and the sunk cost, and no effects with past or future subjective time perception, and any dimension of temporal focus. Notably, those participants in the positive narrative group demonstrated lower rates of discounting and higher levels of sunk cost than those in the negative narrative group when using aggregate measures of sunk cost and delay discounting. Ln (overall sunk cost) and delay discounting demonstrated a modest negative correlation, however; none of the temporal measures used were found to underlie Ln (overall sunk cost) and delay discounting. The measures of time perception index and joint time perception only related to the sunk cost and delay discounting, respectively. A disproportionate amount of variance for delay discounting is uniquely accounted for by joint time perception above and beyond that of the income narrative manipulation. There are three further points of note.

First, the current experiment failed to demonstrate that the current income narrative manipulation affected temporal attention, delay discounting, and the sunk cost effect. These findings stand somewhat at odds with the argument that income narratives affect discounting by constricting the temporal window (Bickel et al., 2016b). These findings also contrast with arguments that negative income shocks lead to short-sighted attentional focus due to negative affect (Haushofer & Fehr, 2014). Indeed, robust differences in mood corresponding to the valence of the income narratives groups were observed for temporal focus, time perception, delay discounting, and the sunk cost. Further, mood prior to the delay discounting task was negatively correlated with delay discounting rate in the current study, which appears to replicate findings linking negative affect to higher rates of discounting (see Haushofer & Fehr, 2014 for a review). In conjunction, these findings suggests that in certain contexts, negative affect may increase delay discounting without affecting subjective time perception. This finding falls in line with those reported by Shah, Mullainathan, and Shafir (2012), who found that scarcity conditions increased attentional engagement for low-income (experimentally-speaking) participants. Importantly, however, existing evidence only has demonstrated a general effect of scarcity on attentional engagement (Kim & Zauberman, 2013; Shah et al., 2012) not necessarily an effect on temporal attention. Future research might benefit by first targeting the process (es) that might underlie temporal attention. Comparing the effects of scarcity conditions both with and without temporal factors, for example, may be useful in better understanding the interplay of measures such as subjective time perception, joint time perception, and time perception index.

Second, temporal attention may be considerably more complicated than previously thought, such that multiple temporal processes may undergird temporal attention. Data from the current experiment, for example, suggest that joint time perception is a separate but related construct to time perception index. Further, the degree to which individual participants focused on the past relative to the future was positively related to the degree to which they perceived the past as closer to the present than the future. Within the context of subjective time perception, joint time perception and time perception index were uniquely related to delay discounting and Ln (overall sunk cost), respectively. In conjunction, these findings suggest that both joint time perception and time perception index may represent unique temporal constructs. A similar stance was taken by Bickel et al. (2016b), who differentiated the narrowing of attention and constriction of the temporal window. Unlike the Bickel et al. (2016b) report, however, the current data do not show that income narratives constricted the temporal window.

To better pinpoint whether temporal attention underlies valuation measured in discounting and sunk cost paradigms, the effects of temporal and non-temporal manipulations on temporal measures such as joint time perception and time perception index could be evaluated as potential mediators or moderators of delay discounting and the sunk cost effect. Future research might use some of the manipulations discussed in Bickel, Stein, et al. (2017a) to differentially target future and past-specific effects. Alternatively, it may be important to first understand how measures such as subjective time perception, joint time perception, and time perception index respond to common temporal manipulations separate from measurement of delay discounting. Manipulations such as the date/delay effect (Read et al., 2005), hidden zero affect (Magen et al., 2008b; Naude, Kaplan, Reed, Henley, & DiGennaro-Reed, 2018), and temporal priming (Radu et al., 2011; Zauberman et al., 2009), for example, may help uncover how joint time perception and time perception index covary and potentially interact to affect the sunk cost affect and delay discounting.

Third, there were several limitations of the current study. First, hypothetical rewards were used in the current study; however, there is a close correspondence between hypothetical and real rewards (Baker, Johnson, & Bickel, 2003; Fantino & Stolarz-Fantino, 2013; Johnson & Bickel, 2002; Madden et al., 2003; Madden et al., 2004), even at the neural level (Bickel et al., 2009a). Further, although there is not yet evidence showing correspondence between real and hypothetical rewards within a sunk cost task, the current experiment explicitly told participants that their performance on the sunk cost task was linked to a bonus that, when earned, effectively doubled their experimental earnings.

Second, hypothetical temporal gaps were used in the current study; however, participants had to select the correct temporal gap in which they would make sunk cost decisions prior to starting each round of the sunk cost task. Further, sunk cost instances, sunk cost proportion, and terminal investments systematically declined as a function of temporal gap in a similar fashion to circumstances wherein initial costs and temporal gaps were actually experienced by participants (Arkes & Blumer, 1985; Gorville & Soman, 1998).

Third, the independent variable used in the current study (valenced income narratives) was hypothetical in nature. Despite this, delay discounting has been shown to be sensitive to hypothetical income narrative manipulations (Bickel et al., 2016b; Sze et al., 2017). Further, the income narratives demonstrated a clear effect on affect (i.e., mood scores prior to each task) performed in the current study, which has been suggested as a primary route by which income narratives may function (see Haushofer & Fehr, 2014 for a review).

Fourth, although there was sufficient power to evaluate differences in the primary dependent measures across the income narrative groups, there was not sufficient power to evaluate both income narrative groups and income (low/high). Such an analysis would be prudent for future research because of previous findings linking poverty to higher rates of delay discounting (Haushofer & Fehr, 2014; Haushofer et al., 2013; Shah et al., 2012; Tanaka, Camerer, & Nguyen, 2010). Lastly, due to insufficient power, the current experiment did not add a temporal manipulation already known to affect delay discounting (e.g., episodic future thinking; Sze et al. (2017)) to compare the effects of the temporal and non-temporal manipulations on the primary dependent measures. Such an addition may have been fruitful, but would require a considerably larger number of participants to achieve the necessary statistical power.

Finally, all participants experienced the subjective time perception procedure immediately after the income narrative generation and prior to the delay discounting and sunk cost measures. Because the subjective time perception procedure is similar to a time-estimation task used by Radu et al. (2011) to reduce rates of delay discounting, the administration of the subjective time perception task prior to delay discounting and sunk cost tasks may have influenced the lack of observed effects on the dependent measures. Based on arguments made by Bickel et al. (2016b) and Haushofer et al. (2013), however, any experimental effects from the subjective time perception task were hypothesized to interact with the income narratives by affecting the temporal window in which delay discounting and sunk cost choices were made. Further, there is no evidence to my knowledge suggesting that valenced income narratives and temporal priming affects would result in competing effects. Therefore, prior to the current study, any potential effect of completing the subjective time perception task was hypothesized to only strengthen the effect of income narratives on the primary dependent measures. Nevertheless, the lack of significant effects of income narratives on any of the primary dependent measures could have been due to interference from the subjective time perception task. Alternatively, the lack of effects could have been a result of changes to the income narrative conditions from those reported in Bickel et al. (2016b). Specifically, the lack of effects observed in the current study could have been due to omitting income narrative features pertaining to job loss and moving due to changes at one’s job, and equating the amount of pay change between negative and positive income narrative groups. Ideally, future research would evaluate the effects of temporal and non-temporal manipulations previously shown to independently affect rates of delay discounting and investigate how those manipulations alter subjective time perception measures, delay discounting, and the sunk cost effect.

Fourth, due to unique correlations observed between joint time perception and time perception index with delay discounting and Ln (overall sunk) respectively, the negative correlation observed between Ln (overall sunk cost) and delay discounting may have been a product of non-temporal factors. Such a statement is difficult to confirm from the current data, however, because there was not an effect of income narrative group on any of the temporal measures (e.g., subjective time perception). A clearer understanding of the relation between the sunk cost and delay discounting may occur if both temporal and non-temporal manipulations are implemented in conjunction with the temporal measures used in the current study. Although research on potential overlap between delay discounting and the sunk cost effect is nascent, there is considerable potential for conceptual and translational value. Specifically, both delay discounting and the sunk cost effect are phenomena wherein reward processes (mPFC) and time-based processes (dlPFC) undergird a tradeoff context representative of competing neural systems (Haller & Schwabe, 2014; McClure & Bickel, 2014; McClure et al., 2004). Differentially stimulating the left dlPFC using techniques such as repetitive transcranial magnetic stimulation (rTMS) in a clinical context, for example, has been shown to decrease delay discounting and increase abstinence (nicotine) compared to a sham condition (Sheffer et al., 2018). Such an approach may also help determine the overlap between the sunk cost and delay discounting. Further, as proposed by Rachlin (2000), engaging in the sunk cost may be an important component underlying persistence directed towards larger later reinforcers. In the pilot study by Sofis and colleagues (under revision), those in the higher subjective time perception group showed greater levels of sunk cost and decreased discounting rates compared to those in the low subjective time perception group. In other words, perceiving distant events as subjectively closer to the present corresponded with a greater the propensity to commit the sunk cost and lower rates of discounting. The direction of the relation between sunk cost and delay discounting as a function of high and low subjective time perception groups observed in the pilot study, in conjunction with the direct correlation observed between Ln (overall sunk cost) and delay discounting in the current study, suggests that further investigation into the overlap between these two phenomena is warranted. Although the findings from the two studies cannot pinpoint exactly how delay discounting and sunk cost relate, these data suggest that delay discounting and the sunk cost effect could share both temporal and non-temporal processes. In such a case, a better understanding of the shared processes underlying these phenomena may prove fruitful in future translational efforts.

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Table 1.

Key Temporal Constructs Related to Temporal Attention.

	Definition	**Time-Scale**	**Example**
Time Perspective	Assumed link between positive/negative attitudes and relative consideration of past, present, and future (Zimbardo & Boyd, 1999)	Long	"I take each day as it is rather than try to plan it out." (Zimbardo & Boyd, 1999)
Time Perception *(Subjective)*	Subjective perception of durations between now and another point in time compared to objective time (Zauberman et al., 2009)	Typically Long	Participants are asked to imagine a day x time from now, and indicate how long the given duration is on a 181 mm line with "very short" on the left end and "very long" on the right end (Zauberman et al., 2009)
Time Perception *(Time Estimation)*	Accuracy in measuring objective clock time (Wittmann, Rudolph, Gutierrez Linares, & Winkler, 2015)	Typically Short	A participant might be asked to verbally report when x minutes have passed or report after the fact how clock time much time has passed (Wittmann, Leland, & Paulus, 2007; Zakay & Block, 1997)

Table 2.

Continuous Demographic Measures

Variable	Overall		Negative		Neutral		Positive		*p value*
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	
Age	39.9	12.0	40.2	11.6	40.3	12.1	39.3	12.5	0.83
BMI	27.8	6.6	26.4	6.9	28.1	5.5	28.9	7.0	**0.04**
Completion Time (min)	34.6	11.1	36.2	12.2	33.9	10.7	33.7	10.4	0.56

Note: Significant effects of Kruskal-Wallis H tests are (i.e., $p < .05$) bolded in far-right column

Table 3.

Non-Continuous Demographic Measures

	Overall		Negative		Neutral		Positive		*p* value
			Income Narrative Groups						
	n	%	*n*	%	*n*	%	*n*	%	
Gender									0.99
Male	72	46	23	46	23	46	26	46	
Female	85	54	27	54	27	54	31	54	
Ethnicity									0.25
Caucasian/White	128	83	37	76	44	88	47	84	
African American/Black	7	5	4	8	2	4	1	2	
American Indian/Alaskan Native	2	1	1	2	1	2	0	0	
Asian	10	7	5	10	1	2	4	7	
Native Hawaiian/Pacific Islander	1	1	0	0	1	2	0	0	
Other	7	5	2	4	1	2	4	7	
Education									0.45
Less than High School	0	0	0	0	0	0	0	0	
High School/GED	12	8	3	6	2	4	7	12	
Some College	44	28	12	24	19	38	13	23	
2-year College	22	14	6	12	8	16	8	14	
4-year College	58	37	23	46	13	26	22	39	
Professional Degree	20	13	6	12	7	14	7	12	
Doctorate	1	1	0	0	1	2	0	0	
Income									0.34
Less than $10,000	20	13	7	14	5	10	8	14	
$10,000-$19,999	15	10	3	6	8	16	4	7	
$20,000-$29,999	19	12	5	10	8	16	6	11	
$30,000-$39,999	24	15	7	14	8	16	9	16	
$40,000-$49,999	18	12	6	12	2	4	10	18	
$50,000-$59,999	17	11	3	6	4	8	10	18	
$60,000-$69,999	17	11	9	18	5	10	3	5	
$70,000-$79,999	12	8	6	12	2	4	4	7	
$80,000-$89,999	4	3	2	4	1	2	1	2	
$90,000-$99,000	0	0	0	0	0	0	0	0	
$100,000-$149,999	11	7	2	4	7	14	2	4	
More than $150,000	0	0	0	0	0	0	0	0	
Employment									0.63
Full-time	94	61	30	61	33	66	31	55	
Part-time	22	14	8	16	4	8	10	18	
Unempl. looking	6	4	3	6	0	0	3	5	
Unempl. not looking	18	12	4	8	7	14	7	13	
Retired	10	7	2	4	5	10	3	5	
Student	2	1	1	2	0	0	1	2	
Disabled	3	2	1	2	1	2	1	2	

Note: *p* values derived from the results of chi-squared tests are shown in the far-right column

Table 4.

Correlation Coefficients of Temporal Focus and Time Perception

		2		3		4		5	
		r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
1.	**Past TF**	0.01	.94	**.41**	**<.001**	.05	.58	**.20**	**.013**
2.	**Current TF**			-.05	.56	.04	.61	.02	.77
3.	**Future TF**					-.06	.48	.01	.90
4.	**TP (Ln (k_{past})**							**.74**	**<.001**
5.	**TP (Ln (k_{fut})**								

Note: Significant correlations (i.e., $p < .05$) bolded

Table 5.

Mean Investment Percentage for Initial-Terminal Combinations and Temporal Gaps

Link		**Number of Days Ago**				
Initial	**Terminal**	**0**	**7**	**30**	**365**	**1825**
	5	0.99	0.99	0.98	0.98	0.98
	30	0.92	0.94	0.95	0.92	0.94
5	**50**	0.76	0.81	0.83	0.82	0.84
	75	0.57	0.56	0.59	0.61	0.68
	105	0.33	0.21	0.22	0.25	0.40
	5	0.98	0.97	0.97	0.96	0.97
	30	0.91	0.92	0.94	0.92	0.95
35	**50**	0.79	0.77	0.79	0.81	0.84
	75	0.54	0.49	0.50	0.53	0.61
	105	0.38	0.21	0.20	0.25	0.39

Table 6.

Correlation Coefficients of Primary Dependent Measures

		2	3	4	5	6	7	8	9
		r	*r*	*r*	*r*	*r*	*r*	*r*	*r*
1.	**DD Ln (*k*)**	-.06	-.07	-.14	**.25**	**.21**	.06	.07	.05
2.	**SC Inst**		**.98**	**-.19**	.08	-.06	.07	-.05	.03
3.	**SC Prop**			**-.26**	.07	-.06	.06	-.06	.02
4.	**Invest %**				-.10	-.03	.03	.03	.04
5.	**TP (Ln (k_{fut})**					**.74**	**.20**	.02	.01
6.	**TP (Ln (k_{past})**						.05	.04	-.06
7.	**PTF**							.01	**.41**
8.	**CTF**								-.05
9.	**FTF**								

Note: Significant correlations (i.e., $p < .05$) bolded

Table 7.

Correlation Coefficients for Primary Dependent Measures and Supplemental Measures

		2		3		4		5		6	
		r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
1.	**Ln (k_{disc})**	**-.18**	**.02**	**.25**	**.001**	**.21**	**.01**	**-.24**	**.003**	-.10	.21
2.	**Ln (Overall SC)**			.04	.62	-.06	.46	.03	.75	**-.20**	**.01**
3.	**TP (Ln (k_{fut})**					**.74**	**<.001**	**-.92**	**<.001**	**-.56**	**<.001**
4.	**TP (Ln (k_{past})**							**-.90**	**<.001**	.03	.74
5.	**Joint TP**									**.29**	**.001**
6.	**Time Perception Index**										

Note: Significant correlations (i.e., $p < .05$) bolded

Table 8.

Sunk Cost and Supplemental Time Perception Correlation Coefficients

Variable	2	3	4	5
1. Sunk Cost Instances	**0.98**	**-0.19**	0.00	**-0.20**
2. Sunk Cost Proportion		**-0.26**	0.01	**-0.19**
3. Mean Investment %			0.06	0.06
4. Joint TP				**0.29**
5. Time Perception Index				

Note: Significant correlations (i.e., $p < .05$) bolded

Table 9. Correlation Coefficients of Supplemental Measures (B)

Correlation Coefficients of Supplemental Measures (B)

		2	3	4	5	6
		r	*r*	*r*	*r*	*r*
1.	**Ln (k_{disc})**	**-.22**	**-.20**	-.15	**-.24**	-.10
2.	**SC Propensity**		**.89**	**.73**	.07	-.08
3.	**SC Propensity (NonEsc)**			**.46**	.08	-.03
4.	**SC Propensity (Esc)**				.08	-.08
5.	**Joint Time Perception**					**.29**
6.	**Time Perception Index**					

Note: Significant correlations (i.e., $p < .05$) bolded

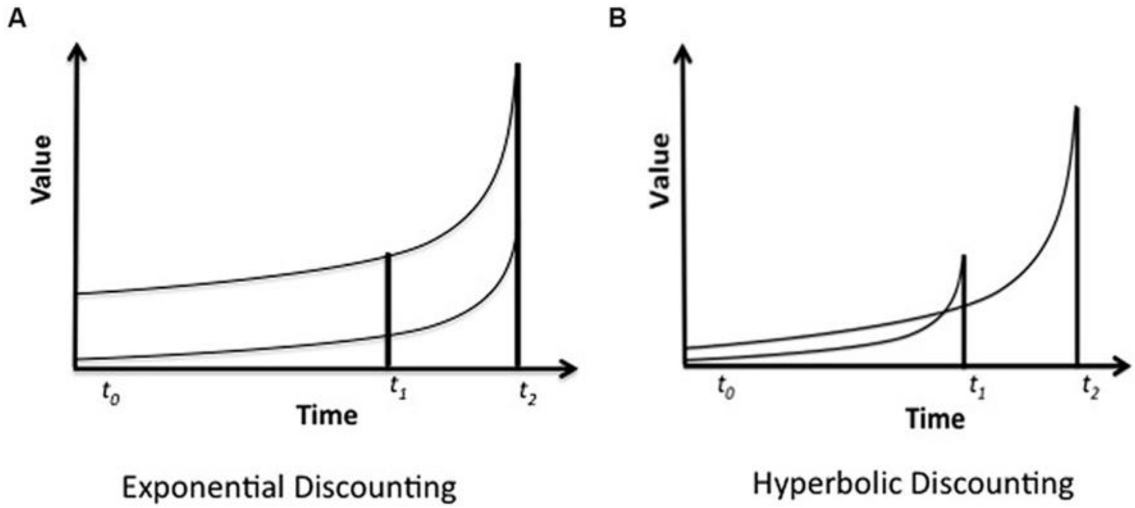

Figure 1. Potential Reversals from Exponential and Hyperbolic Discounting Models. Scenarios demonstrate preference reversals from an initial self-controlled choice.

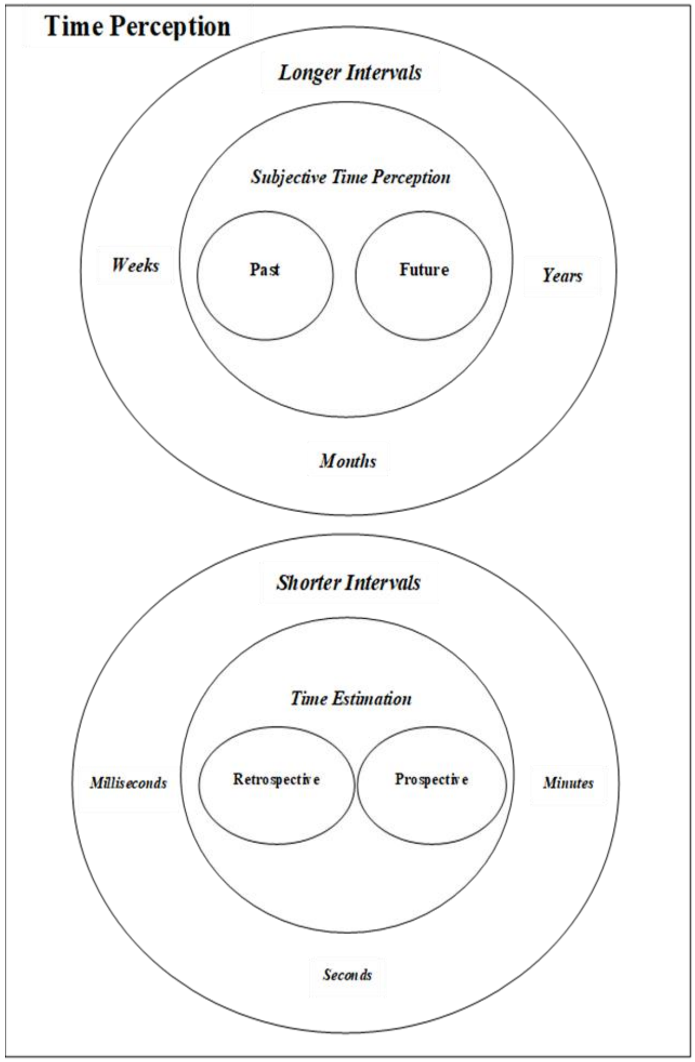

Figure 2. Conceptual Representation of Time Perception. Subjective time perception (top half of panel) measures test for one's perceived duration between the present and a temporally distant event (e.g., weeks months or years). Time estimation procedure (bottom half of panel) usually probe for one's best guess of the objective amount of time that has passed during relatively short intervals (e.g., seconds, minutes, or hours).

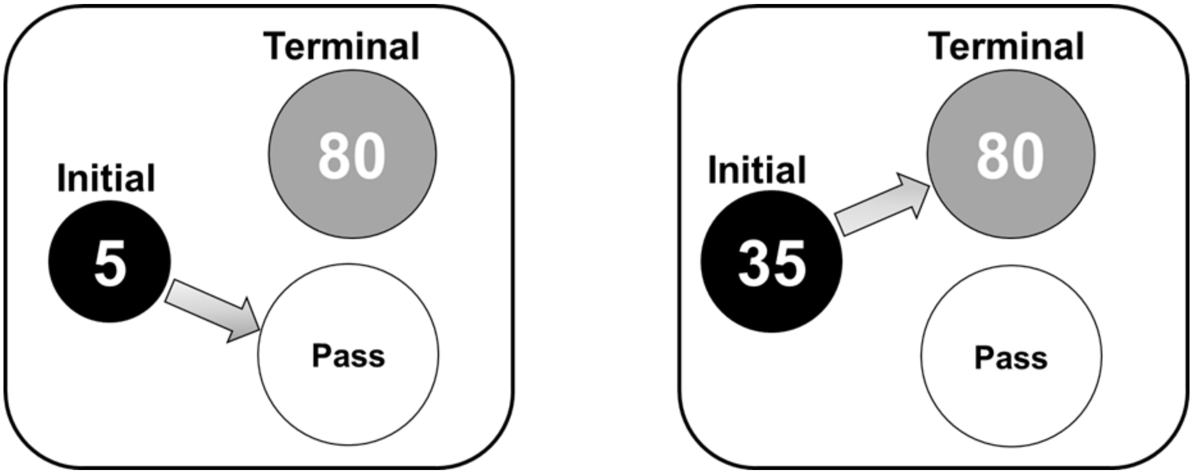

Figure 3. Sunk Cost Instance Two-Trial Example. The left panel shows a trial wherein the participant passes on an $80 terminal link following the completion of a forced-choice $5 initial link. The right panel shows a trial wherein the participant completes an $80 terminal link following the completion of a forced choice $35 initial link. In conjunction, these two events constitute a single instance of the sunk cost.

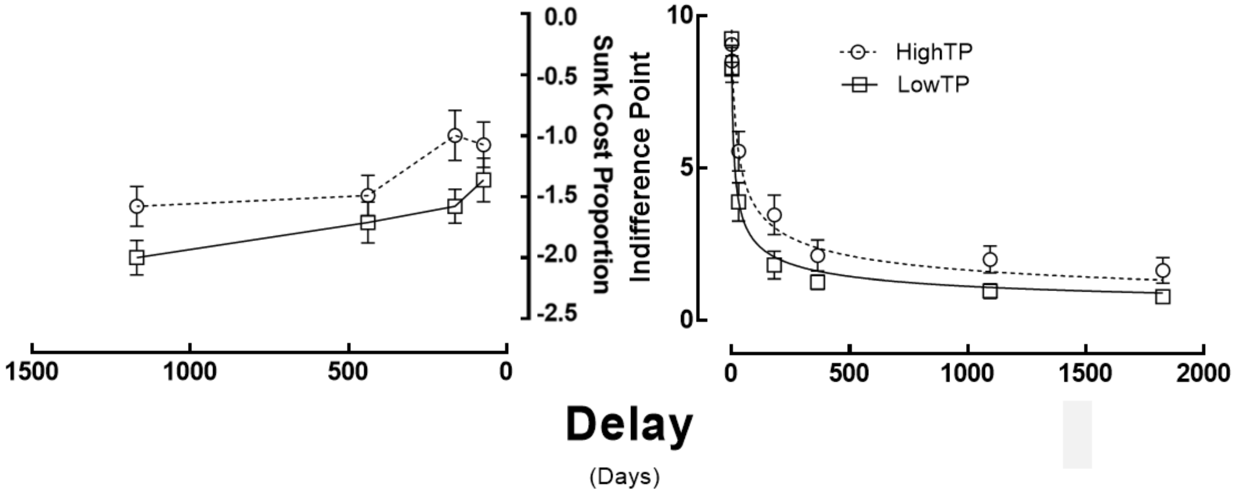

Figure 4. Pilot Temporal Attention, Sunk Cost, and Delay Discounting. The left panel shows Ln (mean sunk cost proportion) (y-axis) across temporal gaps (x-axis) and the right panel shows mean indifference points (y-axis) across delays (x-axis) for those in the high (open circles and dashed lines) and low (open squares and solid lines) subjective time perception conditions. Error bars represent standard error of the mean.

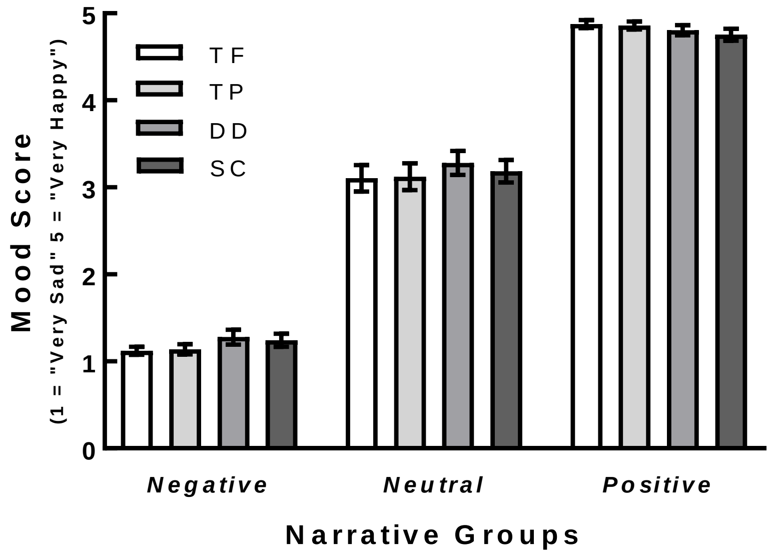

Figure 5. Mood Scores Taken Prior to Temporal Focus, Time Perception, Delay Discounting, and Sunk Cost Tasks. Mean mood scores (y-axis) are shown as a function of income narrative group (x-axis) for the measures of temporal focus (white bars), time perception (light grey bars), delay discounting (medium grey bars), and sunk cost (dark grey bars). Error bars represent standard error of the mean.

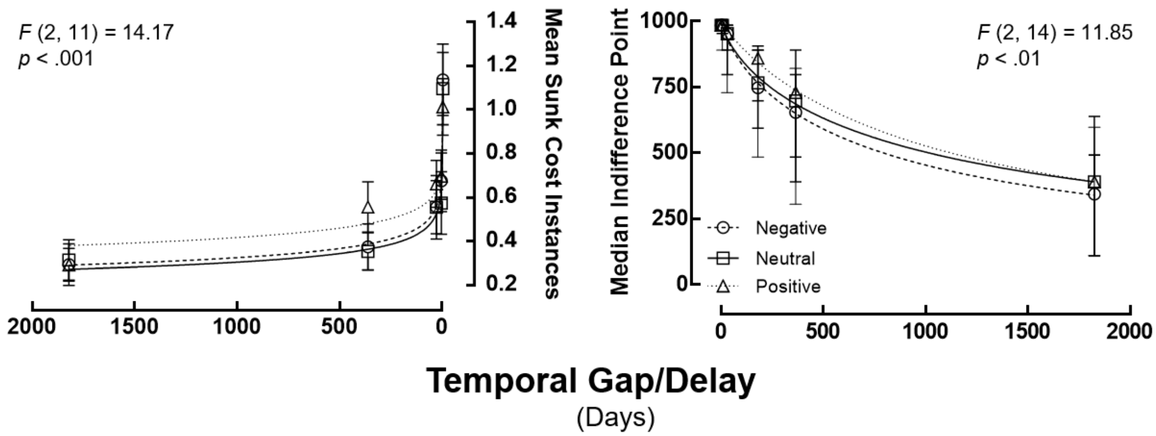

Figure 6. Mean Sunk Cost and Indifference Points Across Time Conditions and Income Narrative Groups. The left panel shows mean sunk cost instances (y-axis) across temporal gaps (x-axis) and the right panel shows median indifference points (y-axis) across delays (x-axis) for those in the negative (open circles with heavy dashed lines), neutral (open squares with solid lines), and positive (open triangles with lightly dashed lines). Error bars represent standard error of the mean for the left panel (mean sunk cost values) and inter-quartile range for the right panel (indifference points).

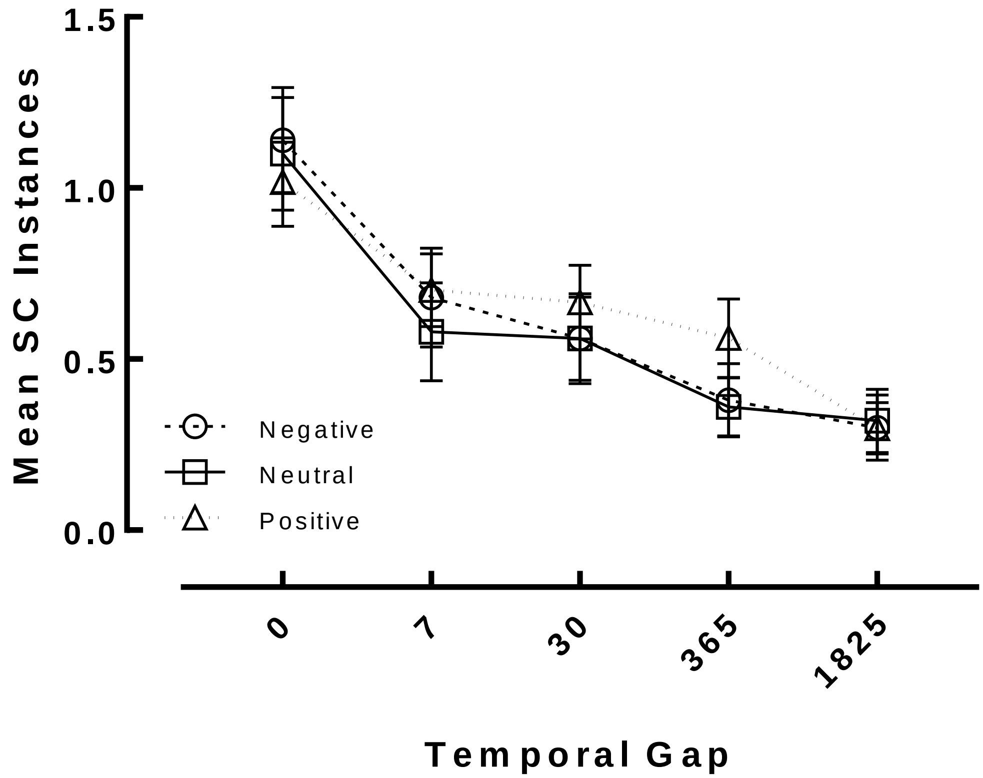

Figure 7. Mean Sunk Cost Instances Across Temporal Gaps and Income Narrative Groups. Mean sunk cost instances (y-axis) across temporal gap (x-axis) for those in the negative (open circles with heavy dashed lines), neutral (open squares with solid lines), and positive (open triangles with lightly dashed lines). Error bars represent standard error of the mean.

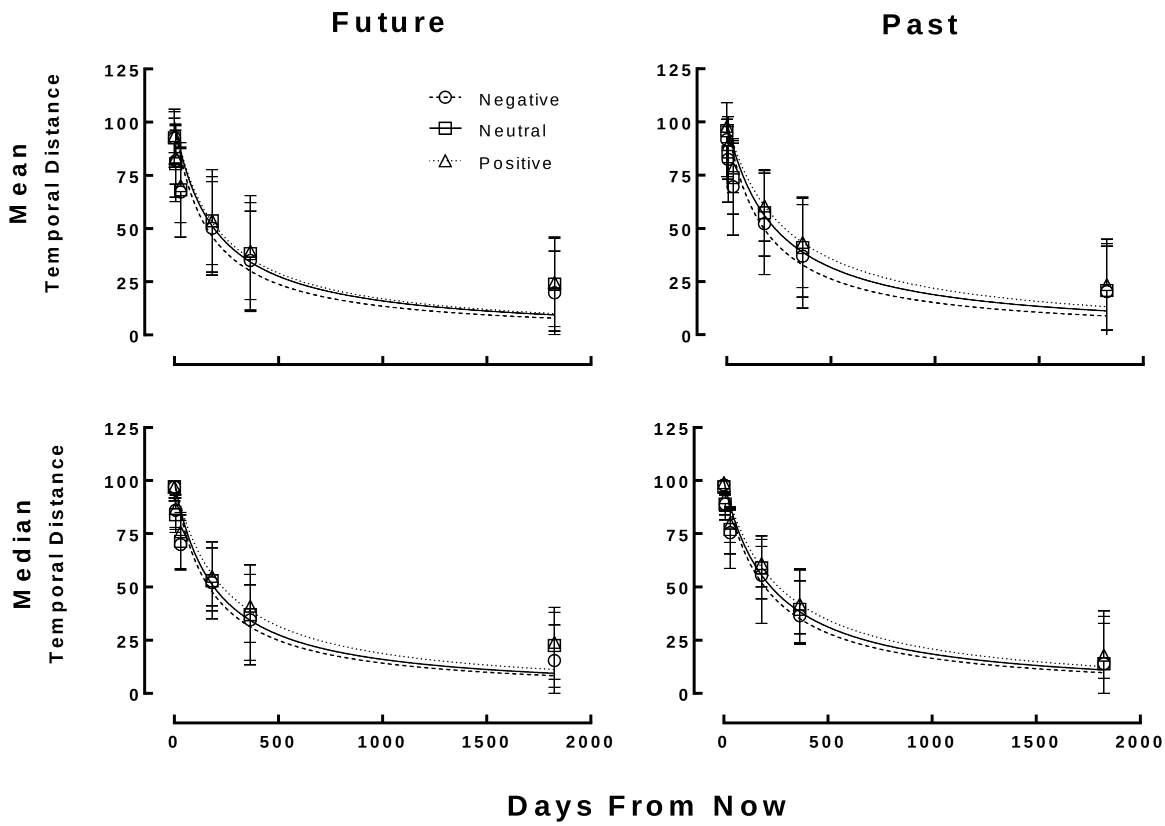

Figure 8. Mean and Median Temporal Distances Across Income Narrative Groups for Future and Past Time Perception. Mean temporal distance is reverse scored (top panels; y-axes) as is median temporal distance (bottom panels; y-axes) across days from the now (x-axis) for those in the negative (open circles with heavy dashed lines), neutral (open squares with solid lines), and positive (open triangles with lightly dashed lines). Error bars for mean temporal distance graphs (top panels) represent standard error of the mean. Error bars for median temporal distance graphs (bottom panels represent inter-quartile range).

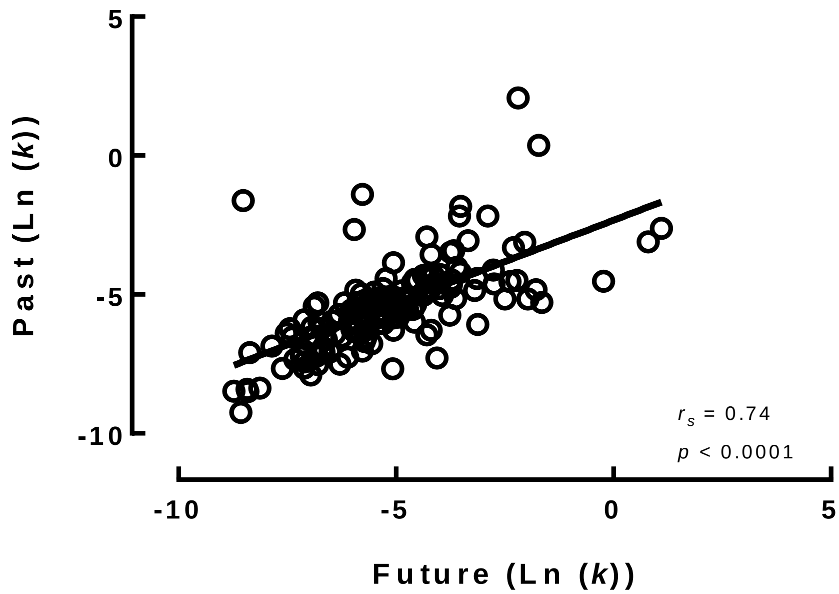

Figure 9. Correlation Between Past (Ln (k_{past})) and Future (Ln (k_{fut})) Subjective Time Perception. A linear regression line is plotted with the spearman's rank order correlation coefficient denoted in the bottom right corner (r_s = 0.74, p < .0001)

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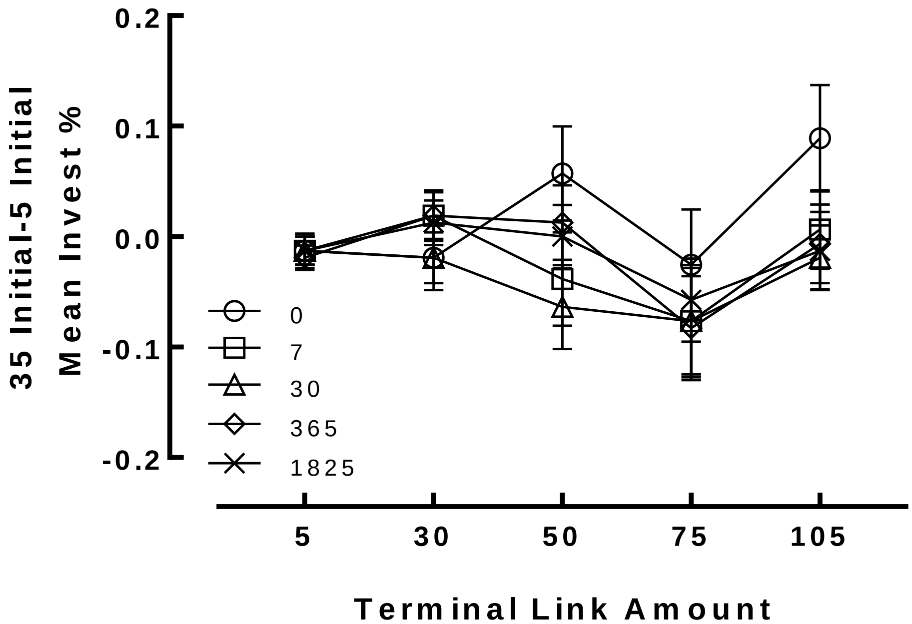


Figure 10. $35-$5 Mean Initial Investments Across Terminal Link Amounts. Means of $5 initial investments subtracted from the mean of $35 initial investments for each participant are aggregated (y-axis) across terminal link amount (x-axis). Temporal gaps are represented by open circles (0 days), open squares (7 days), open triangles (30 days), open diamonds (365 days), and x marks (1825 days). Error bars represent standard error of the mean.

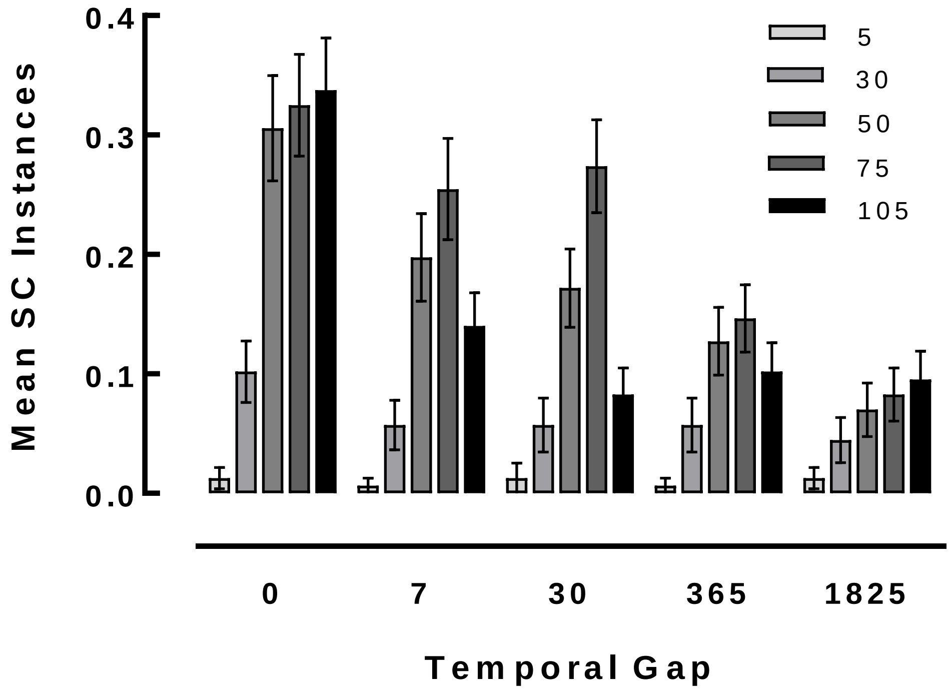


Figure 11. Mean SC Instances Across Temporal Gaps and Terminal Amounts. Mean sunk cost instances (y-axis) are shown as a function of temporal gaps (x-axis). Colored bars of light grey ($5), medium light grey ($30), medium grey ($50), dark grey ($75), and heavy dark grey ($105) note terminal amounts. Error bars represent standard error of the mean.

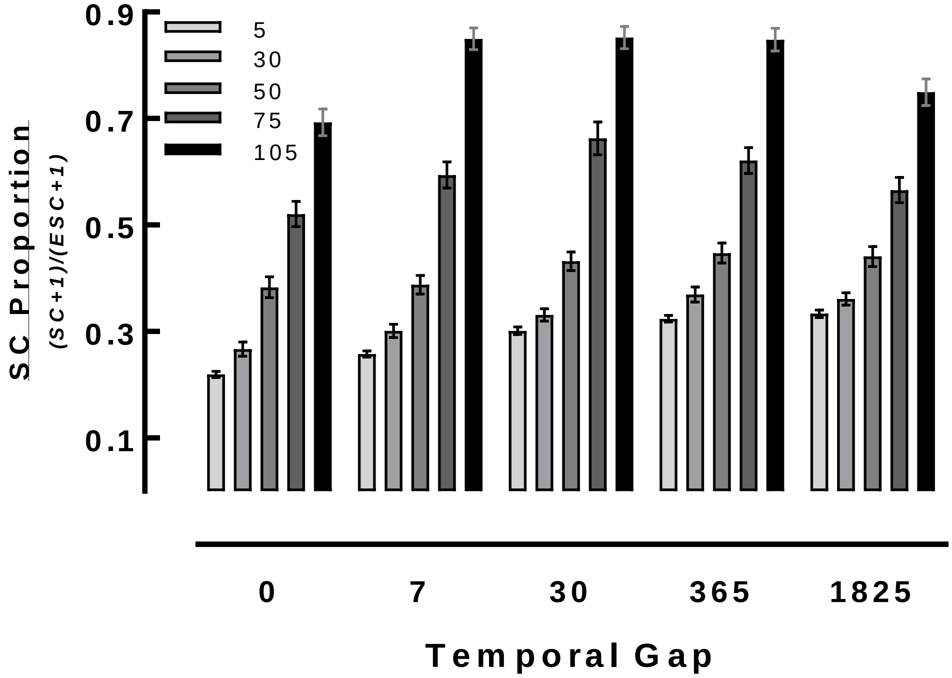


Figure 12. Sunk Cost Proportion as a Function of Temporal Gap and Terminal Amount. Sunk cost proportion (y-axis) is shown as a function of temporal gaps (x-axis). Colored bars of light grey ($5), medium light grey ($30), medium grey ($50), dark grey ($75), and heavy dark grey ($105) note terminal amounts. Error bars represent standard error of the mean.

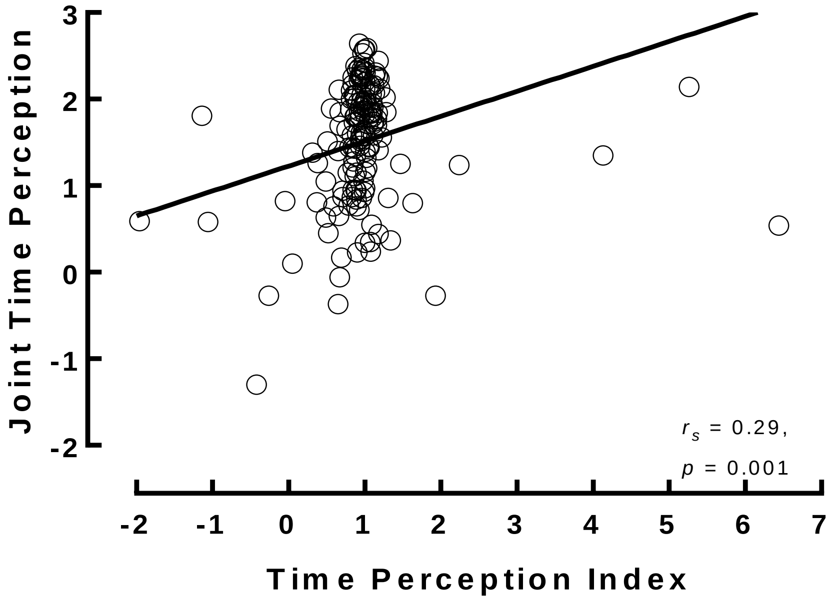


Figure 13. Joint Time Perception and Time Perception Index Scatterplot. Scatter plot with joint time perception (y-axis) and time perception index (x-axis). A linear regression line is plotted with the spearman's rank order correlation coefficient denoted in the bottom right corner (r_s = 0.29, p = .001).

Appendix A

Power Analysis I

Haushofer & Fehr (2013)

Positive Income Shock-Always Rich (Tom vs. 6 months): .096

Positive Income Shock-Always Rich (Tom vs. 12 months): .034

Positive Income Shock-Always Rich (6 months vs. 12 months): .19

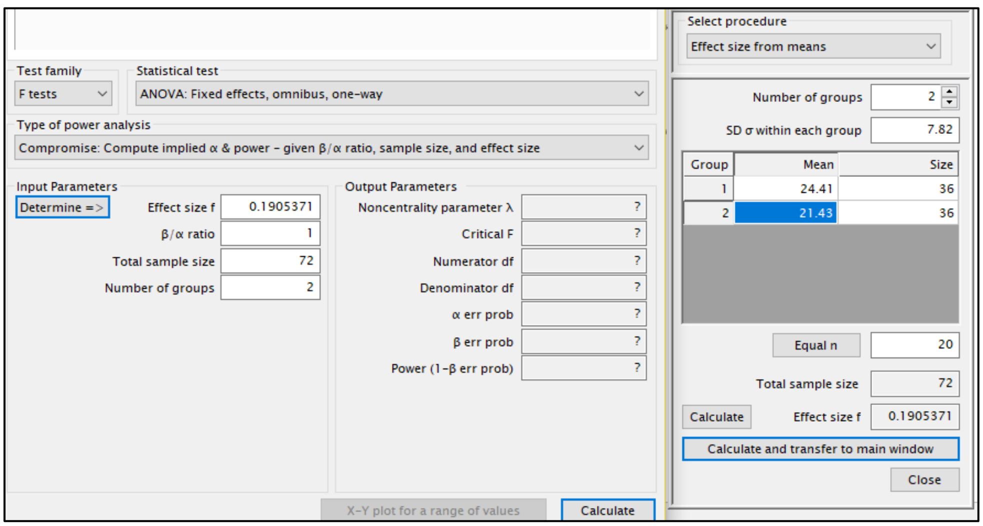
Mean = .1067

Negative Income Shock-Always Poor (Tom vs. 6 months): .249

Negative Income Shock-Always Poor (Tom vs. 12 months): .122

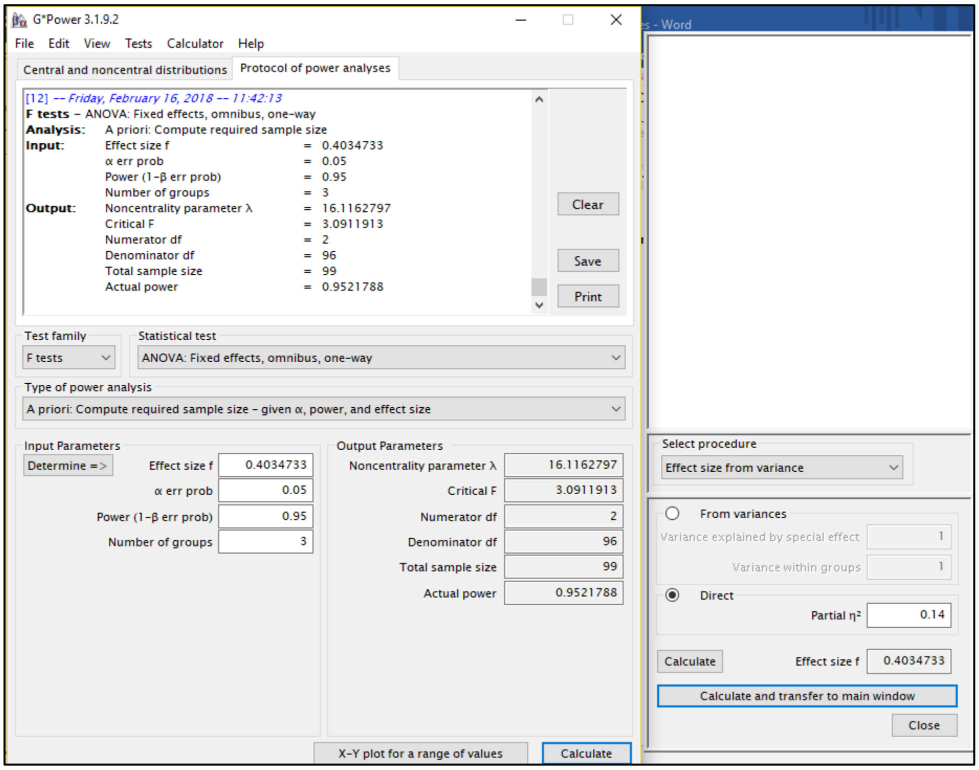
Negative Income Shock -Always Poor (6 months vs. 12 months): .092

Mean: .1513



Appendix B

Power Analysis II



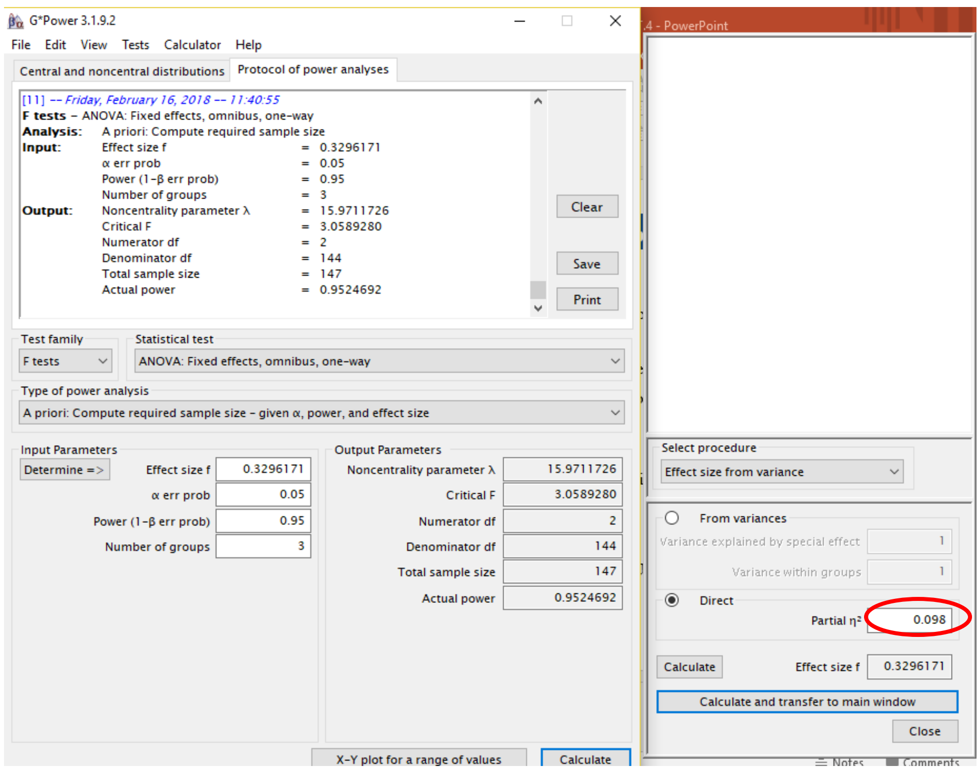
Appendix C

Power Analysis III

Haushofer & Fehr (2013) and Sze et al., 2017

.1067/.1513 = **.7052**

.14 *.7052 = .098 *(Positive Income Shock)*



Appendix D

Participant Instructions

In this experiment, you will be asked to first read and envision yourself experiencing a scenario for 15 seconds. You will then be given four tasks and a survey to complete. For each of the tasks, you will be asked to make choices based on hypothetical scenarios. Some of these scenarios involve hypothetical financial decisions and others will involve hypothetical sexual decisions.

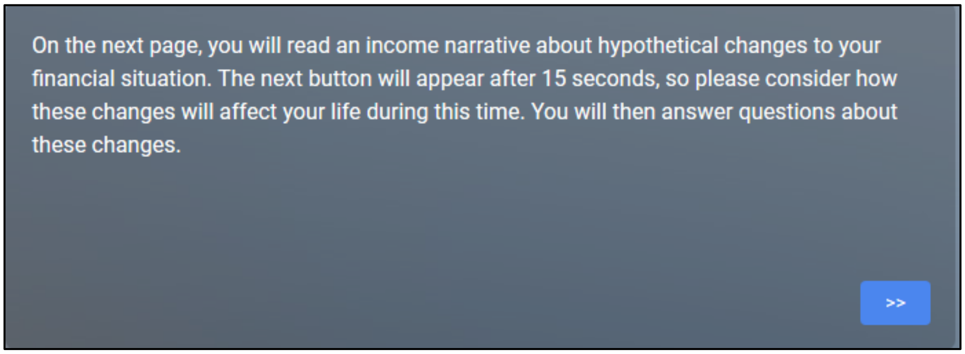
Please note that you can earn an extra 75 cents (totaling $1.50) if you honestly and realistically answer during the task labeled, "financial decision-making." Based on our experience administering this task, we can identify if you are not paying attention. There are no right or wrong answers, and if you are carefully attending to the questions, you will earn the bonus of 75 cents. We will remind you of these criteria prior to the 'financial decision-making task'.

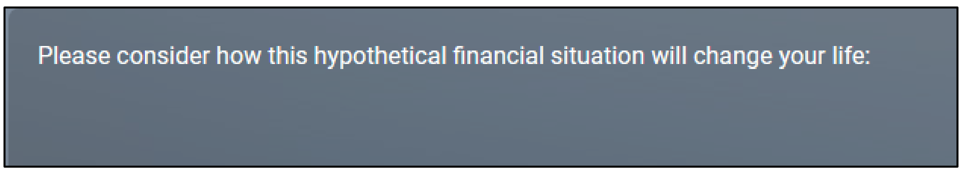
Okay

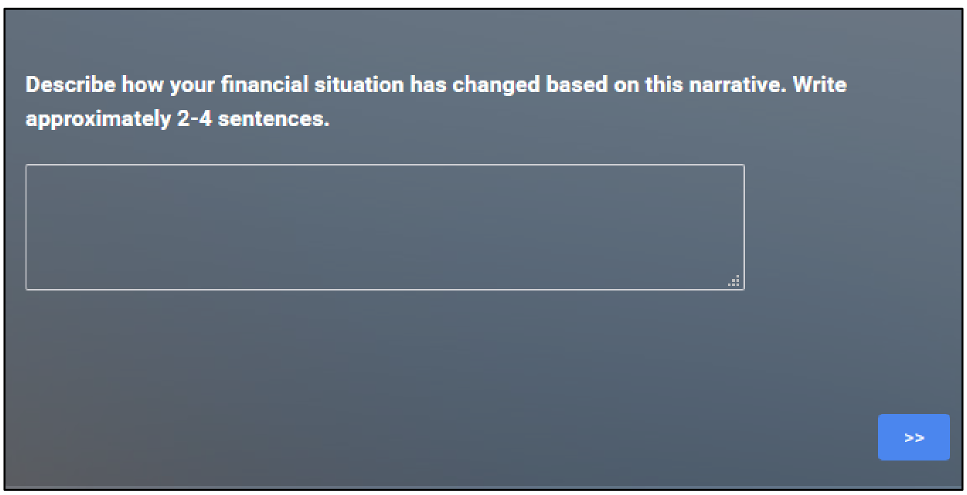
>>

Appendix E

Income Narrative Prompt

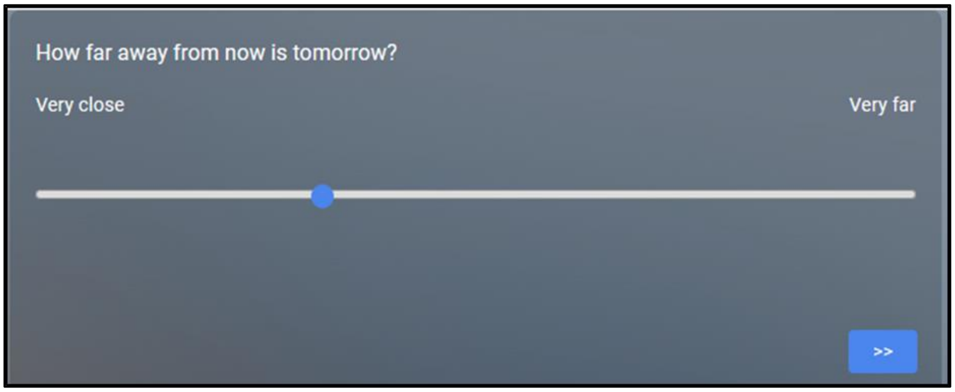






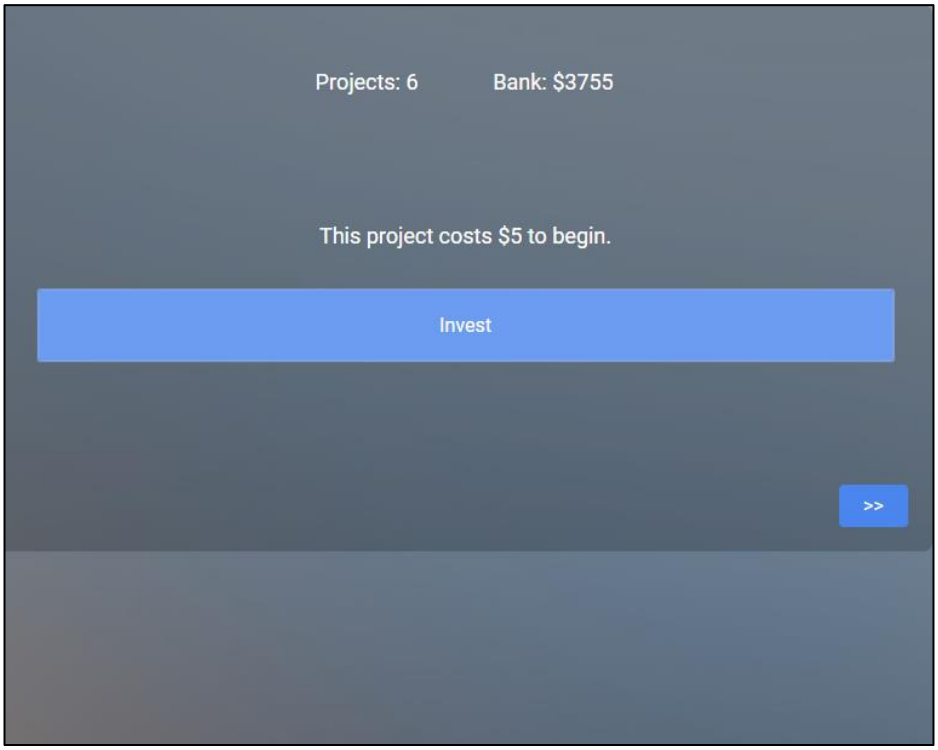
Appendix F

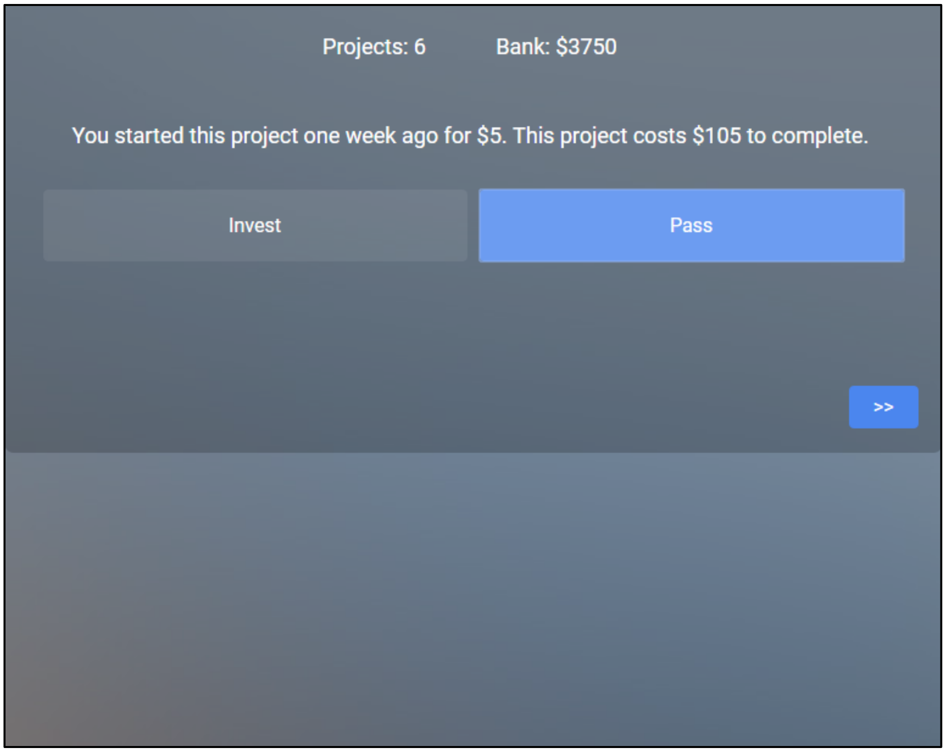
Subjective Time Perception Example



Appendix G

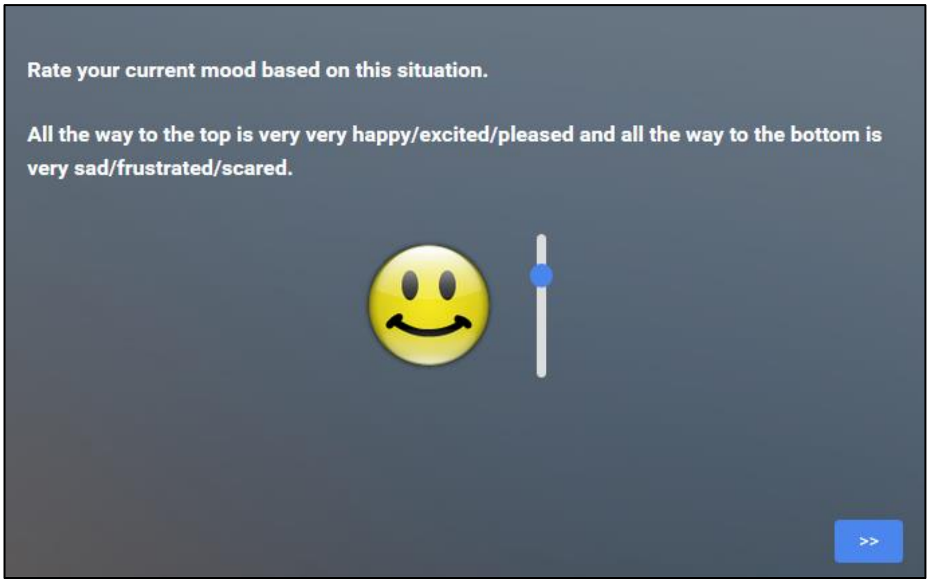
Trial Example from Sunk Cost Task





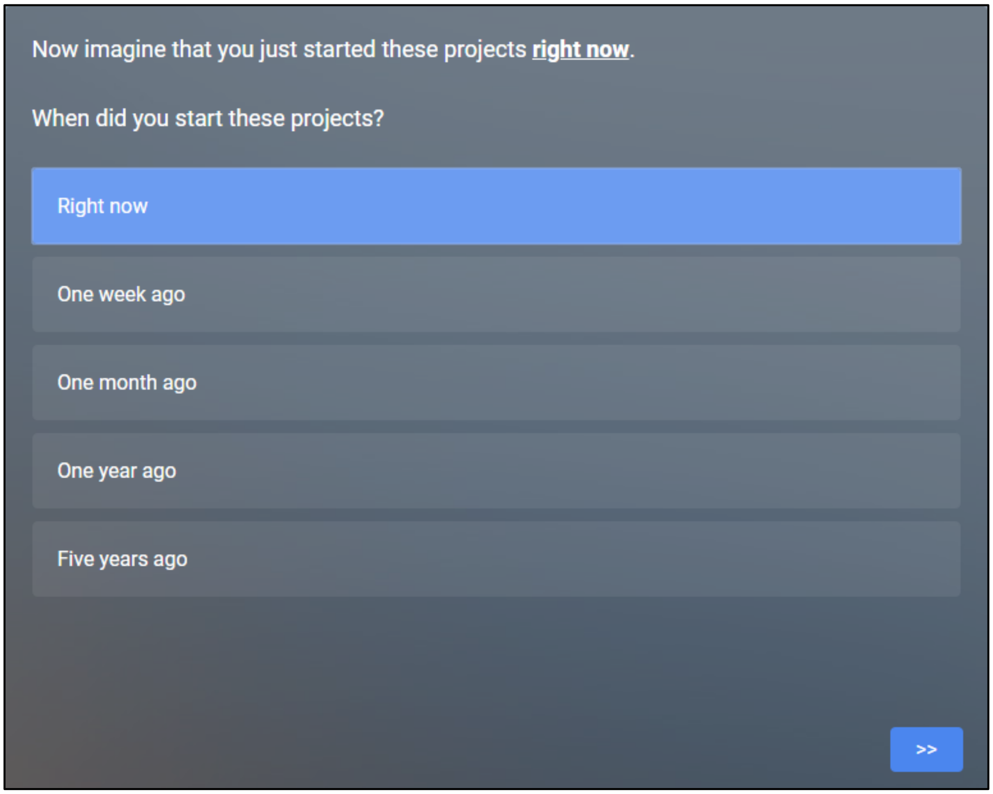
Appendix H

Mood Rating Example



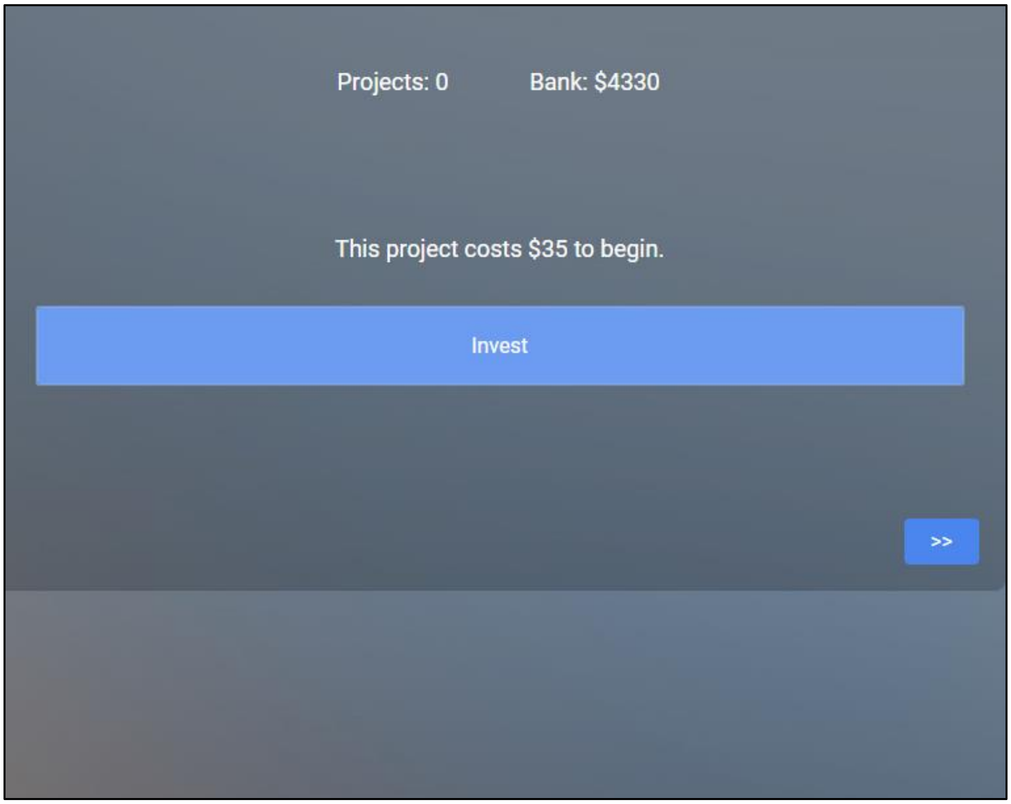
Appendix I

Sunk Cost Temporal Gap Manipulation Check Example



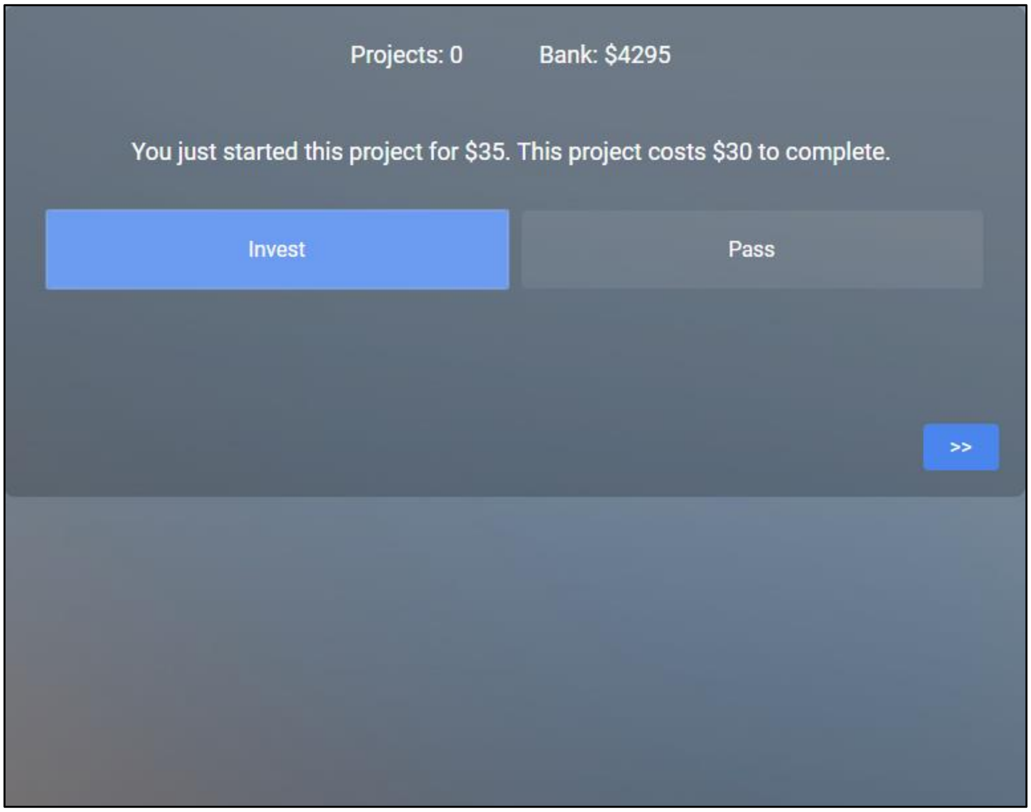
Appendix J

Sunk Cost Forced Choice Initial Link



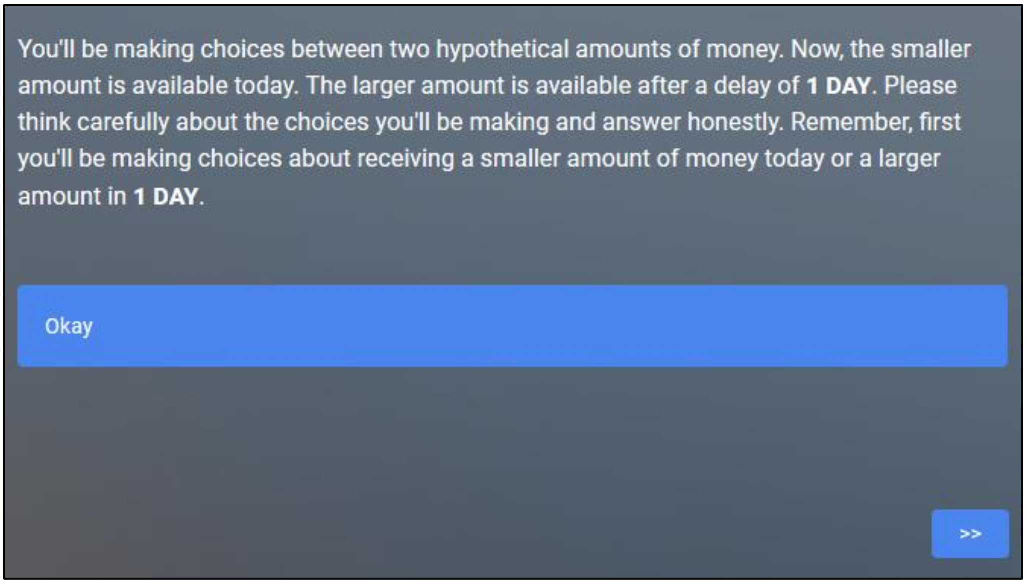
Appendix K

Sunk Cost Free-Choice Terminal Link



Appendix L

Delay Discounting Example Instructions



Appendix M

Delay Discounting Choice Context