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An Examination of How Qualitatively Different Delayed Outcomes are Discounted

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AN EXAMINATION OF HOW QUALITATIVELY DIFFERENT

DELAYED OUTCOMES ARE DISCOUNTED

by

Jonathan E. Friedel

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of

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ABSTRACT

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Delay discounting is the process by which delayed outcomes lose value. Different types of delayed outcomes (e.g., food and money) lose value to different degrees. Higher degrees of delay discounting are related to a wide variety of psychosocial maladies. Chapter I provides context for the studies described in Chapters II-IV. Specifically, cigarette smokers routinely discount delayed money to a greater degree than nonsmokers. Chapters II and III explore the generality of the relation between cigarette smoking and delay discounting by examining how different types of delayed outcomes are discounted. The data presented in these chapters indicate that smokers show a pervasive tendency to steeply discount various types of outcomes when compared to nonsmokers. Across both smokers and nonsmokers, the degree to which a person discounts one delayed outcome is correlated with how they will discount other outcomes. The additive utility model is a recently proposed model of delay discounting that provides potential mechanisms of delay discounting to explain the findings of Chapters II and III. Chapter IV describes the results of empirical test of the additive utility model as it relates to qualitatively different delayed outcomes. In this study, the additive utility model described delay discounting data as well as a more standard model of delay discounting, the hyperbolic model. This study provides tentative support for the additive utility model of delay discounting as an explanatory model. Finally, Chapter V provides a summary of all three studies.

(160 pages)

PUBLIC ABSTRACT

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Jonathan E. Friedel, a graduate student in the Experimental and Applied Psychological Sciences program at Utah State University, will complete this dissertation as part of the requirements of the degree of Doctor of Philosophy in Psychology.

Outcomes that are received far in the future are less valuable than outcomes that are to be received more proximally. Delay discounting describes how outcomes in the future lose value. The goal of this dissertation is to examine how people discount different types of delayed outcomes. Two experiments examine the value of a wide variety of delayed outcomes for cigarette smokers and nonsmokers. These experiments indicate that these outcomes have far less value for cigarette smokers than for nonsmokers. Also, the degree to which one outcome loses value is related to the degree to which other outcomes lose value. The final experiment, compares a popular model of delay discounting to a newer model of delay discounting, the additive utility model. This experiment indicates that the newer additive utility model is just as good as the more popular model. While the newer model is as good as the popular model, the newer additive utility model does provide potential causal factors for delay discounting that the popular model does not.

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Jonathan E. Friedel

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CHAPTER I

INTRODUCTION

Humans are frequently faced with choices between small and immediate outcomes and larger but delayed outcomes. Intertemporal choice scenarios are the primary way the phenomenon of impulsive choice in humans is studied. A pattern of choices in which small, immediate outcomes are selected is considered impulsive when compared to a pattern of choices in which the larger, delayed outcomes are frequently selected. Delay discounting is the process that can describe and explain how the delay to an outcome affects an organism's choice for that outcome. Higher degrees of delay discounting are related to a wide variety of psychosocial disorders such as cigarette smoking (Bickel, Odum, & Madden, 1999; Mitchell, 1999), obesity and overeating (Rasmussen, Lawyer, & Reilly, 2010), problematic gambling (Dixon, Marley, & Jacobs, 2003), and attention deficit hyperactivity disorder (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001). One area of impulsive choice research that is of interest is the extent to which delay discounting is a stable, trait-like pattern of behavior (Bickel, Jarmolowicz, Mueller, Koffarnus, Gatchalian, 2012; Odum, 2011).

To assess an overall pattern of impulsive choice in humans, intertemporal choice scenarios that involve multiple different hypothetical outcomes are used (see Odum, 2011 for review). With qualitatively different outcomes, we can assess the extent to which a higher degree of delay discounting in one domain is predictive of a higher degree of delay discounting in another domain. Chapter II will present an experiment that was designed to assess delay discounting for qualitatively different tangible reinforcers in a group of cigarette smokers and a group of nonsmokers. Chapter III will present an experiment that was designed, in part, to assess delay discounting for qualitatively different reinforcers that are not tangible in a group of cigarette smokers and a group of nonsmokers. Chapters II and III catalogue the similarities and differences in how smokers and nonsmokers make intertemporal choices across qualitatively different outcomes. One common finding across Chapters II and III as well as other studies (e.g., Charlton & Fantino, 2008) is that qualitatively different outcomes are discounted to different degrees. Chapter IV will present an experiment that was designed to assess the recently proposed additive utility model of delay discounting, which can potentially explain why different outcomes are discounted to different degrees. Finally, Chapter V will provide a summary of Chapters II-IV.

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CHAPTER II[1]

DISCOUNTING OF MONETARY AND CONSUMABLE OUTCOMES IN CURRENT AND NONSMOKERS

Introduction

Cigarette smoking is the leading cause of preventable death in the United States and results in an estimated $167 billion per year in lost productivity and health care expenditures (Centers for Disease Control and Prevention [CDC] 2002, 2005). Multiple factors contribute to the initiation and maintenance of cigarette smoking (Li 2006). One personality factor that is consistently associated with vulnerability to and severity of smoking is impulsivity (e.g., Flory and Manuck 2009; Mitchell 1999; Nieva et al. 2011). Impulsivity is a multi-faceted concept that includes inability to wait, difficulty in refraining from actions, and insensitivity to delayed consequences (de Wit 2008).

Insensitivity to delayed consequences is encompassed by the process of *delay discounting*: the decline in the present value of a reward with delay to its receipt (e.g., Mazur 1987; Odum 2011a). In humans, delay discounting is often investigated by asking the participant to choose between a smaller, more immediate alternative and a larger, more delayed alternative. Across choice opportunities, the experimenter changes the

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[1] Note: Chapter II of this dissertation proposal was adapted from "Impulsivity and cigarette smoking: Discounting of monetary and consumable outcomes in current and non-smokers," J. E. Friedel, W. B. DeHart, G. J. Madden, & A. L. Odum, 2014,. *Psychopharmacology*, *231*(23), 4517-4526.

amount of the immediate option until an indifference point is reached. At indifference the amount of the smaller-sooner outcome provides the present value of the larger-later outcome. If delayed outcomes hold comparatively little value, a person would choose smaller more immediate outcomes relatively often, which is deemed impulsive choice (e.g., Logue 1988).

Cigarette smoking is strongly related to delay discounting. For example, current smokers more steeply discount delayed money than do non-smokers (e.g., Baker et al. 2003; Bickel et al. 1999; Heyman and Gibb 2006; Mitchell 1999; Ohmura et al. 2005; Reynolds and Fields 2012; Wing et al. 2012; see MacKillop et al. 2011 for review and meta-analysis). Furthermore, the degree of discounting of delayed money is predictive of smoking initiation and likelihood of success in quitting. For example, in a prospective longitudinal study, adolescents who steeply discounted delayed money were more likely to begin smoking by young adulthood than adolescents who discounted money less steeply (Audrain-McGovern et al. 2009). In a laboratory analog model of relapse to smoking, in which participants are paid for remaining abstinent, steeper discounting of delayed money is predictive of shorter latency to smoke (Dallery and Raiff 2007; Mueller et al. 2009). Additionally, steep discounting of delayed money is predictive of poorer treatment outcome for cigarette dependence in clinical settings (MacKillop and Kahler 2009; Sheffer et al. 2012; Yoon et al. 2007). Thus, steep delay discounting is associated with cigarette smoking and predicts important outcomes for cigarette smokers. With better understanding, delay discounting could provide a vital role in the development of prevention and cessation strategies.

Although steep discounting of delayed hypothetical money is a robust feature associated with cigarette smoking, in some ways the generality of this relation has been little investigated. The difference between smokers and nonsmokers in discounting of money, for example, could reflect smokers' intent to purchase cigarettes with at least a portion of the money. Several studies have revealed that smokers discount cigarettes very steeply (e.g., Bickel et al. 1999; Odum & Baumann, 2007) and if money and cigarettes are treated as partially equivalent, then steep discounting of delayed money may reflect no more than this tendency to steeply discount delayed cigarettes.

In the present study, we evaluated if, relative to nonsmokers, cigarette smokers more steeply discount a variety of delayed outcomes. Specifically, in addition to delayed money, we compared how current cigarette smokers and nonsmokers discounted delayed alcohol, food, and entertainment. These commodities were chosen because they are widely available and consumed, but are unlikely to be exchanged directly for cigarettes. On one hand, if cigarette smokers discount non-monetary outcomes more steeply than do nonsmokers, then this result could support the hypothesis that delay discounting is a pervasive trait-like tendency (see Odum 2011 a, b). On the other hand, if cigarette smokers discount only money more steeply than do non-smokers, then this result could suggest that smokers may show steep discounting of money in part because it is used to purchase cigarettes.

Method

Participants

A total of 63 participants (31 smokers, 32 nonsmokers) were recruited through a combination of newspaper advertisements, radio advertisements, fliers posted throughout the community, and referrals from other participants. By telephone, potential participants were asked a series of questions to determine if they qualified.

Only occasional alcohol drinkers 21 years or older were invited to come to the laboratory to participate. Nonsmokers reported having smoked fewer than 100 cigarettes in their lifetime and smokers reported smoking at least 10 cigarettes per day (CDC 2006). People who met these qualifications were invited to the laboratory for additional screening and testing.

Procedure

Each participant completed a single session while seated at a desk with a computer in a private office with no windows. Participants read and signed an informed consent form that was approved by Utah State University's Institutional Review Board.

Biological Samples. Participants first provided two biological samples. The first sample, administered through the FC 10 Breathalyzer (Lifeloc), measured recent alcohol consumption. Any participant with a blood-alcohol level above 0.000 was not included in the study (one participant was excluded based on this criterion). The second sample, administered with a Micro+ Smokerlyzer (Bedfont Scientific LTD, n.d.), measured carbon monoxide (CO) as an indication of recent cigarette use. Reported smokers had to measure a CO level of 6 ppm or higher (Bedfont Scientific LTD, n.d.) to qualify for participation. All smokers met this criterion.

Questionnaires. Next, participants completed a series of questionnaires on the computer. The questionnaires were administered through E-Prime computing software.

The Eating Disturbance Scale (EDS-5; Rosenvinge et al. 2001) is a 5-item questionnaire that measures problematic eating habits and beliefs (alpha = .666). Questions include: “Are you satisfied with your eating habits?” Scores can range from 5 to 35.

The South Oaks Gambling Screen (SOGS; Lesieur and Blume 1987) is a 36-item questionnaire that measures gambling behavior (with an answer scale of “not at all,” “less than once a week,” and “once a week or more”; alpha = .812). Questions include: “In your lifetime, how often have you gone to a casino (legal or otherwise)?” Scores can range from 0 to 20.

The Michigan Alcohol Screening Test (MAST; Selzer 1971) is a 25-item questionnaire that identifies alcohol abuse in respondents using “yes” or “no” questions (alpha = .888). All questions are based on the participants’ experience in their lifetime. Questions include “Has your significant other (or other family member) gone to anyone for help about your drinking?” Scores can range from a minimum of 0 to a maximum of 53 (answering yes to specific questions is weighted more than other questions).

The Information Inventory (II; Altus 1948) is a 13-item IQ questionnaire that asks a variety of questions ranging from events in history to vocabulary. Sample questions include “Who was Confucius?” Scores can range from 0 to 30.

Participants also provided demographic information including their age, ethnicity, gender, marital status, income, and highest obtained education.

Delay discounting tasks. In the final portion of the session, participants completed four different delay discounting tasks on the computer. Prior to the delay discounting tasks, the participants read instructions similar to those in described in Odum et al. (2006). The tasks were presented in randomly determined order and all four were completed in approximately 40 minutes. Before the first discounting task, participants completed a ten-question practice block with money. The delay to the larger-later reward of $100 was set to one week and the immediate amount increased from $10 to $100 in $10 increments across practice trials.

In each delay discounting task indifference points were obtained at six different delays to the larger-later reward, presented in the following order: 1 week, 2 weeks, 1 month, 6 months, 5 years, and 25 years. For the monetary task the first question was, "Would you prefer $50 now or $100 in (delay)?" The positioning of the immediate and delayed options alternated randomly across the right and left positions of the computer screen. Participants registered their choice by using the mouse to click one of the two options. After each question, the amount of the immediate reward was adjusted according to the titration procedure outlined by Du et al. (2002). Briefly, if the smaller-sooner reward was selected (forgone), the amount of that reward was decreased (increased) by $25 in the next choice trial. Subsequent adjustments to the immediate reward were 50% of the preceding adjustment. The amount of the immediate reward following the tenth choice trial was used as the indifference point for that delay. At each subsequent delay, the amounts of the smaller-sooner and larger-later rewards were returned to $50 and

$100, respectively, and the 10-trial titration procedure was repeated. All values displayed to participants were rounded to the nearest penny ($0.01).

The other three delay discounting tasks asked about different commodities: food, alcohol, or entertainment. For each task, the participant was asked to name their favorite item in the commodity category (e.g., favorite alcoholic drink) and to report how much that item cost. The reported cost was then divided into $100, and the quotient served as the larger-later reward amount throughout that discounting task, similar to the procedure first used in Odum and Rainaud (2003). The initial amount of the smaller-sooner reward was half the amount of the larger-later. For example, if a participant indicated that their favorite food was a hamburger and that it cost five dollars, their first question would read "Would you rather have 10 servings of hamburger now or 20 servings of hamburger in one week?" From there, the titration procedure outlined above was used to obtain indifference points for that commodity at each delay. Across outcomes all indifference points were scaled by the amount of the larger, later outcome so that all indifference points reported are standardized between 0 and 1. Favorite foods reported by participants included bread, enchiladas, and fish. Participants' reports of favorite alcohol included beer, long island iced tea, and wine. Favorite entertainment reported by participants included mp3's, iTunes albums, and CD's.

No major changes were made to the Du et al. (2002) discounting task between commodities. Each indifference point was determined by a 10-trial titration procedure and all values were rounded to the nearest hundredth. If a participant chose a relatively expensive favorite option, it would have a small number of items in $100. Therefore, as an unintended consequence, a participant could be given a choice in which the smaller, sooner option did not change across a trial because the titration amount was less than 0.01. Of 1,512 indifference points (i.e., 4 commodities tested at 6 delays for 63 participants), a total of 33 indifference points were affected by this issue.

Participants were compensated $25 for completing the approximately one-hour session.

Analyses

The Mazur (1987) hyperbola and Myerson and Green (1995) hyperboloid model were fit to the median indifference points for each commodity via curvilinear regression (Graphpad Prism®**):**

$$V = \frac{A}{(1+kD)^s} \qquad \text{(Equation 2.1)}$$

where V is the present (discounted) value of a future outcome, A is the amount of that future outcome, D is the delay to that outcome, k quantifies steepness of the hyperboloid delay discounting function and s is a scalar of delay and/or amount. The key difference between the two models is that the Mazur (1987) hyperbola has no exponential scaling parameter (so s was constrained to 1 for the model fit). To select the most appropriate model for further analysis, comparisons between the models were made with Akaike information criteria (AIC) and goodness of fit (R^2) of individual participant data (described in the Results).

To be consistent with prior studies examining within-subject relations between the discounting of different commodities (Charlton and Fantino 2008; Johnson et al., 2010; Odum 2011b), correlation coefficients were computed using the Area Under the Curve

(AUC) as the measure of delay discounting. AUC is the sum of the trapezoidal area between each set of adjacent indifference points. The formula for a single trapezoid is $x_2 - x_1 [(y_1 + y_2)/2]$, where x_1 and x_2 are successive delays and y_1 and y_2 are indifference points associated with those delays. AUC is standardized to fall between 0 and 1, with lower values indicating steeper delay discounting (Myerson et al. 2001).

For reasons described below, a General Linear Model (GLM) was used as a repeated measures ANOVA to examine the effects of smoking status and type of outcome (e.g., money) on the indifference points (cf. Evenden & Ryan 1996). For the omnibus test of smoking status, all the indifference points obtained from non-smokers (24 for each participant) were averaged and compared to all of the average indifference points obtained from smokers. For *between-group* pairwise comparisons, all indifference points (6 for each participant) for one outcome type (e.g., money) for nonsmokers were averaged and compared to all of the average indifference points obtained for that outcome type for smokers, resulting in 4 between-group pairwise comparisons. For *within-group* pairwise comparisons, for each group (e.g., nonsmokers) average indifference points for each outcome (e.g., money) were compared to the average indifference points for the other outcomes (e.g., food), resulting in 6 within-group comparisons for each group. In the Results, all comparisons are reported as the difference between the means under consideration (e.g., mean indifference points for nonsmokers minus mean indifference points for smokers).

GLM was chosen due to its ability to analyze repeated measures and provide pairwise comparisons while adjusting for multiple comparisons. The family-wise Type I error rate was held constant at $p = .05$. AUC was not used in a more standard ANOVA for this analysis because (a) Shapiro-Wilk tests revealed that AUC for all commodities violated the assumption of normality ($p < .01$), which is an assumption of ANOVA and (b) there is no widely available or accepted non-parametric omnibus test that accounts for multiple comparisons and provides pairwise comparisons (a minimum of 2 Friedman's tests and 7 Mann-Whitney U-tests would be required to non-parametrically provide the information reported by the GLM). The profile of results with AUC was the same as presented here with indifference points. We were not able to use the value of the free-parameter k from Equation 1 for these analyses for two reasons. (1) As described below, the Myerson and Green (1995) hyperboloid was determined to be the best model; and (2) in the hyperboloid model the value of k interacts with the value of s, so k does not provide an independent measure of the degree discounting.

We did not exclude any of the discounting data obtained from participants from analysis for two reasons. First, the present study is an extension of Bickel et al. (1999), which predated the data exclusion criteria developed by Johnson and Bickel (2008). Second, due to the within-subjects nature of many comparisons in the present study, if a participant had data that met exclusion criteria for one outcome type, all four of that person's discounting curves (one for each outcome type) would have to be excluded. This strategy would necessarily exclude a large amount of systematic data. The pattern of results was the same regardless whether we included or excluded data according to the Johnson and Bickel algorithm. Thus, for these reasons, we did not exclude any data.

Results

Demographic characteristics and mean questionnaire scores of the smoker and non-smoker groups are shown in Table 2.1. Fifty-two participants self-identified as Caucasian (80%) followed by 4 reporting as Hispanic and 1 as African American and 6 as other. Additionally, 3 participants self-identified as Latino. Reported ethnicity did not differ between groups (χ^2 (3, N = 63) = 2.73, p = 0.44). The groups differed with respect to MAST and SOGS scores, with smokers reporting greater problematic alcohol use and gambling. Therefore, MAST and SOGS scores were included in the GLM as covariates.

Table 2.1

Means and Standard Errors of Questionnaires

Means and Standard Errors of Questionnaires			
	Nonsmoker mean (SE)	Smoker mean (SE)	*t*
Caucasian	84%	81%	
Male	56%	61%	
Education[a]	3.13 (.22)	2.65 (.17)	1.68+
Age (years)	38.38 (2.79)	36.90 (2.51)	0.39
Monthly Income ($)	2080 (301)	2055 (447)	.047
Information Inventory	10.13 (.58)	8.52 (.63)	1.88
MAST[b]	3.00 (0-8)	12 (0-33)	197.00*
SOGS[b]	0.00 (0-1.75)	1.00 (0-5)	292.50*
CO (ppm)	1.97 (.13)	9.35 (.34)	-20.15*+

* p < .05
+ Violation of Levene's Test for Equality of Variances, equal variances not assumed.
[a]. Education was measured using seven categories and participants were asked about their highest level of obtained education. 1 = did not complete high school; 2 = high school degree or equivalent; 3 = associate degree; 4 = bachelors degree; 5 = graduate degree; 6 = doctorate degree or equivalent.
[b]. Median and interquartile ranges (25% and 75% percentiles) reported instead of mean and standard error. Shapiro-Wilk test for normality indicates that scores are not normally distributed. Non-parametric Mann-Whitney U test reported in place of t-test.

A chi-squared test for independence did not reveal gender differences between the nonsmoker (18 males, 14 females) and smoker (19 males, 12 females) groups, χ^2 (1, N = 63) = 0.17, p = 0.69. For biological samples, smokers had higher CO levels than non-smokers [t(61) = 20.39 p < .01], but did not differ in BAL, which was required to be 0.000 for participation.

Table 2.2 allows evaluation of the fit of two common models of delay discounting to the indifference points. The left column shows the value of the AIC for the fit of the Mazur (1987) hyperbolic model and hyperboloid Myerson and Green (1995) model to the median indifference points. The AIC weighs how much variance is accounted for in light of how many free parameters a model has. AIC values from the hyperboloid model were

Table 2.2

Evaluation of Hyperbolic and Hyperboloid Models of Discounting

		AIC		Median R^2	
	Outcome	Mazur (1987)	Myerson and Green (1995)	Mazur (1987)	Myerson and Green (1995)
Non-smoker	Money	9.11	7.57◊	.96	.98◊
	Alcohol	14.92◊	15.97	.52	.75◊
	Ent.	5.69◊	7.68	.87	.95◊
	Food	15.90	13.68◊	.63	.80◊
Smoker	Money	15.74	14.32◊	.74	.82◊
	Alcohol	17.63	16.43◊	.12	.54◊
	Ent.	12.08◊	12.99	.70	.85◊
	Food	8.31	6.94◊	.38	.61◊

Model fit comparisons for the Mazur (1987) hyperbola and Myerson and Green (1995) hyperboloid (see text). Values with diamonds indicate the better fit. For median indifference points, the AIC results indicate that the hyperboloid provided a better fit five out of eight times. Comparisons of R^2 values obtained from fitting both models to individual participant data indicate that the hyperboloid fit better in all cases than the hyperbola.

less than AIC values from the hyperbola model, indicating a superior fit, for 5 out of 8 comparisons. For model fits to the individual participant data, the right column of Table 2.2 shows the median R^2 values for the hyperboloid model were exclusively higher than for the hyperbolic model. AIC was also calculated for model fits to indifference points for each participant and commodity. AIC values indicated a superior fit for the Myerson and Green (1995) model 182 times and a superior fit for the Mazur (1987) model 78 times. For these reasons, the Myerson and Green (1995) hyperboloid model was selected for analysis.

Figure 2.1 shows the median indifference points, expressed as a percentage of the delayed reward amount at each delay, in the four delay discounting tasks for smokers and nonsmokers. The insets in the panels for alcohol, entertainment, and food constrain the *x*-axis to more clearly show the indifference points at the shortest delays. The hyperboloid decay functions (Myerson and Green 2005) were fit to the median indifference points. Table 2.3 lists the obtained best-fit parameters of Equation 1, *k* and *s* for each group and commodity as well as goodness of fit of the model, R^2. The hyperboloid model had R^2 values that were greater than .9 for seven of the eight data sets obtained, with the model performing poorly for alcohol for smokers ($R^2 = .71$).

Between-group differences in indifference points are considered next for the GLM analysis. Across outcomes, smokers discounted delayed outcomes more than did nonsmokers (significant main effect of group, $F\ (2.57, 149.22) = 8.52$, $p < .01$, $\eta\rho^2 = 0.13$), with standardized indifference points for nonsmokers averaging 0.14 greater than that of smokers. Pairwise comparisons revealed that nonsmokers' indifference points were significantly greater than those of smokers on the discounting tasks involving

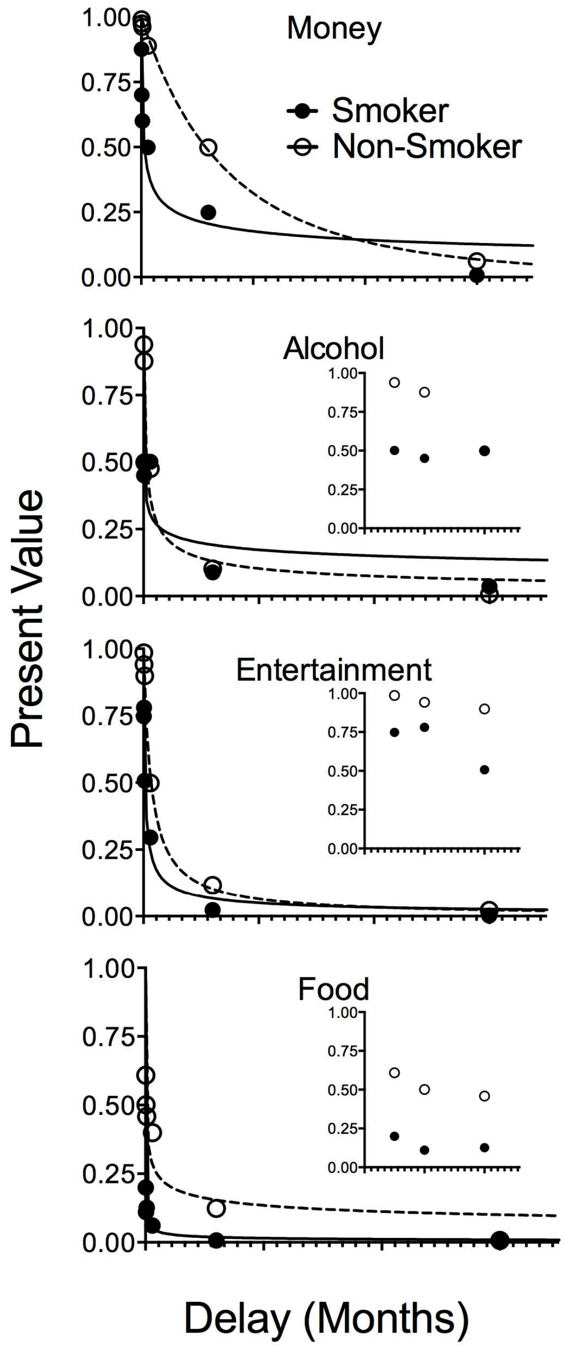

Fig. 2.1 Discounting functions for smokers and nonsmokers for the commodities of money, alcohol, food, and entertainment. In all four panels, the points show median indifference points and lines show the best fitting hyperbola like discounting function (Myerson and Green 1995). Insets for the commodities of alcohol, entertainment, and food are the same data with the *x*-axis scaled to show indifference points at the shortest delays. In some cases, data points may overlap.

Table 2.3

Hyperboloid Parameter Estimates

	Outcome	k	s	R^2
Non-smoker	Money	0.004	3.61	0.99
	Alcohol	1.30	0.47	0.92
	Entertainment	0.16	0.97	0.99
	Food	19.91	0.26	0.91
Smoker	Money	3.28	0.30	0.94
	Alcohol	66.18	0.20	0.71
	Entertainment	1.71	0.58	0.97
	Food	206.30	0.42	0.94

The *k* and *s* parameters as well as R^2 for hyperboloid model (Myerson and Green 1995) fits to median indifference points for each outcome for each group.

money (mean difference, MD = 0.22, $p < .01$) food (MD = 0.17, $p < .05$) and entertainment (MD = 0.16, $p < .05$) but not alcohol (MD = -0.03, $p = .73$). Mauchly's Test of Sphericity was statistically significant for two out of the three comparisons, indicating that the variance in the indifference points for at least one of the commodities was significantly different from that of the other commodities. Therefore, the more conservative Greenhouse-Geisser *F* test is reported. The use of the Greenhouse-Geisser *F* tests did not alter the results of the GLM.

To investigate differences in discounting of the different commodities within groups, pairwise comparisons were analyzed using mean indifference points for each outcome (Table 2.4). For nonsmokers, indifference points obtained for money were greater than indifference points obtained for alcohol and food. For smokers, the indifference points for money were greater than the indifference points for the food, but the indifference points for money were not different from those for alcohol or

Table 2.4

Mean differences in indifference points between discounting outcomes and across groups

Group	Mean Difference			
		Alcohol	Entertainment	Food
Non-smoker	Money	0.28***	0.13*	0.27***
	Food	0.05	-0.15*	
	Entertainment	0.15*		
Smoker	Money	0.03	0.07	0.20*
	Food	-0.18	-0.14	
	Entertainment	-0.04		

* p < .05, ** p < .01, *** p < .001

Mean difference of indifference points obtained from the general linear model (GLM) organized by group.

entertainment. Thus, when comparing money to other outcomes for nonsmokers, all of the commodities were significantly different than money, whereas for smokers, only food was significantly different than money. The inclusion of MAST and SOGS scores as covariates did alter these results, reducing the number of significant differences between commodities for the smokers but not the nonsmokers.

To examine whether a person's discounting of one outcome was related to discounting of another outcome, within group correlations between AUC values obtained with the different commodities were conducted (Table 2.5). The Spearman rho correlation was used because AUC was not normally distributed. All within-group correlations between commodities were statistically significant. For nonsmokers, the effect sizes for all of the correlations are in the medium range (*r* between .3 and .5). For smokers, three of the effect sizes are medium while the other three are large (*r* greater

Table 2.5

Correlation of AUC between discounting outcomes and across groups

Group	Spearman Correlations			
		Alcohol	Entertainment	Food
Non-smoker	Money	0.34*	0.41*	0.37*
	Food	0.35*	0.42**	
	Entertainment	0.37*		
Smoker	Money	0.42*	0.65**	0.50**
	Food	0.38*	0.68**	
	Entertainment	0.38*		

* p ≤ .05, ** p < .01
Spearman correlations of area under the curve by group. For both groups, AUC for one commodity was predictive of other AUC values within that group.

than .5). Therefore, within individuals, delay discounting for one commodity was associated with discounting of other commodities. That is, a person who tended to discount one outcome steeply also tended to show steep discounting for other outcomes, and a person who tended to discount one outcome shallowly also tended to show shallow discounting for other outcomes.

Discussion

Our results replicate and extend the result that cigarette smokers discount money more steeply than non-smokers do (e.g., Bickel et al. 1999; Mitchell 1999). Steeper discounting of money by smokers has been found across a variety of populations, amounts of money, delays, and procedural methods (see MacKillop et al. 2011). Furthermore, cigarette smokers discount health outcomes (Baker et al. 2003; Odum et al. 2002), as well as money for a group of people including themselves, more steeply than do non-smokers (Bickel et al. 2012a). Despite the generality of these effects, prior research has shed little light on the source of these differences. We elucidated the finding that smokers discount money more steeply than non-smokers do by extending it to food and entertainment. Smokers discount money more steeply than non-smokers, but not necessarily because money is a means to purchase cigarettes. Instead, smokers may show heightened discounting of multiple types of delayed outcomes.

In the current experiment, cigarette smokers also discounted alcohol nominally (but not significantly) more steeply than non-smokers did. There are several possible reasons for this finding. Perhaps a difference exists between their discounting of this commodity, but our measure of delay discounting was not sensitive enough to detect it. Although this explanation is plausible, we were able to detect differences in discounting with our measures with the other commodities. One possible procedural modification that could help differentiate steeply discounted commodities would be to include shorter delays to the larger-later reward. This inclusion would allow more fine-grained distinctions between discounting over shorter time frames.

Another possibility is that for some as yet unknown reason, smokers and non-smokers do not differ in the degree to which they discount alcohol, but they do differ in the degree to which they discount other things. This finding seems unlikely, but possible, given the pattern of discounting for other things, and also given the nominal but non-significant differences in discounting for alcohol. Further research is needed to determine the nature and degree of differences, if any, in delay discounting for alcohol by smokers and non-smokers.

Our results add to the growing number of findings that steeply discounting one delayed commodity is predictive of how steeply other commodities will be discounted

(Charlton & Fantino 2008; Johnson et al. 2010; Odum 2011b). For example, in a comprehensive analysis of data from prior studies, Odum (2011b) found that college students who tended to discount money steeply, also tended to discount food steeply. Similarly, opioid-dependent outpatients who showed steep discounting of money also discounted heroin steeply. Community members who discounted money more steeply similarly discounted alcohol, and discounting of money and food was related to discounting of alcohol. Finally, cigarette smokers who showed steep discounting of money also showed steep discounting of cigarettes. The results of the present study replicate and extend those from our laboratory and others showing that a person who shows precipitous loss of value with delay in one domain will also likely show similar changes in value with delay to an outcome in another domain.

Together, these results extend support for our suggestion that in addition to showing strong state (environmental) influences, delay discounting may also have a trait-like component (Odum 2011a, 2011b). A state influence is an environmental manipulation that affects behavior over a relatively short time frame (see e.g., Odum and Baumann 2010). There are robust state influences on delay discounting, including the amount of an outcome, whether it is gained or lost, and the context in which the choice is made. The present study provides a clear example of state influences on discounting in the differences between discounting for money and other outcomes. The same people, in a relatively short time frame, can show steep discounting for food, for example, and then more moderate discounting by delay with money (see also Estle et al. 2006; Odum and Rainaud, 2003; Odum et al. 2006).

Delay discounting also shows clear trait influences. A trait may be defined as 'a relatively enduring pattern of thoughts, feelings, and behaviors that reflects the tendency to respond in certain ways under certain circumstances' (Roberts 2009). To address the first part of the definition of a trait, delay discounting is relatively enduring in the sense that it is by and large stable across the time frames in which it has thus far been measured (e.g., up to one year as in Kirby 2009; see Odum 2011b for discussion). The present study and others showing strong correlations in the degree of discounting for one type of outcome and degree of discounting for another type of outcome constitute evidence for the second part of the definition of a trait, that it reflects the tendency to respond certain ways under certain circumstances.

Our interpretation of these results is consistent with the view that steep discounting is trans-disease process (Bickel et al. 2012b). The view that discounting is a trans-disease process points to patterns of steep discounting *across* many psychological disorders. The view that discounting is like a trait points to discounting patterns *within* a person that extend through time and across the outcome being discounted. A person who tends to prefer immediate but reduced benefits in one area will also tend to choose immediate but reduced benefits in another area, and have a higher risk of psychopathology. The converse is also true, that a person who prefers to wait for a larger gain in the future in one domain will also prefer to wait for a larger gain in the future in other domains, and will have a lower risk of psychopathology.

One possible limitation of the present experiment is the amount of the rewards that we used in the delay discounting assessments. For example, most people may rarely consume $100 worth of just food or alcohol at one time. While the choices in the consumable-commodity discounting tasks may have seemed less plausible than those in the monetary discounting task, Odum et al. (2006) showed that people discounted $10 worth of food more steeply than money. Because we replicated this difference between discounting of larger amounts of food and money in both the smoker and nonsmoker groups, it appears that the implausibility of consuming large amounts of food, for example, does not compromise our findings.

In general, cigarette smokers tend to consume more alcohol than do non-smokers (e.g., DiFranza and Guerrar 1990; Carmody et al. 1985). In the present study, smokers had higher MAST scores (indicating that they had greater and more problematic alcohol use) than non-smokers did. Few prior studies comparing delay discounting as a function of smoking status have reported alcohol consumption, so there is little basis in the literature to evaluate the contribution of this difference to the present results. We included MAST scores as a covariate in our analyses of indifference points, thus providing statistical control of its influence in our results. Furthermore, the results of the analyses were the same when we included MAST scores as a covariate and when we did not. Thus, it is currently unclear how concomitant alcohol use contributes to steep discounting in smokers.

In the present study, cigarette smokers also had higher SOGS scores, indicating more gambling activity and problems associated with gambling, than non-smokers. This finding is consistent with prior results showing that pathological gamblers discount more steeply and smoke more than non-gamblers (e.g., Petry 2001; Rodda et al. 2004). Future studies could include participants with a wider range of SOGS scores to address the interaction of gambling and smoking status in determining the degree of discounting of different outcomes.

In conclusion, we found that relative to non-smokers, cigarette smokers more steeply discounted delayed money, food, and entertainment. This finding is important in clarifying prior findings of more impulsive decision making for delayed money by smokers compared to non-smokers. One possibility was that because smokers can spend a substantial portion of their income on cigarettes (e.g., Steinberg et al. 2004), steeper discounting of money merely reflected the use of money to purchase cigarettes. This hypothesis was not supported. Instead, cigarette smokers also discount other outcomes more steeply than non-smokers do, suggesting that smokers may show relatively pervasive steep discounting of delayed outcomes in general.

How much a person discounts an outcome when it is delayed is a potentially powerful measure. Degree of delay discounting is associated with a variety of social maladies, including drug addiction, obesity, problematic gambling, as well as reduced academic performance, self care, and personal safety (see Bickel et al., 2012a; Odum 2011b, for a summary). Furthermore, steepness of delay discounting is predictive of a person's likelihood of initiating as well as overcoming substance abuse (e.g., Audrain-McGovern et al. 2009; MacKillop and Kahler 2009). Degree of delay discounting appears to be heritable (e.g., Anokhin et al. 2010; Madden et al. 2008; Wilhelm and Mitchell, 2009), and thus have a genetic component. Delay discounting may also be modifiable by a variety of techniques (e.g., Bickel et al. 2011; Black and Rosen 2011; Koffarnus et al. 2013; Morrison et al. *in press;* Stein et al. 2013). Thus, how much a person values an outcome when delayed could serve as an important diagnostic as well as outcome measure.

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CHAPTER III

DISCOUNTING OF QUALITATIVELY DIFFERENT DELAYED HEALTH OUTCOMES INCURRENT AND NEVER SMOKERS[2]

Introduction

The leading cause of preventable death in the United States is cigarette smoking (Centers for Disease Control and Prevention [CDC], 2012). Cigarette smoking costs an estimated $193 billion per year in the form of lost productivity and health care expenditures (CDC, 2008). While smoking is multiply controlled (Li, 2006), one variable that is commonly associated with smoking is impulsivity (e.g., Flory & Manuck, 2009; Mitchell, 1999; Nieva et al., 2011). Impulsivity encompasses several different phenomena (Broos et al., 2012; de Wit, 2008; Jentsch et al., 2014) and includes relative insensitivity to delayed outcomes, often referred to as impulsive choice.

Impulsive choice is encompassed by the process of delay discounting. Delay discounting refers to how delayed outcomes lose value (Ebert & Prelec, 2007; Mazur, 1987; Odum, 2011a). Specifically, discounting is hyperbolic: short delays produce

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relatively large decreases in value, whereas longer delays have proportionally less impact (Ebert & Prelec, 2007; Mazur, 1987; Myerson & Green, 1995). In humans, delay discounting is frequently assessed by having participants repeatedly choose between two outcomes: a smaller immediate outcome and a larger delayed outcome (see Du, Green, & Myerson, 2002). Within a block of choices, the amount of the smaller immediate outcome is manipulated across choice opportunities until an indifference point is determined. The indifference point is the amount of a smaller immediate outcome that is equal in value to the larger delayed outcome. Across blocks of trials, the delay to the larger later outcome is manipulated and indifference points are determined for each presented delay. The degree of discounting is the extent to which indifference points decrease as the delay to receiving the larger alternative increases. Impulsive choice is defined as a pattern of steep discounting (Odum, 2011a).

Delay discounting and cigarette smoking are highly related. Smokers discount delayed monetary gains more than do nonsmokers (Baker, Johnson, & Bickel, 2003; Bickel, Odum, & Madden, 1999; Friedel, DeHart, Madden, & Odum, 2014; Heyman & Gibb 2006; Mitchell, 1999; Ohmura, Takahashi, & Kitamura, 2005; Reynolds & Fields 2012; Wing, Moss, Rabin, & George, 2012; see MacKillop et al., 2011 for review and meta-analysis). Smokers also discount delayed monetary losses more than do nonsmokers (Baker et al., 2003). Additionally, smokers discount non-monetary outcomes (food and entertainment) more than do nonsmokers (Friedel et al., 2014). Furthermore, the degree of discounting across different outcome types is correlated (Friedel et al., 2014; Odum, 2011b). For example, people who discount one type of outcome steeply tend to discount other types of outcomes steeply. These correlations point towards delay discounting being a trait-like construct (Odum, 2011b). Delay discounting also relates to the likelihood of initiating cigarette smoking (Audrain-McGovern et al., 2009) and the likelihood of success in treatment for smoking cessation (Dallery & Raiff, 2007; Mueller et al., 2009). This link between discounting and smoking could be important in developing strategies for smoking prevention and treatment via methods to decrease discounting (Bickel, Yi, Landes, Hill, & Baxter, 2011; Morrison, Madden, Odum, Friedel, & Twohig, 2014).

Despite the clear evidence that smokers discount delayed tangible outcomes more steeply than nonsmokers discount those same tangible outcomes (e.g., money), it is surprisingly unclear how smokers and nonsmokers discount delayed health outcomes. Odum, Madden, and Bickel (2002) provided evidence that smokers more steeply discount temporary relief from a debilitating, incurable disease. Other studies, however, have found no difference between how smokers and nonsmokers discount health outcomes (Baker et al., 2003; Johnson, Bickel, & Baker, 2007; Khwaja, Silverman, & Sloan, 2007). Baker et al. (2003) and Johnson et al. (2007) found no difference in the degree of discounting of overall health wellness between smokers and nonsmokers. It is possible that the conflicting findings as to whether smokers and nonsmokers differentially discount health are based on whether participants are discounting temporary cures (i.e., removing illness; Odum et al., 2002) or temporary changes in health (e.g., adding wellness; Baker et al., 2003).

There are, however, two other factors that could explain the divergence in the literature in regards to how smokers and nonsmokers discount delayed health outcomes. The first factor relates to the type of health outcome and the procedures that were used across the studies to determine indifference points. Odum et al. (2002) used a questionnaire (Bickel et al., 1999) to establish indifference points for a temporary cure. Baker et al. (2003) and Johnson et al. (2007) used a variation of the titrating double limit procedure (Richards, Zhang, Mitchell, & de Wit, 1999) to establish indifference points for changes (increases and decreases) in health. The difference in these procedures may contribute to the differential outcomes across studies.

Another factor that could explain the differential results of these studies is differences in statistical power. Odum et al. (2002) found a statistically significant difference in how smokers and nonsmokers discount delayed health outcomes. While post hoc, the significant difference indicates that the study was sufficiently powered. Baker et al. (2003) and Johnson et al. (2007) report many significant relations between delay discounting and smoking status (e.g., sign effects, magnitude effects). However, the higher degrees of discounting for health outcomes by smokers relative to nonsmokers were not statistically significant. The authors calculated power, based on the nominal group differences, and reported that the studies were underpowered for these specific comparisons. A replication, with increased statistical power, may affirm the nominal differences in how smokers and nonsmokers discount delayed health outcomes reported by Baker et al. (2003) and Johnson et al. (2007).

The present experiment was designed to compare discounting of delayed temporary cures (illness removal) and delayed temporary health boosts (wellness addition) in smokers and nonsmokers. Across both health outcomes, the same procedure to determine indifference points was used. Participants were also asked about monetary gains and monetary losses as a commonly used measure of group differences between smokers and nonsmokers (e.g., Baker et al., 2003). If smokers were generally more impulsive than nonsmokers (Friedel et al., 2014; Odum, 2011b) then we would expect that smokers would more steeply discount both delayed health boosts and cures than nonsmokers. An alternative possibility is that there are differences in how smokers and nonsmokers discount delayed health cures (Odum et al., 2002) but no differences in how the groups discount delayed health boosts (Baker et al., 2003). In addition to the novel comparison of the relative degree of discounting for smokers and nonsmokers, we also examined for the first time how discounting for health outcomes was related to discounting of other outcomes within individuals.

Method

Participants

Smokers (*n* = 38) and nonsmokers (*n* = 32) were recruited for participation via flyers posted in the community, radio advertisements, and online postings in help-wanted classifieds. Potential participants initially contacted us by telephone or e-mail, depending on the type of advertisement seen, to determine if they qualified for the study. To qualify for the study, participants needed to be at least 21 years of age, occasionally drink alcohol, and meet one of the criteria to be classified as a smoker or nonsmoker. Participants were classified as smokers if they smoked at least 10 cigarettes per day (CDC, 2006); participants were classified as nonsmokers if they had smoked less than 100 cigarettes in their lifetime (CDC, 2006). If participants qualified, they were invited to participate in the study.

Procedure

All portions of the procedure were conducted in a private office containing two desk chairs, a desk, and computer. Prior to beginning any experimental tasks, we obtained informed consent from each participant and answered any questions about the study procedures. The experimental tasks were controlled by a custom-written program using E-Prime (Psychology Software Tools, Inc.). All experimental tasks were completed in one two-hour session. Upon completion of the study, participants were compensated $60 for their time. All procedures were approved by the Institutional Review Board at Utah State University.

Biological Samples. After informed consent was obtained, participants provided three biological samples. The first sample was to verify smoking status and measured expired carbon monoxide (CO) using a Micro+ Smokerlyzer (Bedfont Scientific LTD, n.d.). Smokers whose expired CO concentrations were less than 6 ppm (Bedfont Scientific LTD n.d.) and nonsmokers whose expired CO concentrations were greater than 6 ppm were allowed to complete the study but were excluded from all data analyses. The second biological sample measured recent alcohol consumption. Blood alcohol level (BAL) was assessed with an FC 10 Breathalyzer (Lifeloc). Participants with a BAL greater than 0.000 were allowed to complete the study but were excluded from all data analyses. Three self-reported smokers were excluded: two based on CO and one based on BAL. All of the self-reported nonsmokers met the CO and BAL requirements for inclusion. The final biological sample taken was saliva; data from that sample are not reported here.

Discounting Tasks. All participants completed two monetary delay-discounting tasks and two health-related delay-discounting tasks. Participants also completed four other delay-discounting tasks not related to the goals of this experiment and not reported here (manuscript in preparation; see unreported discounting tasks, below). The order in which the delay-discounting tasks were presented to participants was randomized.

In all tasks, discounting was assessed using the adjusting amount procedure initially developed by Du et al. (2002). Within a trial, participants indicated which of two options they would prefer: a smaller amount of an outcome available immediately or a larger amount of that same outcome available after a delay. The options were shown simultaneously on the screen, with the position of choice options alternating across trials. Participants indicated their choice by touching, via the touchscreen monitor, the option they would prefer. After each choice, a feedback message appeared on the screen that displayed, "You chose" followed by the text displayed on their desired choice alternative. For the first trial within a block of trials, the smaller immediate amount was set to half of the larger delayed amount. Across trials, the smaller immediate amount changed based on the participant's choices. If a participant chose the smaller immediate option then on the next trial that option was made less desirable (for example, if a participant chose $250 immediately instead of $500 after a delay, then on the next trial the immediate amount would be $125). If a participant chose the larger delayed option then on the next trial the smaller immediate option was made more desirable (for example, if a participant chose $500 after a delay instead of $250 immediately, then on the next trial the immediate amount would be $375). The amount of the first adjustment in a block of trials was equal to one fourth of the larger delayed amount. The amount of each subsequent adjustment was one half of the previous adjustment. Thus, the first adjustment was one fourth of the delayed amount, the second adjustment was one eighth of the delayed amount, the third adjustment was one sixteenth of the delayed amount, etc. A block consisted of 10 trials with a single delay to the larger delayed option. The amount of the smaller immediate option on the last trial in a block was taken as the indifference point for that delay. There were 6 blocks per discounting task and the delays in each block were presented in the following order: 1 week, 2 weeks, 1 month, 6 months, 5 years, and 25 years.

Prior to beginning the first assigned discounting task, participants were presented general instructions that applied to all tasks. The instructions read:

> You will make your selection by touching the desired button. Please note that the choices will switch sides randomly across questions. The following choices are hypothetical and you will not receive the actual outcomes. There are no "right" or "wrong" answers. Please just pick the one that you prefer. Please sit comfortably in front of the computer and touch the screen to make your choice. If you have any questions, please ask the experimenter now. We will now practice a few trials.

Ten practice trials were then presented. Practice trials were with monetary gains only. In the first practice trial participants were asked to choose between $10 delivered immediately or $100 delivered after 1 day. After each practice trial the amount of the smaller option was increased by $10. The practice trials used a different adjustment procedure than that in the test trials to minimize influence on participants' choices in test trials. Any questions the participants asked of the experimenter were answered by reiterating the relevant portion of the task instructions.

After the practice trials had been completed another instruction screen was presented, which read: “The experiment will now begin. If you have any questions, please ask the experimenter now. Touch the screen to continue.” As before, any questions participants asked of the experimenter were answered by reiterating the relevant portion of the task instructions. A touch on the screen initiated the presentation of one of the randomly selected discounting tasks. When the monetary discounting tasks were selected for presentation, they started immediately after the selection occurred. When the health discounting tasks were selected for presentation, there were breaks in the experimental program to allow the experimenter to read the specific task instructions (described below) to the participants.

Monetary gain. In the monetary gain discounting task, participants indicated their preferences for gaining $500 delivered after a delay or gaining a smaller amount of money delivered immediately. The amount of the smaller-immediate option was set to $250 on the first trial and the larger delayed option was a constant $500 across all trials. The text for the immediate choice alternative was “Gain $[adjusting amount] now” and the text for the delayed choice alternative was “Gain $500 in [delay].”

Monetary loss. In the monetary loss discounting task, participants indicated their preferences for losing $500 after a delay or losing a smaller amount of money immediately. This task was identical to the monetary gain task, with the exception that both outcomes were framed as losses. The amount of the smaller-immediate option was set to $250 on the first trial and the larger delayed option was a constant $500 across all trials. The text for each immediate choice alternative was “Lose $[adjusting amount] now” and the text for the delayed choice alternative was “Lose $500 in [delay].”

Temporary health boost. In the temporary health boost discounting task, participants indicated their preference for gaining a longer duration of temporary wellness (i.e., 10% better health) after a delay or gaining a smaller amount of temporary wellness immediately. When this task was selected for presentation, the computer screen displayed the text, "Please contact the experimenter to continue." When notified by the participant, the experimenter entered the room, advanced the program, and read aloud the task instructions that were displayed to the participant. The instructions used here are identical to the instructions used by Baker et al. (2003) except that the monetary amount used in this study was $500.Those instructions were:

> I want you to think about your health over the past month. Now I want you to imagine that you have a choice between receiving some amount of money and temporarily feeling 10% better. That means you would feel more alert, have more energy, be physically stronger, have less body fat, and be less likely to become sick. However, this 10% increase in your health would only be temporary and then you would return to your current state of health. Receiving $500 right now would be just as attractive as experiencing how much time of 10% better health?

After finishing reading the task instructions to participants, the experimenter then asked, "In other words, if you had to pay $500 dollars to have 10% better health, how long do you think the 10% boost should last?" The rephrasing of the question displayed in the instructions was an attempt to ensure that all participants understood the instructions. Any remaining questions were answered by restating the relevant portions of the instructions or by reiterating the re-phrasing previously described. To provide a response to the question, participants were instructed to type a number and then choose the corresponding time unit: days, weeks, months, or years. This response (typing a value and selecting the unit for that value) was an analogue to the response used by Baker et al. (2003), in which participants wrote a value and then circled the unit on a sheet provided by the researchers. Once participants entered their response, the screen displayed the text: "You said that $500 for a 10% boost in your health should be: [number and time unit {for example, 6 weeks}] long. Press the 'y' button if this is correct. Press the 'n' button if this is incorrect." The participant then made their response on the keyboard. If a participant responded on the "n" key then the instructions were displayed again and the process of entering a value and a time unit for that value was repeated. If the participant pressed the "y" key the delay-discounting portion of the task was initiated.

At the start of the delay discounting task the value of the larger delayed alternative was set to the participant's response during the instruction portion of the task (e.g., 6 weeks of a boost) and the smaller immediate alternative was set to one half of that value (e.g., 3 weeks of a boost). The text for the immediate choice alternative was "[adjusting duration] of a boost now" and the text for the delayed choice alternative was "[larger fixed duration] of a boost in [delay]." The portion of the instructions detailing the health boost was displayed centered and at the top of the screen during each trial.

Temporary cure. In the temporary cure discounting task, participants indicated their preference for gaining a longer duration of temporary illness removal after a delay or gaining a shorter duration of temporary illness removal immediately. The procedures for the temporary cure task were similar to those for the temporary health boost task, described above, with different instructions and different text during the discounting portion. This task was designed to be similar to Odum et al. (2002). The instructions read:

> For the last 2 years, you have been ill because at some time in the past you had unprotected sex with someone you found very attractive, but whom you did not know. Thus, for the past 2 years, you have come down with a lot of colds and other ailments, some of which have required hospitalization. You have lost a lot of weight and are getting increasingly thin. Some friends do not come to see you anymore because of your disorder and those that do feel uncomfortable being with you. Imagine that without treatment you will feel this way for the rest of your life and that you will not die during any of the time periods described here. Receiving $500 right now would be just as attractive as experiencing how much time of a cure?

Participants indicated the duration of the cure that was equivalent to $500 as described above.

At the start of the delay discounting task the value of the larger delayed alternative was set to the participant's response during the instruction portion of the task (e.g., 6 weeks of a cure) and the smaller immediate alternative was set to one half of that value (e.g., 3 weeks of a cure). The text for the immediate choice alternative was "[adjusting duration] of a cure now" and the text for the delayed choice alternative was "[larger fixed duration] of a cure in [delay]."

Unreported delay discounting tasks. Participants also completed four discounting tasks to assess discounting of consumable commodities presented in a random order and as a whole block. This block of unreported discounting tasks was presented randomly either before or after the discounting tasks reported above. Data from the commodity discounting tasks are not presented here, because these tasks were administered for a separate study conducted at the same time.

Demographics Questionnaires. After completing all discounting assessments, participants reported their age, sex, race, ethnicity, monthly income, marital status, and highest level of education achieved. They then completed a series of questionnaires (described below) in the following order.

South Oaks Gambling Screen. The South Oaks Gambling Screen (SOGS; Lesieur & Blume, 1987) consists of 36 items that assess gambling behavior (e.g., “In your lifetime, how often have you gone to a casino (legal or otherwise)?”). Responses on the questionnaire take a variety of forms (yes/no, frequency, etc.). Scores on the SOGS range from 0-20, with higher scores indicative of greater frequency of gambling and gambling-related problems. The internal consistency with our sample was acceptable (α = .74).

Alcohol Use Disorder Identification Test. The Alcohol Use Disorder Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993) consists of 10 items and assesses frequency and amount of alcohol consumption, behavior related to drinking, and problems related to alcohol use (e.g., “How often do you have a drink containing alcohol?”). The majority of responses are on a 5-point Likert scale, with 0 corresponding to the lowest frequency and 4 corresponding to the highest possible frequency. Scores on the AUDIT range from 0-40. The internal consistency of the items in our sample was acceptable (α = .81).

Eating Disturbance Scale. The Eating Disturbance Scale (EDS-5; Rosenvinge et al., 2001) consists of 5 items that measure beliefs about eating and problematic eating behaviors (e.g., "Are you happy with your eating habits?"). Responses occur along a 7-point Likert scale with 1 representing very satisfied or never and 7 representing very unsatisfied or everyday. Scores on the EDS range from 5-35. The internal consistency of the items in our sample was acceptable (α = .68).

Information Inventory. The Information Inventory (II; Altus, 1948) consists of 13 items and measures general knowledge base by asking a variety of questions in categories such as history, vocabulary, etc. (e.g., "How many inches are in a meter?"). All questions are open-ended. Scores on the inventory range from 0-30. The internal consistency of the items in our sample was acceptable (α = 0.71).

Fagerström Test for Nicotine Dependence. The Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991) consists of 6 items and assesses severity of nicotine dependence in smokers (e.g., "How soon after waking do you smoke your first cigarette?"). The response format is multiple choice and yes/no. Scores on the survey range from 1-10. The internal consistency of the items in our sample was acceptable (α = .72). Only cigarette smokers completed this questionnaire.

Analysis

The Mazur (1987) hyperbola and Rachlin (2006) hyperboloid models were fit to the median group indifference points for each delayed outcome via curvilinear regression (Graphpad Prism®):

$$V = \frac{A}{1 + kD^s} \qquad \text{(Equation 3.1)}$$

where *V* is the value of the delayed outcome, *A* is the amount of the delayed outcome, *D* is the delay to the outcome, *k* is the degree of discounting, and *s* is a scalar of delay. With the Rachlin (2006) model of delay discounting, *s* is constrained inclusively between the values of 0 and 1. The Mazur (1987) model is identical to the Rachlin (2006) model except it does not include the exponent *s* (which is functionally the same as $s = 1$). The Akaike Information Criterion (AIC; Akaike, 1974) was used to select the highest quality model for group data. AIC is a measure of the relative quality of a model that accounts for the tradeoff in the goodness of fit of a model and the complexity of that model. The smallest AIC value indicates the highest quality model. We did not use R^2 to select the best fitting model because it is not an appropriate measure of goodness of fit for curvilinear models (see Johnson & Bickel, 2008 for discussion as this relates to delay discounting).

The highest quality model for the median indifference points per group (smokers vs. nonsmokers) for each outcome (monetary gain, temporary cure, etc.) was then fit to the indifference points obtained from each participant for that group and outcome (see Franck et al., 2015). By convention (e.g., Myerson & Green, 1995), R^2 was reported for individual participant data. We did not use the free-parameter *k* for statistical analysis because within the Rachlin hyperboloid (which was favored for some outcomes), *k* does not provide an independent measure of discounting due to its interaction with the *s* parameter. Analysis of *k* when only the Mazur (1987) model was fit to participant data (i.e., *s* was constrained to 1), without regard to which model provided a better fit to the data, produced a similar pattern of results for delay discounting differences as described below for indifference points but is not reported due to redundancy.

We also calculated the Effective Delay 50% (ED-50; Yoon & Higgins, 2008) for each group and outcome. An ED-50 is the delay at which the outcome has lost half of the present value (for the formulae used based on various models of discounting, see Franck, Koffarnus, House, & Bickel, 2015). This measure is helpful because it provides a metric of delay discounting that can be calculated for any model of delay discounting and is easily interpretable.

To investigate differences in the indifference points across groups and outcome type a Generalized Estimating Equation (GEE) was used as a repeated measures regression technique. GEE computes ANOVA-like pairwise comparisons for specific between- and within-group analyses. The pairwise comparisons are also Bonferroni corrected to account for multiple comparisons. GEE is appropriate for this analysis because it is robust against violations of normality, controls for the inter-correlation between dependent variables, and can examine between- and within-group differences within a single analysis (Hanley, Negassa, Edwardes, & Forrester, 2003). In effect, for these data the GEE is conceptually a more robust version of a repeated measures ANOVA. The use of GEE on indifference points provides higher power than a repeated measures ANOVA on *k*-values (as in Baker et al., 2003). All statistical analyses were conducted with Bonferonni corrections to ensure a constant familywise Type I error rate of $\alpha = .05$.

Results

Demographic characteristics and questionnaire scores for smokers and nonsmokers are reported in Table 3.1. Chi-squared tests did not reveal differences in the distribution of sex and ethnicity between smokers and nonsmokers. The groups did differ on highest level of obtained education and AUDIT (problematic alcohol use) scores. The difference in scores on the Information Inventory approached conventional levels of statistical significance ($t_{(69)} = 1.80$, $p = .07$). To be conservative in our analyses, these three variables (education, AUDIT and Information Inventory scores) were included as covariates in the GEE. There was no significant difference in the durations of health reported to be equivalent to \$500 (i.e., the outcome being discounted) for the temporary cure or health boost scenarios (data not shown). There were also no significant differences in the durations of health reported to be equivalent to \$500 by smokers and nonsmokers (data not shown).

Figure 3.1 shows that median indifference points within each group and outcome decreased as the delay to receiving each outcome increased. In general, indifference points for smokers decreased more so with delay than did indifference points for nonsmokers. To determine the highest quality model for the median indifference points for each outcome, the Mazur (1987) hyperbolic and Rachlin (2006) hyperboloid models were compared using AIC for group data. Median R^2 for individual participant data are reported by convention. Table 3.2 displays the results of the model fit analyses for each group and discounting outcome. AIC favored the Rachlin hyperboloid model for four of the eight outcomes: non-smoker health boost, smoker money gain, smoker health cure,

Table 3.1

Nonsmoker and Smoker Demographics

	Non-Smoker (SE)	Smoker (SE)	*t*
Caucasian	90%	81%	
Male	57%	70%	
Education[a]	3.33 (0.06)	2.49 (0.18)	2.81**
Age (years)	37.10 (2.35)	39.41 (2.11)	-0.73
Monthly Income ($)	2,155 (347.92)	1,595 (338.85)	1.14
Information Inventory	8.67 (0.67)	7.24 (0.48)	1.80
Alcohol Use Disorder Identification Test	5.63 (0.71)	14.51 (1.23)	-5.91***
South Oaks Gambling Screen	9.17 (1.15)	8.97 (0.93)	0.13
Eating Disturbance Scale	17.03 (1.30)	17.62 (1.26)	-0.32
Carbon Monoxide (ppm)	1.79 (0.15)	11.14 (0.69)	-12.51***

Means and standard errors for demographics, questionnaire results, and CO levels, separated by groups.
* $p < .05$, ** $p < .01$, *** $p < 0.001$
[a] Participants were asked about their highest level of obtained education: 1=did not complete high school, 2=high school degree or equivalent, 3=associate degree, 4=bachelors degree, 5=graduate degree, 6=doctorate degree or equivalent.

and smoker health boost. Median R^2 values obtained from individual model fits were higher for the Rachlin hyperboloid for six of the eight outcomes; there was no difference in median R^2 for the other two outcomes. For nonsmokers the AIC scores indicated that the Mazur (1987) was the highest quality model for monetary gains, monetary losses, and temporary cures and the Rachlin (2006) was the highest quality model for temporary health boosts. For smokers, the Mazur (1987) was the highest quality model for monetary losses while the Rachlin (2006) was the highest quality model for monetary gains, temporary cures, and temporary health boosts. Table 3.3 includes the parameter estimates for the highest quality model for each group and outcome (see Franck et al., 2015). The parameters in Table 3.3 were those used to create the lines of best fit in Figure 3.1.

To identify differences in indifference points by outcome between- and within-groups, a GEE analysis was conducted (described in the analysis section). An auto-regressive correlation matrix for the GEE was chosen because of the observed trend of decreased correlation between indifference points as the temporal distance between those points increased. An exploratory GEE model was created that included main effects for

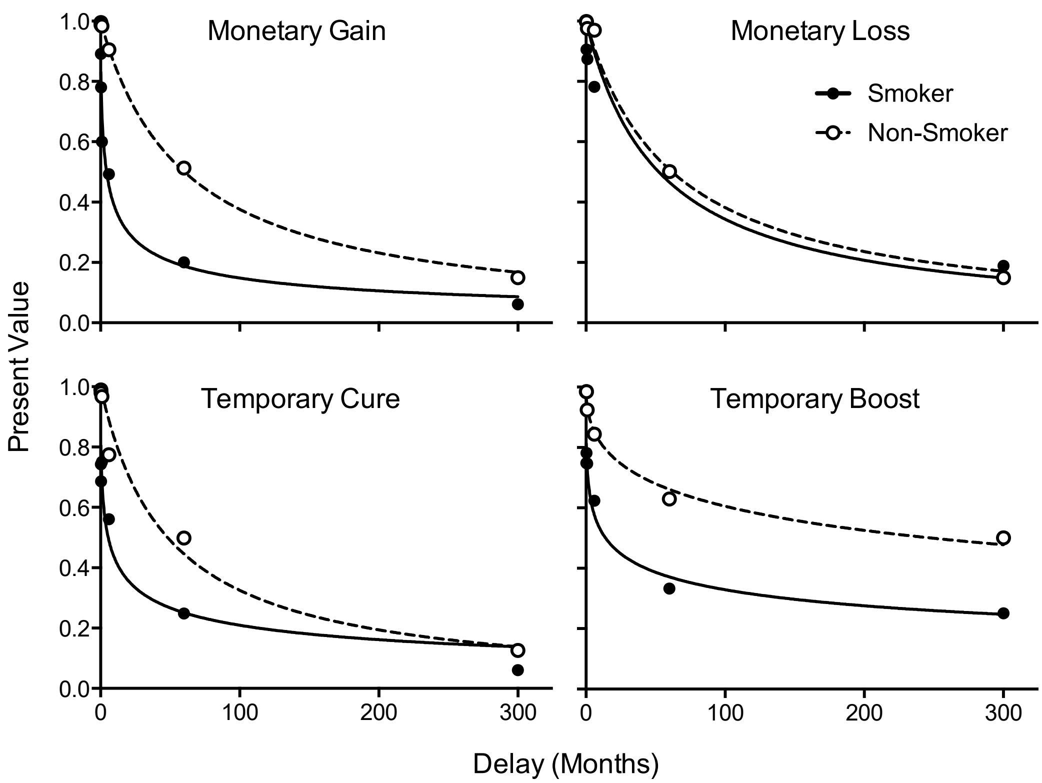

Figure 3.1. Delay discounting curves for median indifference points for smokers and nonsmokers and for each outcome. Model fits to the data from smokers and nonsmokers for four delay discounting outcomes. Present value is expressed as a proportion of the undiscounted amount of the delayed outcome. For each line, the highest quality model is shown. See text and Table 3.2 for model selection.

Table 3.2

Model Fit Comparisons of Mazur (1987) and Rachlin (2006) to Group (AICc) and Individual Indifference Points (R^2*)*

	Outcome	Group AICc Mazur (1987)	Group AICc Rachlin (2006)	Individual R^2 Mazur (1987)	Individual R^2 Rachlin (2006)
Non-Smoker	Money Gain	-48.46◊	-38.46	0.93	0.95◊
	Money Loss	-35.89◊	-25.89	0.93	0.93
	Health Cure	-27.38◊	-20.53	0.93	0.93
	Health Boost	-20.67	-26.76◊	0.70	0.95◊
Smoker	Money Gain	-17.86	-18.05◊	0.74	0.91◊
	Money Loss	-22.92◊	-21.84	0.80	0.88◊
	Health Cure	-14.41	-15.38◊	0.49	0.87◊
	Health Boost	-12.71	-21.43◊	0.69	0.86◊

Values with diamonds indicate the better fit. AIC scores reflect median group indifference points. For AIC, the lowest value indicates the superior model. R^2 values are the median R^2 values obtained from fitting each model to each participant's indifference points.

the final model but remained as covariates for the post hoc adjusted mean indifference point pairwise comparisons. Participant sex was also included in the exploratory model but there was no main effect of sex and using sex as a covariate did not lead to any differences in the results of the GEE. For these reasons, sex was left out as both a factor and covariate in the final GEE model.

Smoking status and the commodity discounted influenced indifference points. In general, indifference points obtained from cigarette smokers were lower than indifference education, AUDIT and Information Inventory scores. However, these variables were not significant predictors of adjusted mean indifference points for either group. In order to report the most parsimonious model, these measures were removed as main effects from

Table 3.3

Model Fits and Parameter Estimates to Median Indifference Points for Best Fitting Model

	Outcome	k	s	R^2
Non-smoker	Money Gain	0.02	-	0.99
	Money Loss	0.02	-	0.99
	Health Cure	0.02	-	0.97
	Health Boost	0.07	0.47	0.98
Smoker	Money Gain	0.44	0.56	0.97
	Money Loss	0.02	-	0.93
	Health Cure	0.46	0.46	0.94
	Health Boost	0.38	0.36	0.97

Model fit values to median group indifference points. The *s* parameter is only reported when the Rachlin (2006) was the better fitting model. See text and Table 3.2 for model selection.

points obtained from nonsmokers, indicated by a main effect of smoking status on indifference points ($\beta = 0.18$, $z = 10.04$, $p < .01$). This finding indicates that, on average, being a smoker resulted in a 0.18 decrease in the adjusted mean indifference point compared to the indifference point for a nonsmoker, indicating smokers were more impulsive than nonsmokers. In general, adjusted mean indifference points for all participants were affected by the outcome discounted, indicated by a main effect of outcome type on indifference points ($\beta = 0.13$, $z = 7.78$, $p < .001$). This β value should be interpreted with caution, as it only informs that there were differences between outcomes but it does not describe where those differences occurred. Pairwise comparisons (reported below) evaluate indifference points by outcome within smokers and nonsmokers.

To investigate the differences across particular outcomes between smokers and nonsmokers, pairwise comparisons were conducted. Table 3.4 reports adjusted mean

Table 3.4

Adjusted Mean Differences for Indifference Points by Group and Outcome

	Adjusted Mean Indifference Point (SE)		
	Smoker	Non-smoker	Mean Difference
Money Gain	0.35 (0.04)	0.53 (0.05)	-0.16 (0.06)*
Money Loss	0.63 (0.04)	0.68 (0.03)	-0.05 (0.05)
Health Cure	0.56 (0.04)	0.75 (0.04)	-0.19 (0.06)**
Health Boost	0.73 (0.04)	0.91 (0.04)	-0.18 (0.06)**

* $p < .05$, ** $p < .01$, *** $p < .001$
Note. Comparisons are Bonferroni-corrected for multiple comparisons. Alcohol Use Disorder Identification Test, Information Inventory, and education scores included as covariates.

indifference points for each group and commodity, differences between the groups for each outcome, and the corresponding statistical significance of those differences. Cigarette smokers had lower indifference points for monetary gains (MD = -0.16, $p < .05$), health cures (MD = -0.19, $p < .01$), and health boosts (MD = -0.18, $p < .01$) compared to nonsmokers, indicating smokers were more impulsive for these outcomes. There was no significant difference between indifference points for smokers and nonsmokers for monetary losses (MD = -0.05, $p = .28$).

Within-group pairwise comparisons were conducted to determine differences in how each outcome was discounted. Table 3.5 contains the adjusted mean differences between each outcome within each group as well as the statistical significance of those differences. For both groups, the discounting of monetary gains was steeper than the discounting of monetary losses (*p*s < .001). For both groups, the discounting of a temporary cure was also discounted more steeply than a temporary boost in health (*p*s < .001). Finally, for both groups monetary gains were discounted more steeply than both temporary cures and temporary health boosts (*p*s < .001).

Table 3.5

Adjusted Mean Differences for Indifference Points by Outcome for Each Group

		Mean Difference		
		Money Loss	Health Cure	Health Boost
Non-smoker	Money Gain	-.15***	-.22***	-.37***
	Health Boost	.22***	.15***	
	Health Cure	.07		
Smoker	Money Gain	-.27***	-.20***	-.37***
	Health Boost	.10	.16***	
	Health Cure	-.06[a]		

* $p < .05$, ** $p < .01$, *** $p < .001$
Note. Comparisons are Bonferroni-corrected for multiple comparisons. Alcohol Use Disorder Identification Test, Information Inventory, and education scores included as covariates. Values are the mean adjusted indifference point for the row minus the mean adjusted indifference point for the column. Lower values indicate higher rates of discounting for the row outcome. For example, the bottom most value, *a*, is the adjusted mean indifference point for health cures minus the adjusted mean indifference point for monetary losses for the smoker group.

The correlation of discounting for one outcome to all other outcomes was completed with a partial correlation on the adjusted mean indifference point for both smokers (Figure 3.2) and nonsmokers (Figure 3.3). Overall, indifference points across the four outcomes were highly positively correlated within groups, indicating that how participants discounted one outcome was related to how they discounted other outcomes. That is, a person who showed relatively steep discounting for one outcome was likely to show relatively steep discounting for another outcome, and similarly, a person who showed relatively shallow discounting for one outcome was likely to show relatively shallow discounting for another outcome. However, for nonsmokers, discounting of

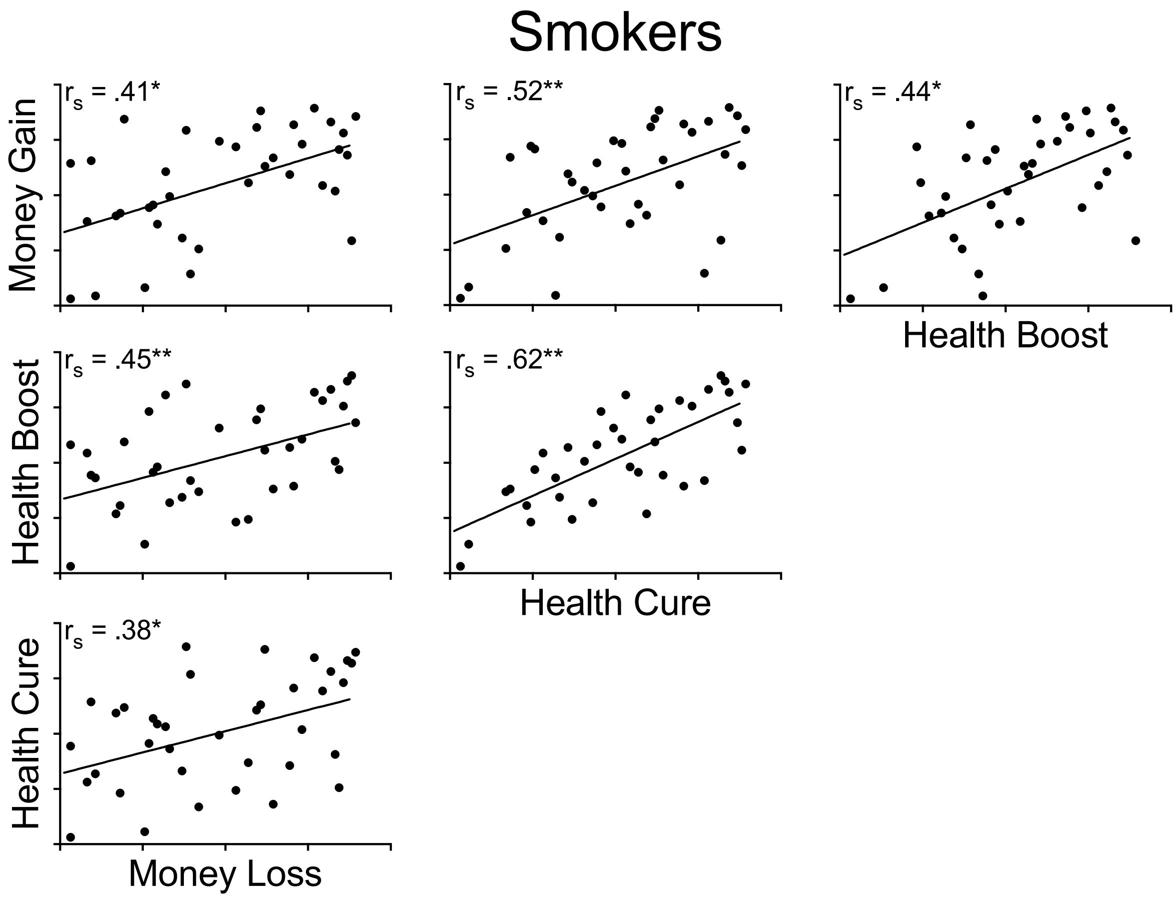

Figure 3.2. Matrix of scatter plots of smoker adjusted mean indifference point ranks for each pairwise outcome. Each plot contains Spearman's Rho correlation coefficient and line of best fit. Alcohol Use Disorder Identification Test, Information Inventory, and education scores included as covariates. Axes on each figure are the rank of the mean adjusted indifference points. *Note*: * $p < .05$, ** $p < .01$

delayed monetary losses was not associated with discounting of either temporary health cures or temporary health boosts.

Discussion

In this study, we compared how cigarette smokers and nonsmokers discounted qualitatively different types of health outcomes (i.e., temporary cures and temporary

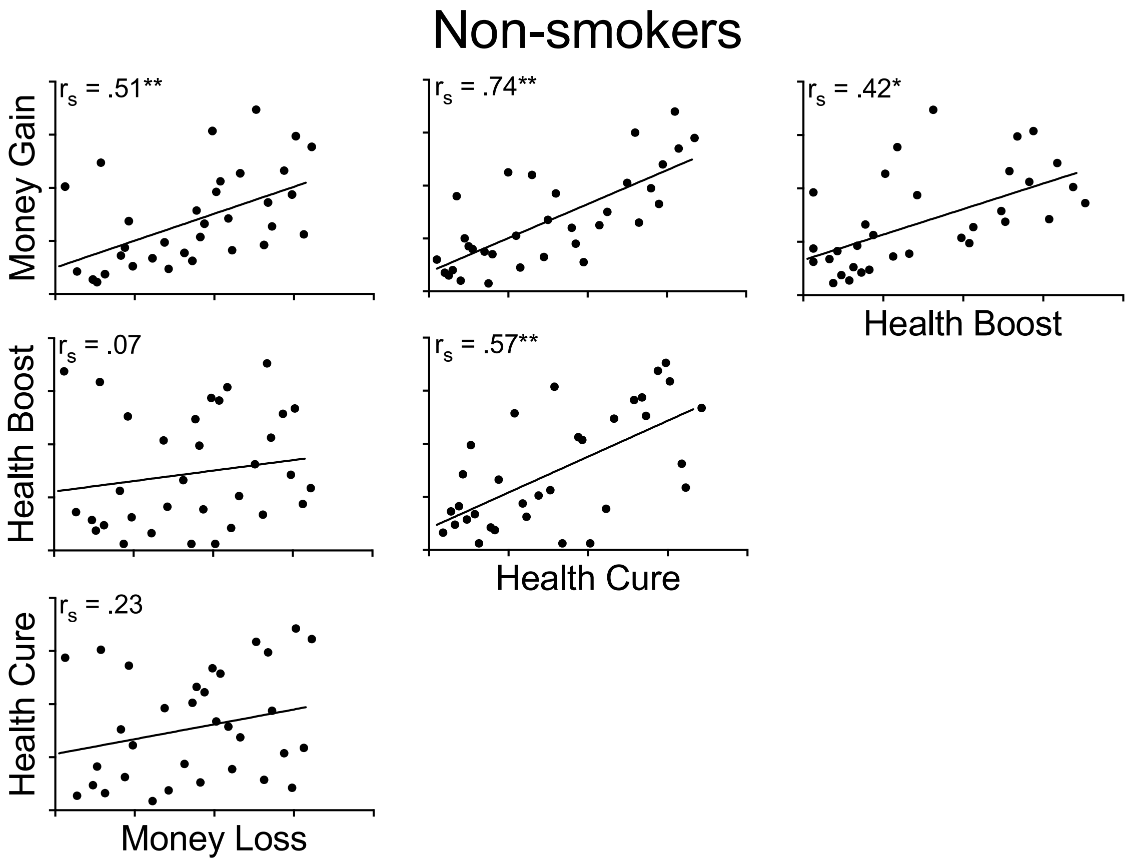

Figure 3.3. Matrix of scatter plots of nonsmoker adjusted mean indifference point ranks for each pairwise outcome. Each plot contains Spearman's Rho correlation coefficient and line of best fit. Alcohol Use Disorder Identification Test, Information Inventory, and education scores included as covariates. Axes on each figure are the rank of the mean adjusted indifference points. *Note*: * $p < .05$, ** $p < .01$

health boosts), monetary gains, and monetary losses. This is the first study to investigate how smokers and nonsmokers discount qualitatively different health outcomes. We replicated the finding that smokers more steeply discount monetary gains and temporary cures than do nonsmokers. We also found that smokers more steeply discount temporary health boosts when compared to nonsmokers. This finding confirms the nominal but non-significant differences in discounting of health boosts that have been previously found between smokers and nonsmokers (Baker et al., 2003; Johnson et al., 2007). We also found correlations in steepness of discounting for monetary gains, monetary losses, health boosts, and temporary cures. These novel correlations extend our previous findings that how steeply a person discounts one tangible outcome correlates with how steeply that person discounts other tangible outcomes (Friedel et al. 2014; Odum, 2011b).

We found that smokers discount delayed monetary gains more than nonsmokers do. When comparing delay discounting of smokers and nonsmokers it is regularly found that smokers more steeply discount monetary gains than nonsmokers (e.g., Bickel et al., 1999; MacKillop et al. 2011; Mitchell, 1999). The fact that we were able to replicate this well-supported finding illustrates that our measures were sensitive to the construct of interest and that we had appropriate power to detect significant differences in our dataset. We also found that smokers and nonsmokers discount delayed monetary losses less steeply than delayed monetary gains. This replicates the common asymmetry in how delayed gains and losses are discounted for both smokers and nonsmokers (e.g., Baker et al., 2003; Estle, Green, Myerson, & Holt, 2006; Johnson et al., 2007)

Our results provide evidence that smokers discount health consequences more steeply than nonsmokers. Specifically, we found that both temporary cures and temporary boosts are discounted more steeply by smokers than by nonsmokers. This replicates the findings of Odum et al. (2002) that smokers discount delayed health cures more than nonsmokers. The finding that smokers also discount temporary health boosts more than nonsmokers affirms the nominal difference reported by Baker et al. (2003) and Johnson et al. (2007). In this study, we find no evidence to support the alternative explanation that smokers more steeply discount delayed health cures but do not differentially discount delayed health boosts when compared to nonsmokers.

Smokers are generally aware of the health risks associated with smoking (Oncken, McKee, Krishan-Sarin, O'Malley, & Mazure, 2005) and many advertising campaigns focused on changing smoking behavior have focused on the health benefits of quitting. One factor in the persistence of smoking, despite knowing the risks, seems to be the greater discounting of both the delayed negative health consequences associated with continued smoking and the delayed positive health consequences associated with abstinence. Perhaps advertising campaigns targeting smoking cessation would be better served with a message that focuses on both the temporally proximal as well as temporally distal consequences of smoking cessation. For example, an advertising campaign on smoking cessation could focus on factors like the more immediate decrease in the risk of heart attack and stroke (Lightwood & Glantz, 1997) as well as the long-term decrease in the risk of lung cancer.

These findings support and extend prior findings that smokers show a trait-like pattern of steep delay discounting across a variety of outcomes, including non-tangible health outcomes (the present study), consumable commodities (Friedel et al., 2014), and money (Bickel et al., 1999; Mitchell, 1999; Baker et al., 2003). How nonsmokers discount one outcome is also correlated with how they discount other outcomes (see Charlton & Fantino, 2008; Odum, 2011b). These studies all support the notion that delay discounting is a trait-like phenomenon (Odum, 2011b) and that when a person steeply discounts one delayed outcome they are likely to steeply discount other types of delayed outcomes.

The understanding of delay discounting as a trait is consistent with the view that delay discounting is a trans-disease process (Bickel, Jarmolowicz, Mueller, Koffarnus, &

Gatchalian, 2012). Delay discounting as a trans-disease process identifies that many people diagnosed with psychosocial disorders tend to have higher degrees of discounting. Delay discounting as a trait-like phenomenon is based on evidence that across different outcomes, how steeply a person discounts one outcome is highly related to how they discount other outcomes and that how steeply a person discounts is stable over long periods (e.g., Kirby, 2009).

The present study also provides supporting evidence that delay discounting is affected by state variables. A state variable is some environmental factor that affects behavior over a relatively short time frame (see Odum & Baumann, 2010). There are several environmental manipulations that can affect delay discounting. For example, Friedel et al. (2014) found that the type of consumable commodity affected the steepness of discounting in both smokers and nonsmokers. Monetary gains and losses are also discounted differentially (e.g., Baker et al., 2003; the present study). Another state level variable that can affect delay discounting is how the hypothetical delays are framed. Framing the delay in terms of a concrete date in the future (for example, saying "January 1, 2030" instead of "25 years from now") significantly decreases delay discounting (DeHart & Odum, 2015; Read, Frederick, Orsel, & Rahman, 2005). There is thus clear evidence that delay discounting has both trait-like features and state-based features.

One limitation of this experiment is the specific health outcomes that we used. We directly replicated the health tasks used by Odum et al. (2002), Baker et al. (2003), and Johnson et al. (2007). The health outcomes that were developed in these studies are relatively complex scenarios when compared to asking a participant to choose between a small amount of money and a large amount of money. The fact that we had to have experimenters available to ensure that the instructions for the health discounting tasks were understood provides some evidence of the relative difficulty of the task. The health boost outcome is also particularly nebulous when compared to the cure outcome: what does it mean to be and/or feel 10% better? Despite these complexities, the health discounting tasks result in orderly data that are similar in kind to other delay discounting data. Furthermore, the general findings with these tasks are replicable across studies and laboratories. Additionally, discounting of health outcomes is correlated with discounting of other outcomes. Despite these positive aspects of the procedures, development of simpler health discounting tasks could be helpful in future research.

Another possible limitation of this study is that all of the outcomes were hypothetical, as is common to use when outcomes are ethically or feasibly not possible to deliver (see Odum, 2011a). Furthermore, the participants did not likely have extensive experience with the health outcome scenarios. Most people are not routinely faced with scenarios in which they have a debilitating disease and must choose either a shorter duration of relief now or a longer duration of relief later. Despite this limitation of hypothetical outcomes, the delayed health outcomes were devalued in a hyperbolic like pattern similar to how other outcomes are devalued. Our study does not address the question as to whether hypothetical outcomes are discounted differently than real outcomes. However, there is evidence of strong similarities between discounting of hypothetical outcomes and real outcomes (Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003; Madden et al., 2004). It is possible that choices for hypothetical outcomes may yet be found to lead to different degrees of discounting relative to choices for real outcomes. However, inasmuch as our participants are verbal organisms and verbal behavior can profoundly affect other behavior (Hayes, Barnes-Holmes, & Roche, 2001) the verbal scenarios and consequences that are used in discounting tasks produce reliable results that do not seem to differ substantially from those made with actual outcomes where such comparison is possible.

Another limitation is that we found significant differences in alcohol consumption between smokers and nonsmokers. This finding is problematic because alcohol usage is related to the degree of discounting. People who abuse alcohol more steeply discount delayed outcomes than control participants (e.g., Petry, 2001; Mitchell, Fields, D'Esposito, & Boettiger, 2005) and heavy drinkers discount delayed outcomes more than light drinkers (Vuchinich & Simpson, 1998). Alcohol use is also linked to cigarette smoking, in general. In this study, we found that smokers had higher overall AUDIT scores, indicating more problematic alcohol consumption. This replicates prior studies showing cigarette smokers tend to consume more alcohol than nonsmokers (e.g., Carmody, Brischetto, Matarazzo, O'Donnell, & Connor, 1985; DiFranza and Guerrera, 1990) and that smokers tend to have more problematic drinking as measured by the Michigan Alcohol Screening Test (Friedel et al., 2014). Within our analyses in this study, AUDIT scores were included as a covariate providing statistical control for the difference in alcohol usage. To separate the possible effects more clearly, future studies examining alcohol use and delay discounting could match participants based on cigarette usage, and studies examining cigarette smoking and delay discounting could match participants based on alcohol usage.

We also found significant differences in the highest level of formal education received between smokers and nonsmokers. Some studies have found no difference in overall educational level between smokers and nonsmokers (see Friedel et al., 2014) and between light and nonsmokers (Johnson et al., 2007) or have matched education level between smokers and nonsmokers (Bickel et al., 1999). However, other studies have found cigarette smokers have received less formal education than nonsmokers (see, Ohmura et al., 2005; Flory & Manuck, 2009). There is also evidence that educational level is a predictor of the degree of discounting in smokers (Wilson et al., 2015). A difference in level of education could be particularly relevant in our study because, as we discussed above, the health outcomes were relatively complex. We did include educational level as a covariate in all of our analyses providing statistical control for the effects of education on discounting. A post-experimental comprehension test would have been useful to determine if there was some interaction between education level and comprehension of the health outcomes. Future studies that examine the discounting of health outcomes would benefit from matching participants based on education level.

Delay discounting is a potentially important measure for various psychosocial disorders (see Odum, 2011b; Bickel et al., 2012). As discussed above, the present study provides further support for the notion that smokers generally discount delayed outcomes more than nonsmokers discount those same outcomes (see also Friedel et al., 2014). Delay discounting as a measure is important because it is predictive of cigarette use initiation (Audrain-McGovern et al., 2009) as well as the likelihood of success for smoking cessation treatment (Dallery & Raiff, 2007; MacKillop & Kahler, 2009; Mueller et al., 2009). These findings also indirectly support efforts to develop methods that rapidly assess delay discounting (e.g., Gray, Amlung, Acker, Sweet & MacKillop 2014; Koffarnus & Bickel, 2014). Our findings support the idea that such an assessment provides a general measure of impulsive choice beyond the specific outcomes assessed. If delay discounting describes a persistent, trait-like pattern of behavior then efforts to change delay discounting (Bickel et al., 2011; Morrison et al. 2014) for one outcome should generalize to other outcomes. This is particularly important if addiction and other psychosocial vulnerabilities are related to excessive delay discounting (Bickel et al., 2012).

In conclusion, we found that smokers discount delayed health outcomes more steeply than do nonsmokers, and that the degree to which a person discounts one outcome is highly related to the degree to which they discount other outcomes. This study extends our previous work (Friedel et al., 2014) and demonstrates that smokers are generally more impulsive for both tangible and non-tangible outcomes. Finally, this study supports our assertion that delay discounting describes a consistent pattern of behavior within an individual (Friedel et al. 2014; Odum, 2011b).

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CHAPTER IV

THE ADDITIVE UTILITY MODEL OF DELAY DISCOUNTING AND QUALITATIVELY DIFFERENT OUTCOMES

Introduction

For humans, opportunities to engage in impulsive or self-controlled choices are an important feature of our lives. We must frequently choose between smaller, immediate outcomes and larger but delayed outcomes. Delay discounting is the process that describes how the delay to an outcome affects a person's choice for that outcome. The degree of delay discounting in one domain is predictive of delay discounting in other domains (Friedel, DeHart, Frye, Rung, & Odum, 2016; Friedel, DeHart, Madden, & Odum, 2014; Odum, 2011b). Of practical concern, higher degrees of delay discounting are related to a variety of psychosocial maladies such as drug abuse, gambling, and obesity (see Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatachalian, 2012 for review). Taken together, these findings indicate that delay discounting describes a pervasive pattern of behavior that is linked to various problematic psychosocial behaviors.

More precisely, delay discounting is the process by which delayed outcomes lose value (e.g., Mazur, 1987). Delay discounting relates to impulsive choice because organisms choose the alternative that has the highest value at the time the choice is made (e.g., Ainslie, 1974). If a delayed, larger outcome has a lower value than an immediate, smaller outcome, then organisms will choose the immediate alternative. A relatively high degree of impulsive choice could also be accurately described as delayed outcomes having relatively little value.

One way to assess the degree to which delayed outcomes lose value is to determine indifference points. An indifference point is the amount of the smaller, immediate outcome that is equal in value to the larger, delayed outcome. When the values of the two outcomes are equal then the participant should have no preference between those outcomes. In other words, the participant is indifferent between those outcomes. Several indifference points are generally determined across a range of delays to the larger, later outcome. With an array of indifference points, it is possible to determine the precise degree to which delay affects the value of the outcome. To determine the degree of delay discounting, theoretically based quantitative models of delay discounting are used. Within the behavior analytic tradition, the three most widely accepted models that describe the process of delay discounting are a simple hyperbola (Mazur, 1987) and two hyperbolas with exponential scalars (different scalars for each model; Myerson & Green, 1995; Rachlin, 2006). A simple exponential model is also a popular alternative in the field of economics (Hull, 1943; Samuelson, 1937).

Within behavior analysis and psychology, hyperbolic models are favored because they capture the experimental finding that shorter delays produce proportionally larger decreases in value and longer delays have proportionally smaller effects on value. The hyperbolic models also provide a relatively simple account of preference reversals while the exponential model requires additional assumptions to account for this phenomenon (Ainslie, 1975; Green & Myerson, 1993). A preference reversal is when an organism chooses a larger, more delayed outcome over a smaller, less delayed outcome at Time 1 and then is given an opportunity to choose again some time later. When the second choice occurs, now at Time 2, the organisms selects the smaller outcome that was previously less preferred (Ainslie, 1975). According to hyperbolic models, the occurrence of preference reversals is caused by the immediate alternative gaining proportionally more value than the delayed alternative as Time 2 approaches because the shorter delays have proportionally larger effects on value as noted above.

All three of the hyperbolic models share a similar theoretical grounding in the matching law (Mazur, 1987). The matching law describes how the relative distribution of behavior matches the relative distribution of reinforcers in the environment. Conceptually, delays decrease the effectiveness of reinforcers and therefore decrease choice for those reinforcers. The basic hyperbolic model (Mazur, 1987) takes the form:

$$V = \frac{A}{1 + kD} \qquad \text{(Equation 4.1)}$$

where V is the present value of the delayed outcome, A is the amount of the delayed outcome, D is the delay to receipt of the outcome, and k is the degree of discounting. This hyperbolic model is one of the most popular models of delay discounting because it has only one free parameter and generally accounts for a large amount of variance in indifference points. The first hyperbola-like model is:

$$V = \frac{A}{1 + kD^s} \qquad \text{(Equation 4.2)}$$

where s is a scalar of delay that is bound between 0 and 1 (Rachlin, 2006). All other parameters are identical to those described above for the basic hyperbolic model. The s parameter scales for the non-linear perception of time. The other hyperboloid model (Myerson & Green, 1995) is also a variation of the basic hyperbolic model. The second hyperbola-like model is:

$$V = \frac{A}{(1 + kD)^s} \qquad \text{(Equation 4.3)}$$

where *s* represents the non-linear scaling of amount and/or delay (Green & Myerson, 2004). In this hyperboloid, *s* is constrained to all positive values but in practice *s* is generally less than one. In both hyperbola-like models, when *s* is less than one then delays have a smaller impact on value than in the simple hyperbolic model. The second hyperboloid model can account for a wider array of data than the simple hyperbola (Green, Myerson, Oliveira, & Chang, 2013a, b). For a review and an experimental comparison of these models as well as the exponential model, see McKerchar, Green, Myerson, Pickford, Hill and Stout (2009).

The hypothetical choice scenarios that are used to determine indifference points most commonly involve monetary outcomes (e.g., Green et al., 2013a, b). Although less common, research with non-monetary hypothetical outcomes has also been conducted. With humans these non-monetary outcomes are necessary to assess whether the effects of delay on value are specific to money or to delayed outcomes in general. For example, to determine if smokers more steeply discount only money or show a persistent pattern of steeply discounting various types of outcomes when compared to non-smokers, Friedel et al. (2014) assessed delay discounting in both groups for money, alcohol, entertainment, and food. A variety of non-monetary outcomes have been used to assess delay discounting. Charlton and Fantino (2008) compared discounting of delayed food, books, DVDs, and CDs. The discounting of delayed cigarettes has been assessed in smokers (Bickel, Odum, & Madden, 1999) and the discounting of delayed heroin has been assessed in heroin addicts (Odum, Madden, Badger, & Bickel, 2000). Several studies have even assessed the discounting of delayed non-tangible outcomes, such as changes in overall health and wellness (Baker, Johnson, & Bickel, 2003; Friedel et al., 2016; Johnson, Bickel, & Baker, 2007; Weatherly, Derenne, & Terrell, 2011), temporary relief from a debilitating disease (Weatherly et al., 2011), and finding the ideal dating partner (Weatherly et al., 2011). Overall, a wide variety of non-monetary hypothetical outcomes have been used to assess delay discounting.

A common finding when studying delay discounting with multiple qualitatively different outcomes is that the degree of discounting depends on the outcome being discounted (see, Charlton & Fantino, 2008; Friedel et al., 2014; Friedel et al., 2016; Odum, 2011b). For example, food is more steeply discounted than money (see Charlton & Fantino, 2008; Friedel et al., 2014; Odum, Baumann, & Rimington, 2006; Rasmussen, Lawyer, & Reilly, 2010). Although the degree to which a person discounts one outcome is related to the degree to which they discount another outcome, the absolute degree of discounting varies across those outcomes. Although studies of discounting of different outcomes are robust, the methods used to describe the degree of discounting across those outcomes do not lead to clear reasons why outcomes are discounted to different degrees.

One frequently used method to compare the degree of delay discounting across different delayed outcomes is to compare estimates of the free parameters from the models of delay discounting. Using curvilinear regression, we obtain parameter estimates (i.e., k, and where applicable s) that describe the degree to which the different outcomes are being discounted. Then, across each outcome that is being assessed, the parameter estimates are compared. For example, Charlton and Fantino (2008) used the hyperbolic model of delay discounting (Equation 4.1) to describe the effects of delay on money, food, music, books, and DVDs. To determine the relative steepness of how each outcome was discounted the *k* values that were obtained were ranked. To determine if there were any relations between how the outcomes were discounted Spearman correlations of the obtained *k* values were also completed. Charlton and Fantino (2008) found that money was less steeply discounted than all other outcomes and the *k* values were correlated across all of the outcomes.

Another measure of delay discounting that is frequently used is Area Under the Curve (AUC; Myerson, Green, & Warusawitharana, 2001). The measure AUC is the standardized discrete integral of the indifference points and therefore does not depend on any model of discounting to calculate. AUC is obtained by calculating the sum of the area of all of the trapezoids between adjacent indifference points and the *x*-axis if those indifference points are plotted on a figure. The overall area is standardized by the maximum delay and the maximum amount of the outcome being discounted. Area under the curve is bound between zero and one, with values close to one indicating very little discounting and values close to zero indicating extremely steep discounting by delay. The measure has also been used to describe the differences in the steepness of discounting of qualitatively different outcomes. For example, Odum et al. (2006) found significant differences in AUC between food and money for small and large amounts of those outcomes. As a measure, AUC can be a valuable description of delay discounting data because it does not rely on any assumptions of a theoretical model.

If our stated goal is to understand why different outcomes are discounted to different degrees then there are several drawbacks of completing analyses with parameter estimates derived from Equations 4.1-4.3 and/or with AUC. The first drawback with using parameter estimates to compare the steepness of discounting across outcomes is a conceptual problem about what the free parameters represent. If we consider Equation 4.1, a higher *k* indicates that delay decreases the value of an outcome to a greater degree than when *k* takes a lower value. However, these estimates of *k* are not explanations as to why delay affects the value of one outcome more than the value of the other outcome. The *k* values are only descriptive free parameters in our models (Odum, 2011a). Finding a higher *k* for one outcome (and thus a higher degree of discounting) provides us no better explanation than if we were to simply say that indifference points are lower for that outcome (e.g., Friedel et al., 2014). Comparing *k* across different outcomes provides no clue as to why, for example, food is more steeply discounted than money. The parameter *k* is useful because it is a discrete quantification of how delay affects value, but *k* does not explain why the pattern of behavior occurred. This drawback is also shared with AUC. Specifically, AUC is just a descriptor of indifference points. A technique that specifically avoids addressing the relation between delay and value dodges the issues that we are trying to address: why are qualitatively different outcomes differentially discounted?

The second drawback with using parameter estimates to compare the steepness of discounting across qualitatively different outcomes relates to how those parameter estimates are interpreted across the various models of delay discounting. There is ample evidence that the simple hyperbolic model does not provide a complete account of delay discounting (e.g., Green et al., 2013b). For example, the hyperbolic model routinely under predicts indifference points at longer delays and over predicts indifference points at shorter delays (see Green & Myerson, 2004; Mitchell, Wilson, & Karalunas, 2015; Odum et al., 2006). If delay discounting is better described by a hyperboloid model (Equations

4.2 & 4.3) then we should compare the degree of discounting of different commodities with estimates of k from the hyperboloid models. However, with the hyperboloid models estimates of k are confounded with estimates of s because the parameters interact. The interaction of these parameters makes interpretation of k more complicated. Imagine a scenario in which we assessed the discounting of two qualitatively different outcomes. Figure 4.1 displays a version of this scenario in which the hyperbolic model (Equation 14.) led to identical parameter estimates of $k = 0.01$ for each outcome. Figure 4.2 displays a different scenario in which there are visually noticeable differences in the steepness of the discounting curves across the outcomes. These discounting curves were obtained using Equation 4.3 where k was set equal to 0.01 for both curves and s was 0.67 for one outcome a 0.33 for the second outcome. How do we interpret these identical estimates of k when the steepness of the discounting curves are clearly different? If the hyperboloid models are better accounts of delay discounting than the hyperbolic model then it is inappropriate to use k to compare the relative steepness of delay discounting. Firstly, k in isolation (Equation 4.1) does not provide a complete picture of delay discounting. Secondly, with the higher quality models (Equations 4.2 & 4.3) k is confounded by s.

A potential theoretical account of why different outcomes are discounted to different degrees can be found in the recently proposed additive utility model. In the additive utility model, the present value of an outcome is composed of the utility gained from receiving that outcome plus the disutility of having to wait to receive the outcome (Killeen, 2009; 2015a). The basic form of the additive utility model is

$$U(A,D) = w(k_A A)^{\alpha} - (1-w)(k_D D)^{\beta} \qquad \text{(Equation 4.4)}$$

where U is the utility gained (or lost) from the choice, A is the amount of the outcome that is obtained at time D in the future, each k parameter transforms units of A and D into utility, α is the marginal utility of the outcome, β is a scalar of the delay, and w is a weighting parameter. In effect, the portion of the Equation 4.4 on the left hand side of the subtraction sign is the weighted utility of the outcome and the portion of the equation on the right hand side of the subtraction sign is the weighted disutility of the delay to receiving the outcome. You gain utility from receiving an outcome, but you are losing some utility by having to wait to receive that outcome. To determine the present value of a delayed outcome, total utility [$U(A,D)$] is set to the utility of an immediate outcome. That model is

$$w(k_A V)^\alpha = w(k_A A)^\alpha - (1-w)(k_D D)^\beta \qquad \text{(Equation 4.5)}$$

where V is the amount of the immediate outcome. A compacted version of the additive utility model that could be more easily used (Killeen, 2015a) is

$$V = (A^\alpha - kD^\beta)^{1/\alpha} \qquad \text{(Equation 4.6)}$$

where k is a free parameter that is the multiplicative combination of coefficients that are indistinguishable in a curvilinear regression. Both Equation 4.5 and 4.6 are analogues of the hyperbolic models discussed above (Equations 4.1-4.3).

According to the additive utility model, differences in how qualitatively different outcomes are discounted are caused by differences in the utility gained by receiving those outcomes. In Equation 4.4, the disutility of waiting for an outcome (k_D) and the scaling of time (β) are independent of the parameters for the utility gained by receiving an outcome. Therefore, changes in k_A and α values are the only conceptually systematic way to

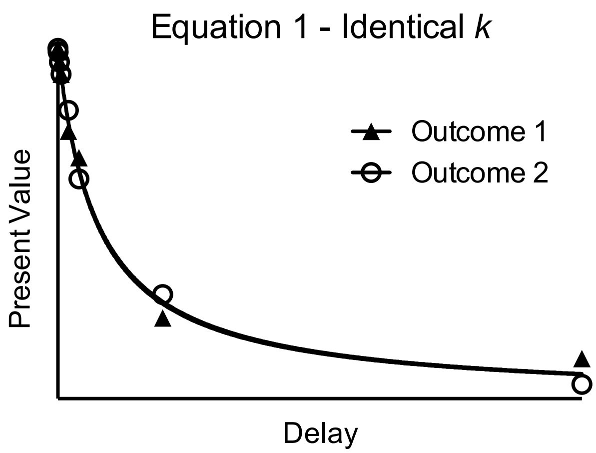

Fig. 4.1. Two discounting curves with identical k and s parameters. Present value as a hyperbolic function (Equation 4.1) of delay. There are slight variations in the indifference points but the *k* for each curve is 0.01. This figure indicates that there is no meaningful difference in delay discounting across the two outcomes because the parameter estimates of *k* are identical.

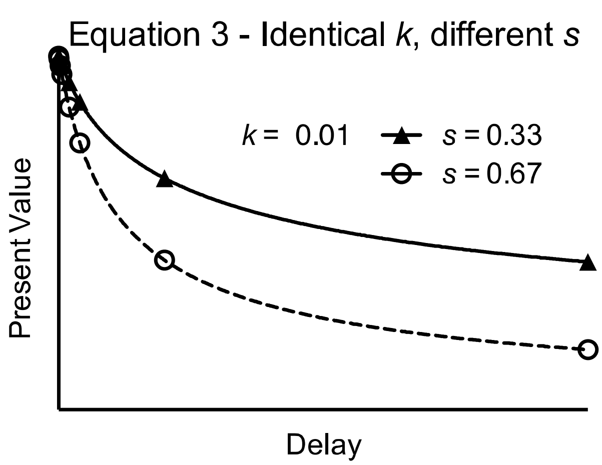

Fig. 4.2. Two discounting curves with identical k parameters and different s parameters.Present value as a hyperboloid function (Equation 4.3) of delay. The *k* value for each curve is 0.01 while the *s* parameters are 0.33 and 0.67. This figure indicates that there are clear differences in delay discounting across two outcomes despite parameter estimates of *k* being identical across the outcomes.

account for changes in the steepness of discounting across outcomes. Changes in k_A would reflect the fact that there are different amounts of utility (i.e., cardinal utility) gained from qualitatively different outcomes. In other words, a person will gain a different amount of utility from \$10 than from \$10 worth of food. Changes in α reflect the fact that different outcomes have differing marginal utilities. In other words, the amount of utility a person gains by doubling how much money he or she has is not proportional to the amount of utility gained from doubling the amount of food that person has. Differences in cardinal and marginal utility across outcomes account for differences in the steepness of discounting across those same outcomes.

One strength of the additive utility model over other traditional behavior analytic models of discounting (Equations 4.1-4.3) is that the parameters in the model do not necessarily have to be free parameters in curvilinear regression. Many of the parameters in the additive utility model can be independently assessed outside of a delay-discounting paradigm because they relate to other psychological processes. If these psychological parameters of the additive utility model are independently assessed then they can be used as constants in a curvilinear regression. In other words, they are more than just descriptors of delay discounting phenomena. The α parameter can be assessed by determining the marginal utility of the outcome (Harinck, Van Dijk, Van Beest, & Mersmann, 2007). The β parameter can be determined by assessing how a participant scales time (Zauberman, Kim, Malkoc, & Bettman, 2009). It is not possible to determine k in the compacted additive utility model (Equation 4.5) because k is composed of other parameters. However, it is possible to determine the k_A and k_D parameters from Equation 4.4 by assessing for the utility of the outcome and the disutility of delays. The parameter for weighting the utility of the outcome against the disutility of waiting for that outcome (w) is the only parameter that cannot be determined via some other psychological process. Again, most of parameters that make up the additive utility model can be determined independently because they are grounded in phenomena outside delay discounting.

One drawback of the additive utility model is that there have been no empirical tests of the model. Killeen (2015a, 2015b) has provided post hoc demonstrations that the model can account for a wide variety of delay discounting data by assuming reasonable values of α, β, and k. There has been a related demonstration that marginal utility (α) is related to the degree of delay discounting (Rachlin, Arfer, Safin, & Yen, 2015). There has also been a demonstration that the scaling of delay (β) is related to the degree of discounting (Wiehler, Bromberg, & Peters, 2015). However, both of these studies provide only preliminary evidence that marginal utility, the scaling of delay, and delay discounting are related. There are no studies examining novel predictions of the additive utility model.

The present study was designed to assess the effectiveness of the additive utility model in regards to how well each model can describe the discounting of qualitatively different foods. The psychological parameters in the additive utility model (α, β, k_A, and k_D) were independently assessed in non-delay discounting tasks. Those psychological parameters could then be fixed on a participant-by-participant basis in the additive utility model.

This study provides two important tests of the additive utility model. Firstly, when the psychological parameters are determined *a priori* does the additive utility model lead to reasonable predictions of indifference points? As mentioned above, Killeen (2015a; 2015b) used *post-hoc* fits with the compacted version of the additive utility model. If the parameters of the additive utility model are interacting in a fashion that reflects the underlying psychological processes of delay discounting then using parameter estimates of those processes in the additive utility model should lead to reasonable predictions of experimentally obtained indifference points. To this end, indifference points were obtained with two different types of delayed food to determine if any differences in the utility gained from those outcomes (e.g., different α and k_A for each outcome) lead to differential predictions with the additive utility model.

A second test of the additive utility model was to compare the goodness-of-fit of the additive utility model to the goodness-of-fit of basic hyperbolic model. The hyperbolic model only has one free parameter (k). When all of the psychological parameters in the additive utility are fixed then the additive utility model also only has one free parameter (w) in a curvilinear regression. This means that neither model has the advantage of a greater number of parameters leading to a better fit of the data. If the additive utility (with one free parameter) can not provide fits that are as good or better than the basic hyperbolic model then its usefulness as a model of delay discounting should be questioned.

The two experimental commodities used in this study were sweet snacks (e.g., M&Ms, Gummi Bears, etc.) and small savory snacks (e.g., peanuts, pretzels sticks, etc.). Food has been frequently assessed in discounting studies (Friedel et al., 2014; Odum et al., 2006) and people can easily identify preferred snacks, making food an ideal outcome in this experiment. The snacks had small, clearly defined units (e.g., M&Ms). These small units ensure identical estimates of amount across participants. The psychological parameters were assessed with several tasks.

Method

Participants

College students (*n* = 77) attending Utah State University were recruited for participation from introductory courses offered by the psychology department; the college of business; and the family, consumer, and human development department. Participants received course credit for participating in the study.

Procedure

All participants were brought to the laboratory and all procedures were completed on a personal computer using the Windows 10 operating system. Prior to beginning any experimental tasks, informed consent was obtained from each participant. The experimental tasks were controlled by a custom-written web-based Qualtrics survey. The survey was hosted online but was only accessible from the laboratory. All of the experimental tasks were completed in a single session that lasted no more than 40 minutes. All procedures were approved by the Institutional Review Board at Utah State University.

Each participant experienced the same block of initial questions. On the first page of the survey, participants typed in their age and indicated their sex and then clicked a button to proceed to the next question. Except where otherwise noted, on each page presented the participants were always required to click a button to proceed to the next question in the survey. After the initial survey page, participants were asked to select their preferred salty snack out of a list of snacks. On the following page, participants were asked to select their preferred sweet snack out of a list of sweet snacks. Table 4.1 includes the lists of sweet and salty snacks that were displayed to participants. The final page in the initial block was to determine the participant's most preferred outcome. The favorite sweet snack was displayed as one option and the favorite salty snack was displayed as a second option. Participants then selected their favorite snack out of the preferred sweet snack and salty snack.

The following sections describe the different tasks that were used to assess the psychological parameters in the additive utility model. All of the following tasks were presented to the participants in a randomized order.

Tasks to determine the utility of the snacks. The first half of the additive utility model pertains to the utility gained from receiving an outcome. There are two steps to determine the psychological parameters associated with the utility of an outcome. The first step is to determine the diminishing marginal utility of the outcome (α in Equation 4.4). The second step is to determine the cardinal utility of the outcome (k_A in Equation

Table 4.1. *List of Sweet and Salty Snacks*

Sweet Snacks	Salty Snack
Skittles	nuts
M&Ms	pieces of popcorn
Reese's Pieces	french fries
jelly beans	pieces of cheese
chocolate chips	potato chips
gummi bears	pretzels
pieces of toffee	crackers
bitesize cookies	pieces of snack mix

4.4). It is possible to determine these psychological parameters in two distinct tasks or to determine both parameters from a single task. To be conservative, both tasks were presented to participants.

Determining marginal utility. The task that was used to independently determine the marginal utility (α) was a visual analogue scale (VAS; Harinck et al., 2007). Participants dragged a slider to a point on a line that represented how happy they would be if they received some amount of an outcome (e.g., 10 M&Ms). Participants were presented with different VAS for each amount of the snack. Participants rated their happiness for 3, 23, 89, 149, 223, and 283 items of the snack. These amounts were chosen for this study because the values are larger prime numbers. Prime numbers were selected to reduce the likelihood that participants would mentally calculate a unit price for a snack and then multiply across the amounts of snacks to be delivered. The concern of a unit price is particularly relevant when trying to determine the cardinal utility (described below). Only a single VAS (and thereby a single amount of the snack) was presented to the participant at a time on separate pages on the survey. The order in which the snack amounts were presented was randomly selected within the block.

The following text instructions were displayed above each VAS:

> Imagine that USU dining services is giving out prizes to random people who have completed a survey. You completed the survey and were selected as a winner. On a scale from 0-100 how happy would you be if you won the listed prize? Zero is not happy and 100 is completely happy.

> We are going to ask you a few questions about different amounts of [selected snack]. The amounts will range from around one to 300.

Participants were told the maximum possible snack amount to ensure a similar context for the snacks across participants. The visual analogue scale was a Qualtrics slider type question with gridlines at 10-point increments along the scale. The slider was not present on the line until the participant initially clicked on the slider question. To the left of the slider was the text: “[amount] [snack type]” (e.g., 23 M&Ms). Each snack type (i.e., sweet or salty) was assessed in a separate block of questions. Each block was treated as a separate task for the purposes of randomizing the task order across participants.

Determining Cardinal Utilities. The second step in calculating the utility of the snacks is determining the cardinal utility (k_A) of each outcome. Cardinal utility is the amount of utility that is acquired when receiving a unit of some thing. I used money as a proxy for utility. Money is ideal because it is versatile and people are familiar with using it to obtain goods or services. To determine the cardinal utilities, participants were prompted to type into a text box how much money they would be willing to pay to receive some amount of the snack. The questions were repeated for different amounts of snacks. The different amounts were 3, 23, 89, 149, 223, and 283, the same amounts used in the previously described task to determine the marginal utility.

For each page displayed to the participants, only a single text box (and thereby a single amount of the snack) was presented at a time. The order the questions were presented was randomly selected within the block. For each question, the following text instructions were displayed above the text box:

> We are going to ask you how much you would be willing to pay for different amounts of [favorite snack]. The amounts will range from around 1 to 300.
>
> Please enter how much money you would be willing to pay for [amount] [snack]. You do not need to enter a "$" and please round to the nearest cent.

Participants were told the maximum possible snack amount to ensure a similar context for the snacks across participants. These open-ended questions were text entry type Qualtrics questions with only a single line entry box. To enter the monetary value, participants would click on the text box and then type in the value using the keyboard. The content validation option was active for this task such that only numerical values were acceptable answers. If a participant entered any non-numeric characters, then the survey would not allow them to proceed to the next question. Each snack type (i.e., sweet or salty) was assessed in a separate block of questions. Each block was treated as a separate task for the purposes of randomizing the task order across participants.

Tasks to determine the disutility of delay. The second half of the additive utility model is the disutility associated with waiting for an outcome. There are two steps in determining the psychological parameters associated with disutility of waiting. The first step is to determine how the participant scales time (β in Equation 4.4). The second step is to determine the cardinal utility lost by waiting (k_D in Equation 4.4). As described above for determining the psychological parameters associated with the utility of the snacks, it is possible to determine these psychological parameters in two distinct tasks or to determine both parameters from a single task. To be conservative, both tasks were presented to participants.

Scaling of time. The task that was used to independently determine how each participant scaled time (*β*) was a VAS (Zauberman et al., 2009). Participants would drag a slider to a point on a line that represented how long different amounts of time in the future would feel. The text "very short" was displayed above the far left end of the VAS and the text "very long" was displayed over the far right of the VAS. There were no numerical values displayed with the VAS in this task. The times in the future that participants were rating were 5 minutes, 15 minutes, 1 hour, 3 hours, 6 hours, and 12 hours.

For each page displayed to the participants, only a single VAS (and thereby a single amount of time in the future) was presented at a time. The order in which the questions were presented to the participant was randomly selected within the block. The following text instructions were displayed above each VAS:

> We are going to ask you to indicate your subjective feeling of duration between right now and various times in the future. Those times will range from 5 minutes to 12 hours. Imagine that these time spans all start right after you wake up in the morning. Now imagine the five minutes that occur after the time span is complete.
>
> On the line below, mark how long or short [time duration] in the future that five-minute time span feels.

The instructions explicitly included the maximum duration participants were rating to avoid any differential scaling effects across participants. The instructions were modified from those used by Zauberman et al. (2009). The modifications reduced the time scale from years to hours. In the discounting assessments (described below), the maximum delay to receiving a larger amount of the snack was 12 hours. The times used in this task were selected because they were the same delays used in the discounting assessment. When each question was first displayed to the participant the slider was placed directly in the middle ends of the VAS. To the left of the slider was the text: “How long does [duration] in the future feel?”

Disutility of delay. The second step in calculating the disutility of waiting is determining the utility lost from waiting (k_D). As described above, money was be used as a proxy for utility. To determine the disutility of delay, participants were asked to type into a text box how much money they would need to receive in compensation for waiting in the laboratory room for different durations of time. The durations participants were asked about were 5 minutes, 15 minutes, 1 hour, 3 hours, 6 hours, and 12 hours, the same amounts of time used in the previously described task to determine the scaling of delay.

For each page displayed to the participants, only a single text box (and thereby a single duration of time) was presented. The order the questions were presented was randomly selected within the block. For each question, the following text instructions were displayed above the text box:

> Imagine that because of this experiment you must wait at this computer for the time specified in the text below. You cannot close this program and therefore cannot use the computer for other activities. All other sources of entertainment (e.g., cell phone, books, music) are unavailable. You cannot sleep. You are free to leave only briefly to eat, drink, or use the restroom

> and then you must return to the computer. However, to compensate you for the time you will spend waiting at the computer we are going to give you some amount of money.
>
> We are going to ask you about various amounts of time from 5 minutes to 12 hours that you would have to wait at the computer. How much money would you have to be compensated to not be unhappy about waiting at the computer?
>
> Please enter how much money you would need to be paid to wait at the computer for [duration]. You do not need to enter a $ and please round to the nearest cent.

The instructions were adapted from the wait condition in Johnson, Hermann, and Johnson (2015). The type of delay was specified to increase the likelihood that participants treated the delays in a similar manner. The instructions also explicitly included the maximum duration decrease the likelihood of any anchoring effects. The question was a text entry type Qualtrics question with only a single line entry box. To enter the monetary value, participants would click on the text box and then type in the value. The content validation option was active for this task such that only numerical values were acceptable answers.

Delay Discounting. The last set of tasks to be described was three delay discounting assessments. The delay discounting assessments were based on an adjusting amount task (Du, Green, & Myerson, 2002). In the adjusting amount tasks, for a given question participants chose which option they preferred between small amounts of a snack delivered immediately and larger amounts of a snack delivered after a delay. The choice alternatives were displayed simultaneously on the screen. Immediately after selecting their response, the next question appeared on a new page. The larger amount was always 300 units of the snack (e.g., 300 M&Ms). The amount of the smaller snack that was to be delivered immediately at the end of a block of questions was used as the indifference point for that block.

On the first trial within a block, the smaller immediate amount of the snack was 150 units. Across questions, the amount of the smaller, immediate snack was adjusted based on the participant's choice on the immediately preceding question. If a participant chose the smaller, immediate amount then on the next trial that option was made less desirable. If a participant chose the larger, later option then on the next question that smaller, immediate snack option was made more desirable. The desirability of the smaller, immediate option was adjusted by increasing or decreasing the amount of the snack on subsequent questions. The amount of the adjustment after the first question in a block was one fourth of the amount of the larger later snack (i.e., 75 units). Each following adjustment was one half of the preceding adjustment rounded to the nearest integer. A block was 8 trials and the amount of the smaller, immediate snack after the 8th choice was the indifference point for that block. Across blocks of trials the delay to the larger, later outcome was changed in the following order: no delay (i.e., immediate delivery of both outcomes), 5 minutes, 15 minutes, 1 hour, 3 hours, 6 hours, and 12 hours.

For each delay-discounting question, two radio buttons were displayed to the participants. Clicking on either radio button was counted as their choice and the survey would proceed to the next question. The following instructions were displayed above both radio buttons:

> Imagine that for the listed delay in the question you must wait at the computer for the time specified in the question text below. You cannot close this program and therefore cannot use the computer for other activities. All other sources of entertainment (e.g., cell phone, books, music) are unavailable. You cannot sleep. You are free to leave only briefly to eat, drink, or use the restroom and then you must return to the computer. At the end of the delay, you will receive the listed snack.
>
> Please select which option in each pair that you prefer.

The instructions include the waiting delay scenario adapted from Johnson et al. (2015). Above the radio button associated with the immediate snack was the text "[amount of] [snack type] now" (e.g., "150 M&Ms now"). Above the radio button associated with the delayed snack delivery was the text "300 [snack type] [delay]" (e.g., "300 M&Ms in 5 minutes"). Discounting of each type of delayed snack was assessed in a separate block of questions. Each block was treated as a separate task for the purposes of randomizing the task order across participants.

Participants also completed a cross-commodity delay-discounting task. Cross-commodity discounting tasks assess the present value of a delayed outcome in terms of a second, qualitatively different, outcome. For this task, the delayed outcome was always the participant's most preferred snack and the immediate outcome was the participants less preferred snack. For example, if the participant reported in the initial block of questions that out of M&Ms and peanuts they preferred peanuts then on the cross-commodity discounting task participants made choices between smaller, immediate amounts of M&Ms and 300 peanuts delivered after a delay. In all other respects, the cross-commodity delay-discounting task was identical to the other delay-discounting tasks described above.

Analyses

One goal of this study was assess the effectiveness of the additive utility model in describing indifference points. A second goal was to compare the relative goodness-of-fit of the hyperbolic model to the additive utility model with predetermined psychological parameters (α, β, k_A, and k_D). For each participant and snack type, the hyperbolic model was fit to the indifference points obtained from the single outcome discounting tasks via curvilinear regression (Matlab lsqcurvefit function). Fitting the additive utility model to the delay discounting tasks had several intermediate steps because the psychological parameters also had to be determined.

Estimating the Psychological Parameters. As mentioned above, for both the utility of the outcome (α and k_D) and the disutility of delay (β and k_D) there are two possible ways to determine the respective parameters. The first method would be to determine the exponential scalars (α and β) using data from the VAS tasks. Those parameters are then used as the respective exponential scaling parameters when determining the cardinal utility of the snack and delay (k_A and k_D) using the data from the open-ended tasks. The second method would be to determine both parameters simultaneously using data from only the open-ended question tasks for each snack type and the delay.

After some preliminary analyses, I decided that for this study it was most appropriate to determine the pairs of psychological parameters simultaneously using the data from the open-ended questions only. The data obtained from the VAS had an inherent ceiling of 100, which was the score that would be obtained if the participants dragged the slider all the way to the right. When examining the data obtained with the VAS, it was apparent that many participants had scores that were at or close to the maximum. This ceiling would affect the curvilinear regressions by artificially reducing the variability across participants. The data from the open-ended questions did not suffer from this ceiling because the participants could respond with any dollar amount they chose. The data from the open-ended questions would more likely lead to accurate estimates of the exponential scaling parameters.

To determine the psychological parameters, power functions were fit to the data from the open-ended tasks associated with the sweet snacks, the salty snacks, and the delay using separate curvilinear regressions. A similar power function was used across all of these tasks because the models that describe utility derived from the snacks and the utility lost from waiting are structurally identical (Allan, 1983; Eisler, 1976; Killeen, 2015a). That power function was $Y = (k\mathrm{X})^{\theta}$, where Y is the value participants entered into the text box, k is the cardinal utility of the snack (k_A) or the disutility of the delay (k_D), and θ is the marginal utility of the snack (α) or the scaling of time (β).

Fitting the additive utility model. The additive utility model (Equation 4.5) was then fit to the obtained indifference points for each participant each snack type. The psychological parameters that were estimated from the open-ended questions (α, β, k_A, and k_D) were treated as constants during this process. The parameter that weights the utility of the snack against the disutility of waiting (*w*) was free to vary. For example, if the best estimate of α for sweet snacks for a participant was 0.26 then in the process of fitting the additive utility model by varying *w*, the value of α was always held constant at 0.26.

In preliminary analyses, Equation 4.5 was fit to indifference points by curvilinear regression (Matlab lsqcurvefit function). However, I detected two recurring problems with the curvilinear regression. Firstly, I discovered that Equation 4.5 can produce several local minima while estimating *w*, depending on the values of the other psychological parameters. A local minimum would lead to an incorrect estimate of the best-fitting *w* parameter. The second recurring issue was that sometimes the curvilinear regression algorithm would estimate an initial value of *w* that provided an extremely high sum of squares. Across several iterations of the algorithm, small changes in the *w* lead to equally high sums of squares. As there was no systematic change in the sum of square based on changes in *w*, the algorithm for the curvilinear regression stopped estimating a better fit. In other words, the algorithm stopped running because it detected that changing the *w* parameter was not making the model fit the data any better. With both of these problems, the estimates of *w* (and the fits of Equation 4.5 to indifference points) were unreliable.

I used two different methods to avoid these errors when fitting Equation 4.5 to the indifference points. The first method to avoid the local minima and bad initial values of *w* was to complete multiple curvilinear regressions with different starting estimates of *w*. By using different initial values, it is more likely that the algorithm would find the true minimum of the sum of squares and find the best estimate of *w*. To ensure I did not use biased starting estimates of *w*, I completed 1,000 regressions for each participant and snack type. The first regression used an initial estimate of *w* of 0.001 and each successive regression increased the initial estimate of *w* by 0.001 until the maximum possible *w* value (1.0) was reached. Across all 1,000 regressions, the estimate(s) of *w* that had the least squares was taken as the best estimate of *w.* In effect, this analysis would establish if the curvilinear regression was useful in determining the best estimate of *w*.

The second method I used to determine the best estimate of *w* was to avoid the curvilinear regression and conduct a brute-force search. For the brute-force search, Equation 4.5 was repeatedly fit to the indifference points with different *w* (and with the fixed psychological parameters). Equation 4.5 was fit to the indifference points and sum of squares was calculated for all 10,000 possible *w* values between 0.0001 and 1.0 in increments of 0.0001. The minimum sum of squares was then determined and the *w* value associated with that sum of squares was taken as the best estimate of *w*. This brute-force search for the smallest sum of squares sidesteps the issue of local minima and the threshold for changes in the sum of squares because the brute-force technique does not rely on an algorithm.

Finally, to determine if the multiple curvilinear regressions and brute-force search techniques converged on the same best estimate of *w* I compared the best fitting parameters obtained from each technique for each participant and snack type. For this comparison, the least squares obtained from the curvilinear regression was compared to the least squares obtained from the brute-force search. The sum of squares was rounded to the nearest ten thousandth because the curvilinear regression could return estimates of *w* that were between the 0.0001 iteration size of the brute-force search. This analysis indicated that the multiple curvilinear regressions and the brute-force search converged on identical estimates of *w* across all of the participants and snack types.

Comparing the additive utility model to the hyperbolic model. Two different comparisons were completed to determine if the additive utility model (Equation 4.5) fit better than, as well as, or worse than the hyperbolic model (Equation 4.1). These comparisons were completed for each snack type. The standard error of the regression (*S*) was used to compare the goodness of fit of each model. As a measure, *S* provides similar information as R^2 but has the added benefit that deviations in the model are in the units of the dependent variable. Using this data set, an R^2 value of .5 typically indicates that the model accounts for 50% of the variance in the data where as an *S* of 15 indicates that, on average, the line of best fit is 15 snack items away from the obtained indifference points. In other words, *S* is an easily interpretable metric of the goodness of fit of a model.

To determine if either model lead to better fits, the *S* values obtained from each model for each outcome were compared. As the obtained *S* values were not normally distributed, a Wilcoxon signed-rank test was completed. A Wilcoxon signed-rank test is the non-parametric equivalent of a paired-samples *t* test. The next step was to determine if there was a noticeable pattern of how each model fit the indifference points that would not be detected statistically. For example, if one model fits irregular discounting data (e.g. Johnson & Bickel, 2008) better and fits more regular discounting data more poorly this would be easily noticed visually but not easily detectable statistically. Therefore, I plotted *S* obtained with the hyperbolic model against *S* obtained with the additive utility model for each participant.

I also plotted the residuals for each participant, outcome, and model fit to determine if there were any differences in how each model fit the indifference points. An ideal model will have residuals normally distributed around zero. One dimension of interest was whether the indifference points were normally distributed for each model across all of the outcomes. The second dimension was how the central tendency of the indifference points was affected by the delay to the larger snack (i.e., the independent variable in the regression). If the central tendency changed as a function of the delay then that would indicate a systematic bias of the model in predicting the indifference points. If there is no relation between the central tendency of the residuals and the delay, then that indicates a model provides an equally good fit across all indifference points.

Results

The power functions provided good fits to the data obtained from the open-ended psychological parameter tasks. Figure 4.3 is a Tukey box-and-whisker plot of the R^2 obtained for each participant from fitting the power function to the open-ended sweet snack utility, salty snack utility, and delay disutility tasks. The plus signs below the *x*-axis labels indicate the number of R^2 values that were below 0.5. The power function accounted for a substantial amount of variance in the monetary values reported by participants in the open-ended tasks. The 25th percentile R^2 for the sweet snack utility was 0.92, for the salty snack utility it was 0.88, and for delay disutility it was 0.96. The power function did provide poorer fits in some cases, particularly for the salty snack utility task and delay disutility task in which there were, respectively, 2 and 5 fits that had R^2s of less than 0.5. However, these poorer fits appear to be outliers considering the bulk of the

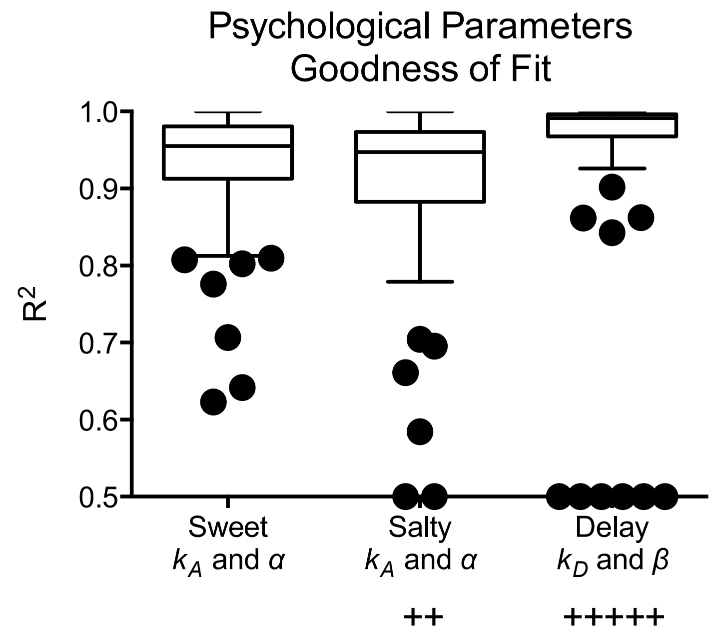

Fig. 4.3. Box and whisker plots of the goodness of fit of the power function utility models to the three separate open-ended tasks. The data that the power functions were fitted to (monetary value of sweet snacks, monetary value of salty snacks, and monetary compensation of waiting) are on the *x*-axis. Filled symbols were identified as outliers. The plus signs represent the number of outliers that fell below the lower *y*-axis limit.obtained R^2 values were greater than 0.85. These data indicate that that power function provided reasonable estimates of the psychological parameters.

The additive utility model (Killeen, 2015a) and the hyperbolic model (Mazur, 1987) provided similar fits to the delay discounting data. Figure 4.4 shows box-and-whisker plots of *S* for each model fit to the indifference points for delayed sweet snacks and delayed salty snacks. There was a cluster poorly fitting of outliers with the Mazur (1987) fits to the sweet snack indifference points. However, the overall range of *S* for the model fits was similar, with the maximum *S* for Mazur (1987) of 175.5 and for Killeen (2015a) of 182.8. To determine if there were differences in *S* obtained from each model, Wilcoxon signed-rank tests were completed to compare *S* obtained from each model for the sweet snacks and salty snacks. There were no significant differences in the fits

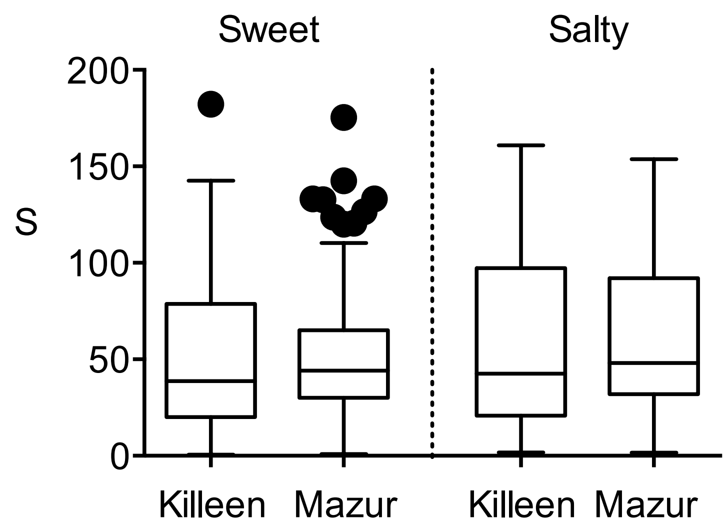

Fig. 4.4. Killeen (2015a) and Mazur (1987) goodness of fit. Box-and-whisker plots of S (standard deviation of the residuals) for each snack type for Killeen (2015a) and Mazur (1987) fit to indifference points. Filled circles were identified as outliers. For each snack type, there were no statistically significant differences between Killeen (2015a) and Mazur (1987) models.

obtained from the models for either the sweet snacks ($W = 223$, $p = .56$) or salty snacks ($W = 399$, $p = .31$).

Figure 4.5 displays scatterplots, for each snack type, for *S* obtained with Mazur (1987) against *S* obtained with Killeen (2015a) for each participant. There does not appear to be any substantial difference in how the additive utility model or the hyperbolic model fit the indifference points for either snack type. Across snack types, there was a strong relation between *S* obtained with the hyperbolic model and *S* obtained with the additive utility model. There are two distinct features on each panel in Figure 4.5: (1) there is a main cluster of fits in the bottom left corner of each plot; and (2) there is a tail extending from the main cluster to the upper right corner of each plot. The cluster in the bottom left of each panel indicates that neither model provided a reliably better fit than

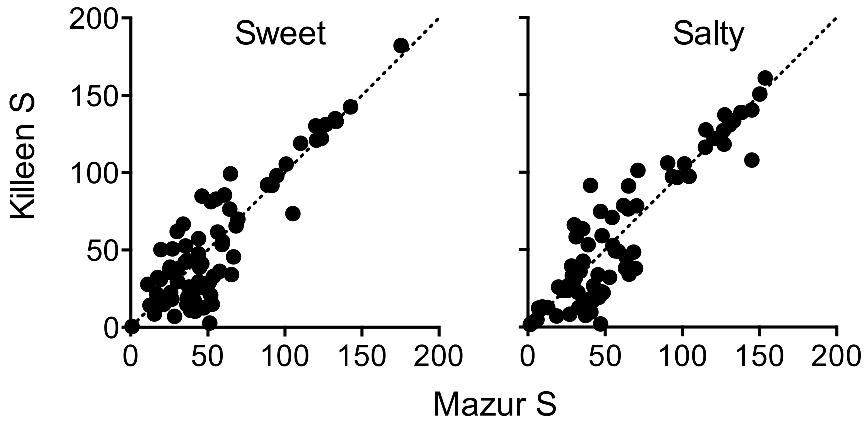

Fig. 4.5. Scatterplot of the standard deviation of the residuals for Mazur (1987) and Killeen (2015) for each snack type. Left panel are fits obtained from sweet snacks; right panel are fits obtained from salty snacks. The dotted lines are Y = X, when S obtained with one model is equal to S obtained with the other model.

the other model. For some participants, the additive utility model provided a better fit and for other participants the hyperbolic model provided a better fit. The tails extending from the clusters to the upper right corners of plots indicate that when one model provides an extremely poor fit, then the other model was also likely to provide an extremely poor fit. In effect when the indifference points were atypical (e.g., Johnson & Bickel, 2008) then neither model provided a good fit.

Participants were asked to select their favorite sweet snack and favorite salty snack and to then select, out of the preferred snacks, which was their favorite. AUC was calculated to determine if there was a difference in how participants discounted their favorite snack and their less preferred snack. The AUC for the favorite snacks was not different than AUC for the less preferred snack (W = -102.0, p = .80). Participants did derive significantly more utility (k_A) from their favorite snacks than they did from their less preferred snack (W = -905, p = .02). The median k_A for favorite snacks was 0.08 and the median k_A for the less preferred snacks was 0.04, indicating that the favorite snack was only slightly better on average than the less preferred snack. As there was no clear distinction in the degree of discounting across the favorite and less preferred snack, no further distinction between favorite and less preferred snacks will be made.

Figure 4.6 displays the residuals, for all non-zero delays, obtained from the model fits for each participant and outcome type. For both snack types, the median of the residuals for the Killeen (2015a) model at the two longest delays was greater than 0, indicating that the model systematically under predicted the indifference points at those

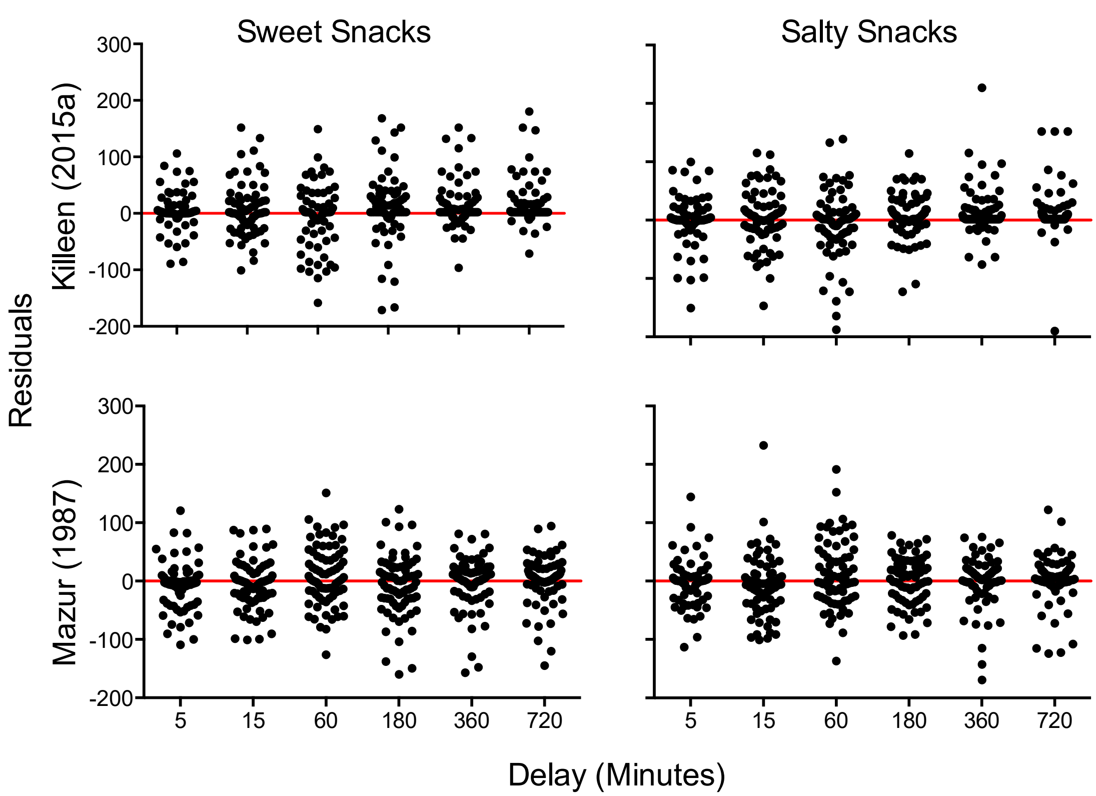

Fig. 4.6. Residuals from each model for each participant and outcome. The red line is at 0 to indicate a perfect fit. The left panels are for sweet snacks and the right panels are for salty snacks. The top panels are for Killeen (2015a) and the bottom panels are for Mazur (1987).

delays. There was no systematic pattern in residuals obtained with the hyperbolic model (Mazur, 1987). Across both snack types, the residuals are mostly clustered around 0.

Finally, Figure 4.7 displays scatterplots of the rank order of the best estimates of *w* from the additive utility model plotted against the rank order of best estimates of *k* from the hyperbolic model. There was a strong, negative correlation in the estimates of *w* from the additive utility model and the estimates of *k* from the hyperbolic model. The data are displayed as ranks instead of absolute values because *k* was not normally distributed. Also, *w* is bound between 0 and 1 and *k* is constrained to all non-negative values. For each snack type, as the ranking of best estimate of *k* increased the ranking of the best estimate of *w* decreased. In the hyperbolic model, higher *k* values are indicative of steeper discounting while in the additive utility model lower *w* are indicative of higher weight on the disutility of delay (and thus steeper discounting). To determine the degree

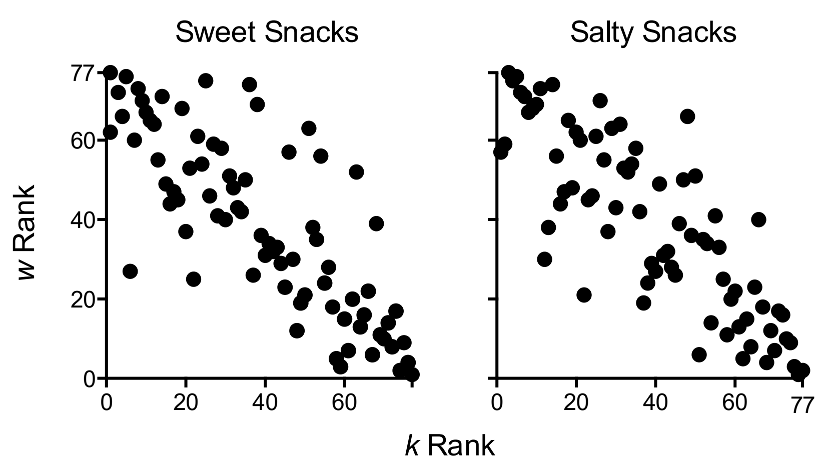

Fig. 4.7. Scatter plot of rankings for the best-fit parameters estimates for *w* (Killeen, 2015a) and *k* (Mazur, 1987). The correlation between *w* and *k* was significant for both sweet and salty snacks.

of the relation between the *k* and *w* rankings across participants, correlations on the rank order (i.e., Spearmans correlations) were completed. There were strong correlations in the parameter estimates for both sweet snacks (r = -.80, p < .001) and salty snacks (r = -.83, p = <.001).

Discussion

This study is the first empirical test of the additive utility model of delay discounting (Killeen, 2015a). There are two key findings of this study that relate to the usefulness of the additive utility model. Firstly, the psychological processes that are proposed mechanisms of delay discounting in the additive utility model do appear to describe the indifference points well. Secondly, the additive utility model describes indifference points as well as the hyperbolic model of delay discounting (Mazur, 1987). Each of these findings will be discussed in turn.

Killeen (2015a) proposes, with the additive utility model, that delay discounting is the result of several psychological processes that in isolation are not delay discounting. Those processes are the utility derived from an outcome, the marginal utility of that outcome, the disutility of waiting for the outcome, the non-linear scaling of delay, and finally how a person weights the utility of the outcome against the disutility of the delay. The above processes, apart from the weighting process, are psychological processes that exist outside of a delay-discounting paradigm. Thus, the first step in this study was to assess these psychological processes. Participants reported how much they would be willing to pay for amounts of sweet snacks and salty snacks and how much monetary compensation they would need to wait in the laboratory room for different durations of time. In essence, these tasks were designed to measure how much utility (in terms of money) were equal to the different snacks and the delay.

The power functions relating money (as utility) to the outcomes and delays generally provided excellent fits to the values reported by participants. While it is not surprising that a power function provides a good description of a psychological phenomenon (e.g., Stevens, 1961) it was nevertheless important to empirically verify the goodness of fit of these power functions. If the estimates of the psychological parameters were bad *and* the additive utility model provided poor fits of the delay discounting data, then there are two possible interpretations of the results are impossible to disentangle from each other. The first interpretation is that the additive utility model made poor predictions of the indifference points because it is a bad model. With this interpretation, bad estimates of the psychological parameters would have only exacerbated the poor fits from the additive utility model. The second interpretation is that the poor psychological parameter estimates interfered with the additive utility model. In other words, the model could have made adequate predictions had the psychological parameters estimates been good. Finding good estimates of the psychological parameters, as was done here, leaves the additive utility model to stand or fall on its own merit.

The second major finding of this study is that the additive utility model describes indifference points as well as the hyperbolic model. There are three distinct parts to this finding. Firstly, across both outcomes, *S* (the standard deviations of the residuals) for the additive utility model and *S* for the hyperbolic model were not significantly different. Secondly, across the snack types there were strong correlations in *S* between the additive utility model and the hyperbolic model. This indicates that the models were not leading to different fits that coincidentally had similar distributions of *S*. Finally, across both snack types the models led to very similar distribution of residuals indicating there were no systematic biases in either model.

There were no significant differences in *S* across the additive utility and hyperbolic models for either sweet or salty snacks. The Wilcoxon signed-rank comparisons of *S* provide a good first pass measure to determine if there were any differences between the models. If the additive utility model lead to significantly higher *S* values than the hyperbolic model, then it is likely that the additive utility model would provide poorer fits across the other analyses. That the *S* values do not seem to be drawn from different distributions (i.e., there were no significant differences) indicates that the models provide similar predictions.

There were also strong correlations in *S* from each model across the two snack types, which also supports the notion that the models were equally effective at accounting for the same data. It is possible that the models provide differential fits based on the pattern of the indifference points. For example, it is possible that because of the complexity of the additive utility model it more easily accounts for complex data that the hyperbolic model does not account for. The reverse could also be true, if the additive utility model is over parameterized it is possible that it fits poorly to data that the hyperbolic model fits well. Finding the strong correlation in *S* values across the outcome types indicates that there was no pattern of one model fitting certain data better than the other model. In other words, when one model fit data from a specific participant well the other model was likely to also fit that data well and when one model fit data from a specific participant poorly the other model was also likely to fit that data poorly.

The final step in comparing the additive utility model to the hyperbolic model was to determine if there were differences in how each model fit indifference points at specific delays. When a model provides a good description of data, the residuals should be normally distributed around 0. A systematic error in a model could lead to a bias in the distribution of residuals that would otherwise be obscured by condensing all of the error into a single *S* parameter. For example, the hyperbolic model frequently leads to residuals that deviate from an expected Gaussian distribution of error (Green & Myerson, 2004; Mitchell el al., 2015; Odum et al., 2006) but this pattern is undetectable if the residuals are reported as a single *S* value.

The pattern of residuals across the models and outcomes indicates that the hyperbolic model is a slightly better predictor of the indifference points. There was a small, persistent bias in the additive utility model predictions. That is, the additive utility model routinely under predicted (i.e., positive residuals) the indifference point at the longest delay of 12 hours. There was no apparent bias in the residuals for the hyperbolic model for any of the indifference points. These data should be interpreted with caution, however. Firstly, the deviations in the residuals are small and only occur with the additive utility model at the longest delay, and to a lesser extent at the 6-hour delay. Secondly, this study failed to replicate the typical deviations in residuals that occur with the hyperbolic model (Green & Myerson, 2004; Mitchell el al., 2015; Odum et al., 2006). Specifically, the hyperbolic model routinely under predicts indifference points at longer delays and over predicts indifference points at shorter delays. It is possible that the typical pattern of residuals with the hyperbolic model was not found because this study examined delay discounting of smaller amounts of snacks at shorter delays that are typically studied.

Future studies comparing the typical models of delay discounting with the additive utility model should carefully examine the pattern of residuals to determine if the data reported here are representative of a systematic bias in the model.

In total, the data are almost uniform in supporting the notion that the additive utility model provides as good of a description of delay discounting data as the hyperbolic model. In this study, four of the five free parameters of the additive utility model were fixed by assessing those psychological parameters prior to fitting the additive utility model. In this regard, for fitting the models to the indifference points the additive utility model and the hyperbolic model were on equal footing with only one free parameter. That the additive utility model fits at all is impressive considering that the shape of the model can vary widely based on the psychological parameter estimates that are being supplied to the model. If the estimates of the psychological parameters were not good then the additive utility model would provide a poor fit. In other words, considering how likely it was that the additive utility model would fit poorly with predetermined psychological parameters it is surprising that the model fit the data as well as it did.

One area for future study is to examine the strong correlation between the degree of discounting in the hyperbolic model (k) and the relative weighting of the outcome and the delay in the additive utility model (w). In this study, we found a strong correlation between k and w. If, as claimed above, that the additive utility model provides better explanatory power than the hyperbolic models then it is problematic that the free parameters in the models are so closely related. In other words, if the models are so different then why are the free parameters in the models so highly correlated? It is not necessarily surprising that w and k are strongly correlated. In the respective models, both *k* and *w* serve to scale the impact of delay on the present value of an outcome. If both free parameters are accounting for similar features of the data, then it is not unreasonable that the parameters are strongly correlated. Future studies examining novel predictions of the additive utility model should carefully assess whether *w* is a distinct construct or if it is indistinguishable from *k*.

One limitation of this study is that there was no differential discounting of the different delayed snacks. After selecting their favorite sweet snacks and favorite salty snacks, participants then selected their overall favorite of their previous choices. Foods that are more tempting are discounted less steeply than non-tempting foods (Tsukayama & Duckworth, 2010). I presumed that a favorite snack would be more tempting than a less preferred snack leading to differential utility and therefore differential degrees of discounting. There was a significant difference in the utility (k_A) participants derived from the favorite and less preferred snacks, but the magnitude of that difference was miniscule. In other words, although there were different utilities derived from the outcomes, participants only slightly preferred the favorite snack over the less preferred snack. Although the additive utility model does predict that outcomes with similar utilities will lead to similar degrees of discounting, this study fails to provide an adequate test as to whether the additive utility model can explain why different delayed outcomes are discounted to different degrees because the outcomes used here did not lead to differential degrees of discounting. Future studies should examine different outcomes that are qualitatively different as well as of different modalities such as food and DVDs (see, Charlton & Fantino, 2008) to increase the likelihood of finding both differential utilites (k_A) and degrees of discounting across those outcomes.

There were several reasons for selecting snacks as the delayed outcomes in this study. Two of the parameters in the additive utility model are related to determining the utility of that outcome (k_A and α). However, utility is a not a directly measurable construct (Allen, 1935) or at best extremely difficult to measure (Köbberling, 2006). For this study, money was used as a proxy for utility. Therefore, despite the fact that money is the most commonly studied delayed outcome, it was not possible to determine the utility of money. Food was an ideal outcome to study because people interact with it on a daily basis and there is a large set of studies investigating the discounting of delayed food (e.g., Charlton & Fantino, 2008; Friedel et al., 2014; Jimura, Myerson, Hilgard, Braver, & Green, 2009; Odum et al., 2006, Rasmussen et al., 2010, Tsukayama & Duckworth, 2010). The small snacks also have clearly defined units, which ensures that participants were not confused on what the amount of "a serving of M&Ms" was (e.g., Friedel et al., 2014; Odum et al., 2006). Although people will have different subjective assessments of the value of a single peanut the amount of a single peanut is not likely to be misunderstood. Future studies examining how people discount different delayed outcomes should continue to use a wide variety of outcomes that are more likely to have disparate structural features and utilities.

There are other criteria to judge the usefulness of a mathematical model of behavior beyond the relative quality of the model that has been the focus of the discussion thus far. Quantitative models are the search for "ways of organizing and interrelating behavioral observations and identifying invariances that cut across diverse situations" (Nevin, 1984, p. 432). Killeen (2009; 2015a) has provided some evidence that the additive utility model can describe a wide variety of extant delay discounting data. Of importance is how the additive utility model will fare as it is expanded to encompass wider arrays of phenomena than indifference points obtained in delay discounting assessments. Another criterion is whether a model provides a parsimonious account of behavior. A mathematical account by its very nature provides strict rules and precepts (Marr, 1989). It is possible to use those rules and precepts to develop an equation that provides an excellent description but is not tied to the facets of nature (e.g., Dyson, 2004). The results of this study have demonstrated that the parameters in the additive utility model are sufficient to describe indifference points but the results do not establish if the parameters are necessary. A final criterion of usefulness is the degree to which one model provides a different account of a phenomenon than other models (Mazur, 2006). Models can drive research and force us to account for increasingly complex behavior-environment relations. It is unclear if the additive utility model will drive future research. It will take several independent studies to fully assess whether the additive utility model fulfills these criteria of a useful model. This study is just the first step forward.

This study has demonstrated that the additive utility model is at least as useful as the hyperbolic model for describing indifference points. It is important to point out that the additive utility model has potentially better explanatory power than the hyperbolic model (Killeen, 2015a). The additive utility model provides mechanisms for delay discounting that the hyperbolic model does not. Future studies should examine how changes in the mechanisms in the additive utility model affect delay discounting. For example, students who took part in a semester long financial education course (e.g., DeHart, Friedel, Lown, & Odum, 2016) showed decreased delay discounting relative to a control group. A possible interpretation of those data is that students in the financial education course become more tolerant of delayed outcomes because a goal of the course was to teach students about planning for retirement. If students in the course learned to tolerate the delays associated with investing than that tolerance should be reflected by decreases in the disutility of delay (k_D) that would then predict higher indifference points. Interventions that specifically target the utility of the outcome, the disutility of the delay, and the scaling of delay should lead to predictable changes in delay discounting based on the additive utility model. These sorts of predictions about how changing the psychological processes should change delay discounting provide other possible avenues to empirically test the additive utility model.

Another avenue for future research is to examine if, and how, the additive utility model relates to steeper delay discounting to those engaging in risky behaviors or such as drug abuse, gambling, and overeating (Bickel et al., 2012). For example, people who smoke cigarettes more steeply discount a wide variety of outcomes than do nonsmokers (Friedel et al., 2014; Friedel et al., 2016). Perhaps the increased delay discounting seen in smokers is related to decreased utility derived from reinforcers. Adolescents low in hedonic capacity are more likely to have recently smoked cigarettes than adolescents higher in hedonic capacity (Audrain-McGovern et al., 2012). Anhedonia (i.e., decreased ability to feel pleasure) in abstaining cigarette smokers predicts the speed of smoking initiation as well as the number of cigarettes smoked (Leventhal et al., 2014). If cigarette smokers derive less utility from outcomes in general, then according to the additive utility model smokers should more steeply discount delayed outcomes. This prediction relating anhedonia to delay discounting would be detectable by systematic differences between smokers and nonsmokers in the utility received from outcomes (k_A and α) and potentially no systematic differences in (k_D and β). Future studies should examine if there are covariations in people engaging in risky or problematic behaviors and people who do not engage in those behaviors with the psychological processes that would give rise to different degrees of discounting.

In summation, the results of this study support the additive utility model of delay discounting. The additive utility model describes indifference points from two different types of snacks at least as well as the hyperbolic model. The psychological parameters in the additive utility model associated with the utility of the outcomes and the disutility of delay can be determined outside of the delay discounting assessment. This supports the notion of Killeen (2015a) that other processes give rise to delay discounting in humans. This study failed to provide an adequate test as to whether the additive utility model explains why different delayed outcomes are discounted to different degrees. While this study generally supports the additive utility model as an explanatory model of delay discounting, future studies should be conducted to both replicate these results and to test other novel predictions of the model to fully assess the model's robustness.

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CHAPTER V

GENERAL DISCUSSION

Delay discounting is the process by which delayed outcomes lose value. People regularly make choices between large outcomes to be delivered in the future and smaller outcomes to be delivered more proximally. People choose whichever outcome has the highest value at the time the choice is made (Ainsle, 1974). A tendency to steeply discount delayed outcomes is related to a wide variety of behavioral problems such as cigarette smoking (Bickel, Odum, & Madden, 1999; Mitchell, 1999), obesity and overeating (Rasmussen, Lawyer, & Reilly, 2010), problematic gambling (Dixon, Marley, & Jacobs, 2003), and attention deficit hyperactivity disorder (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001).

The studies described in Chapters II and III examined how cigarette smokers and nonsmokers discounted a wide variety of delayed outcomes. Smokers more steeply discount delayed money than do nonsmokers (e.g., Bickel et al., 1999; Mitchell, 1999). In Chapter II, smokers were found to discount delayed money, alcohol, and entertainment more steeply than did nonsmokers. Both smokers and nonsmokers discounted delayed food so steeply that there was no difference between the groups. Across both groups, there were also strong correlations in the degree to which each outcome was discounted. If a person discounted one outcome steeply then they were more likely to discount other outcomes steeply. The reverse was also true, if a person more shallowly discounted one outcome they were more likely to discount other outcomes more shallowly. Chapter III found a similar pattern of results with different outcomes. Specifically, cigarette smokers more steeply discounted delayed money gains, temporary cures from debilitating disease, and temporary boosts in overall health than did nonsmokers. There was no difference in how each group discounted monetary losses. Across both groups, there were strong correlations in the degree to which each outcome was discounted. Together, these findings indicate that cigarette smokers display a pervasive tendency to discount a wide variety of outcomes to a greater degree than nonsmokers.

The popular behavior analytic models of delay discounting (Mazur, 1987; Myerson & Green, 1995; Rachlin, 2006) are generally quite effective at describing delay-discounting data. However, the typical analyses conducted with the popular models of delay discounting provide measures of delay discounting data (i.e., *k*) that are, in many ways, no different than describing whether indifference points are lower or higher than other indifference points. In regards to Chapters II and II, demonstrating that smokers persistently make more impulsive choices than do nonsmokers supports the notion that delay discounting is a trait-like phenomenon (Friedel, DeHart, Madden, & Odum, 2014; Friedel, DeHart, Frye, Rung, & Odum, 2016; Odum, 2011). Chapter IV introduces the additive utility as a model that potentially explains differences in discounting across different outcomes and provides causal mechanisms for delay discounting.

The mechanisms of the additive utility model (Killeen, 2015a) are the utility that is gained by receiving some outcome and the utility that is lost by waiting to receive that outcome. Importantly, these mechanisms can be assessed outside of a delay-discounting paradigm. This means that delay discounting is potentially an emergent phenomenon of the relative utilities associated with a delayed outcome. According to the additive utility model, deriving different amounts of utility from qualitatively different outcomes is what causes differences in the degree of discounting across those outcomes. While the additive utility model can potentially account for differences in the degree of discounting across qualitatively different outcomes it has previously only been used as a *post hoc* descriptive tool (Killeen, 2015a; 2015b). Therefore, Chapter IV set out to experimentally test the additive utility model by trying to determine the underlying utilities: (1) gained by different outcomes; and 2) lost by waiting for those outcomes. Those different utilities were then used to predict indifference points with the additive utility model.

Chapter IV indicates that the additive utility model provides as good of a description of delay discounting data as the hyperbolic model of delay discounting (Mazur, 1987). The hyperbolic model is the most popular as well as the simplest account of delay discounting in psychology. The additive utility is more complex than the hyperbolic model but in this study, many of the free parameters in the additive utility model were fixed because they were determined via other psychological tasks. When both the additive utility model and the hyperbolic model were equally complex with only one free parameter, both models fit the delay discounting data equally well. It is important to note that, when assuming reasonable parameters, all models of delay discounting are negatively sloped decelerating functions. However, in this study the parameters of the additive utility model were not bound to these sorts of reasonable values. If bad parameters are supplied to the additive utility model then it can take a wide variety of atypical shapes such as a negatively sloped accelerating function. The possibility for an atypical additive utility curve is in contrast with a hyperbolic curve, which will always be a negatively sloped, decelerating function (when k is drawn from non-negative values). The fact that the additive utility model fits as well as the hyperbolic model, given the possibility for the additive utility model to fit poorly, provides support for the model as an account of delay discounting.

While the results of Chapter IV provide tentative support for the additive utility model of delay discounting, the results do not provide clear evidence that the additive utility model can account for differences in the degree of discounting across qualitatively different outcomes. In the study, there were no clear differences in how the qualitatively different outcomes were discounted. Because both outcomes were discounted to a similar degree, the additive utility model did not have to account for those differences. In other words, the study failed to provide an adequate test of whether the additive utility model can account for differences in how qualitatively different delayed outcomes are discounted. Future studies should investigate outcomes that are qualitatively different, of different domains (i.e., food and entertainment), and are demonstrably preferred to different degrees to increase the likelihood of finding different utilities across those outcomes.

Understanding why qualitatively different outcomes are discounted to different degrees provides interesting data to account for theoretically. More importantly though is that the development better theoretical accounts of delay discounting will hopefully lead to interventions that more reliably change delay discounting (e.g., Bickel, Yi, Landes, & Backter, 2011; Black & Rosen, 2011; DeHart & Odum, 2015; Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013; Morrison, Madden, Odum, Friedel, & Twohig, 2014; Stein, Johnson, Renda, Smits, Liston, Shahan, & Madden, 2013). If the additive utility model properly identifies the underlying mechanisms the drive delay discounting then interventions aimed at changing delay discounting should be targeted at changing how people evaluate outcomes and tolerate delays to receiving those outcomes. If steeper delay discounting plays a causal role in a wide variety of psychosocial maladies (Bickel, Jarmolowicz, Mueller, Koffarnus, Gatchalian, 2012) then developing reliable and effective techniques to change delay discounting are profoundly important.

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APPENDICES

Appendix A

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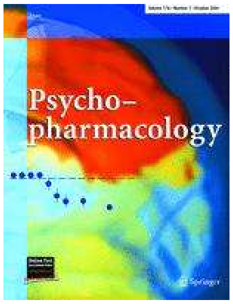

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Appendix B

Derivations of the Additive Utility Model

The derivations of the additive utility model in Chapter IV are included here. To derive Equation 6, we start with Equation 5 and solve for the amount of the smaller (immediate) outcome, V

$$w(k_A V)^\alpha = w(k_A A)^\alpha - (1-w)(k_D D)^\beta \qquad \text{(Equation 4.5)}$$

we first distribute the exponents and divide both sides of the equation by $w_1 k_{1,A}{}^{\alpha 1}$,

$$\frac{wk_A^\alpha V^\alpha}{wk_A^\alpha} = \frac{wk_A^\alpha A^\alpha}{wk_A^\alpha} - \frac{(1-w)k_D^\beta D^\beta}{wk_A^\alpha} \qquad \text{(Equation A1)}$$

and simplifying for clarity

$$V^\alpha = A^\alpha - \frac{(1-w)k_D^\beta}{wk_A^\alpha}(D^\beta) \quad . \qquad \text{(Equation A2)}$$

This is then followed by eliminating the exponential scaling of the amount of the immediate outcome to leave us with

$$V = \left(A^\alpha - \frac{(1-w)k_D^\beta}{wk_A^\alpha}(D^\beta) \right)^{1/\alpha} \qquad \text{(Equation A3)}$$

Equation A3 leaves us with a formulation for calculating the present value of a delayed outcome. A version of this formula was used to fit the additive utility model to the indifference points. Many of the parameters, unless independently determined, can be compacted into a single coefficient. Specifically,

$$k = \frac{(1-w)k_D^\beta}{wk_A^\alpha} \qquad \text{(Equation A4)}$$

Substituting the compacted coefficient in for the free parameters leaves us with,

$$V = \left(A^\alpha - kD^\beta \right)^{1/\alpha}$$

which is the formulation that Killeen (2015) used for post-hoc fits of the additive utility model.

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Morrison, K. L., Madden, G. J., Odum, A. L., Friedel, J. E., & Twohig, M. P. (2014). Altering impulsive decision making with an acceptance-based procedure. *Behavior Therapy, 45(*5*),* 630-639.

Publications under review or in preparation

Friedel, J. E., Galizio, A., Frye, C. C. J., DeHart, W. B., & Odum, A. L. (accepted pending revisions). Rapidly obtaining indifference points: Measures of delay discounting from a visual analogue scale and a survey. *Journal of the Experimental Analysis of Behavior.*

DeHart, W. B., Friedel, J. E., Lown, J. M., & Odum, A. L. (in preparation). The effects of consumer financial education on delay discounting in undergraduate students. *Journal of Behavioral Decision Making.*

Friedel, J. E., DeHart, W. B., & Odum, A. L. (in preparation). Turn it up to eleven: The effects of 100 db 1 kHz and 22 kHz tones on lever pressing in rats.

Friedel, J. E., & Odum, A. L. (in preparation). The mental accounting of delay discounting.

Friedel, J. E., DeHart, W. B., Frye, C. C. J., Rung, J. M., & Odum, A. L. (in preparation). Area under the curve with delay scaled logarithmically as a better measure of discounting.

Papers presented at professional meetings

Odum, A. L., DeHart, W. B., Friedel, J. E., Galizio, A., Frye, C. C. J. (2016).Organismic and environmental influences on delay discounting: Evidence for a general

process. Paper presented at the annual meeting of Winter Conference on Animal Learning and Behavior, Winter Park, CO.

Friedel, J.E., DeHart, W. B., Frye, C. C. J., Rung, J. M., Madden, G. J., & Odum, A. L. (2014). The generality of steep discounting in cigarette smokers. Paper presented at the annual meeting of the Association of Behavior Analysis, International, Chicago, IL.

Odum, A. L., Friedel, J. E., & DeHart, W. B. (2014). Delay discounting as a process. Paper presented at the annual meeting of the Society for the Quantitative Analysis of Behavior, Chicago, IL.

Friedel, J.E., DeHart, W. B., Frye C. C. J., Rung, J. M., Madden, G. J., & Odum, A. L. (2014). The generality of steep discounting in cigarette smokers. Paper presented at the Intermountain Graduate Research Symposium, Logan, UT.

Odum, A. L., Friedel, J. E., & DeHart, W. B. (2014). *Delay discounting across commodities.* Paper presented at the annual meeting of the Texas Association for Behavior Analysis, San Antonio, TX.

Friedel, J. E., & Odum, A. L. (2013). Temporal discounting of multiple outcomes. Paper presented at the annual meeting of the Association for Behavior Analysis, International, Minneapolis, MN.

Friedel, J. E, Hudgins, C. D., & Vaidya, M. (2011). A procedure to rapidly generate forgetting functions in pigeons. Paper presented at the annual meeting of the Association for Behavior Analysis, International, Denver, CO.

Friedel, J. E., Hudgins, C. D., & Vaidya, M. (2011). Short-term memory in the pigeon. Paper presented at the University of North Texas, Behavior Analysis Research Colloquia series, Denton, TX.

Friedel, J. E., Vaidya, M., & Hudgins, C. (2010). The Impact of environmental factors on short-term remembering in the pigeon. Paper presented at the annual meeting of the Association for Behavior Analysis, International, San Antonio, TX.

<u>Posters presented at professional meetings</u>

Friedel, J. E., DeHart, W. B., Frye, C. C. J., Galizio, A., & Odum, A. L. (2015) Impulsivity and tobacco use: discounting qualitatively different outcomes in non-smokers, cigarette smokers, and smokeless tobacco users. Poster presented at the annual meeting of The Society of the Quantitative Analysis of Behavior, San Antonio, TX.

Friedel, J. E. & Odum, A. L. (2015). Within subject comparisons of indifference points obtained from a survey and a visual analogue scale. Poster presented at the annual convention of the Association of Behavior Analysis, International, San Antonio, TX.

Frye, C. C. J., Friedel, J. E., Galizio, A. & Odum, A. L. (2015). Resurgence of operant variability. Poster presented at the annual convention of Association of Behavior Analysis, International, San Antonio, TX.

Galizio, A., Friedel, J. E., Smith, B. M., Frye, C. C. J., McIntyre, S., & Odum, A. L. (2015). Reinforced behavioral variability is resistant to change under extinction and reinstatement. Poster presented at the annual convention of the Association for Behavior Analysis, International, San Antonio, TX.

DeHart, W. B., Mahamane, S., Friedel, J. E., Odum, A. L., & Jordan, K. (2015). Blue Goes Green II: Implicit preference for natural vs. man-made environments. Poster presented at the Intermountain Sustainability Summit 6th Annual Meeting, Ogden, UT.

Friedel, J. E., DeHart, W. B., Mahamane, S, Odum, A. L., & Jordan, K. (2015). Blue Goes Green I: increased delay discounting for better air quality. Poster presented at the Intermountain Sustainability Summit 6th Annual Meeting, Ogden, UT.

Mahamane, S., DeHart, W. B., Friedel, J. E., Odum, A. L., & Jordan, K. (2015). Blue Goes Green III: Does visual pollution affect nature/built categorization? Poster presented at the Intermountain Sustainability Summit 6th Annual Meeting, Ogden, Utah.

DeHart, W. B., Friedel, J. E., Frye, C. C. J., Rung, J. M., Odum, A. L. (2014). Differences in delay discounting across outcomes by smokers and non-smokers. Poster presented at the annual meeting of the Society for Judgment and Decision Making, Long Beach, CA.

Frye, C. C. J., Rung, J. M., Friedel, J. E., DeHart, W. B., & Odum, A. L. (2014). Assessing differences in discounting use linear versus exponential delay progressions. Poster presented at the annual meeting of the Association of Behavior Analysis, International, Chicago, IL.

McIntyre, S. L., Friedel, J. E., &Odum, A. L. (2014). Operant variability and persistence. Poster presented at the annual meeting of the Four Corners Association of Behavior Analysis, Park City, UT.

Friedel, J. E. & Odum, A. L. (2013). A modification of Area Under the Curve (AUC) for better analysis of discounting data. Poster presented at the annual meeting of the Nevada Association of Behavior Analysis, Reno, NV.

Friedel, J. E., Cottrel, J. M., & Odum, A. L. (2012). Temporal discounting of combined gains and losses. Poster presented at the annual meeting of the Society for the Quantitative Analysis of Behavior, Seattle, WA.

Jenkins, S., Baker, J. M., Friedel, J. E., & Jordan, K. E (2012). Incomplete understanding of number in adults. Poster presented at the Intermountain Graduate Research Symposium, Logan, UT.

Friedel, J. E. & Vaidya, M. (2011). Sample-observing latency in delayed matching-to-sample procedures: A behavioral economic interpretation and some data. Poster presented at the Behavioral Economics special meeting of the Association for Behavior Analysis – International, Chicago, IL.

Friedel, J. E. & Vaidya, M. (2009). Remembering in the Pigeon: The effects of a titrating delay match-to-sample procedure. Poster presented at the annual meeting of the Southeastern Association for Behavior Analysis, Willmington, NC.

Friedel, J. E. & Vaidya, M. (2009). Remembering in the pigeon: The effects of a titrating delay match-to-sample procedure. Poster presented at the annual meeting of the Association for Behavior Analysis – International, Phoenix, AZ.

Ongoing Research

The effects of quality and amount of an outcome on delay discounting

This broad topic covers several ongoing projects. In these projects we are trying to better understand the quantitative models that are used to predict delay discounting. Project goals include: 1) determining if current quantitative models account for how choice alternatives with more than one outcome are discounted and 2) developing accounts of how qualitatively different outcomes are discounted.

Differences in impulsive choice between smokers and non-smokers

My ongoing research in this area is in collaboration with Dr. Odum's laboratory group. Primarily, my research interests within this area involve describing how smokers and non-smokers discount qualitatively different outcomes.

Research Training

Experience from Utah State University

Experimental design and implementation, training in research with human participants, training in research with rats, basic analysis and scripting in Matlab, programming human experimental sessions (E-Prime experimental software, VB.NET, some JavaScript)

Experience from University of North Texas

Design, computer programming, implementation, data analysis, interpretation and summarizing of behavior analytic experiments; managing and co-running Dr. Vaidya's pigeon laboratory including operant chamber maintenance(wiring, computer, and Med-PC issues), running experimental sessions, and maintenance of the pigeon colony

Experience from University of Florida

Analysis of daily session data, programming in ECBasic, coding video for experimental sessions, administering experimental sessions for human operant experiments

Relevant Coursework

Utah State University

Advanced Seminar on Theories of Behavior, Advanced Seminar on Behavioral Pharmacology, Advanced Seminar on Human Development, Advanced Seminar on Psychometrics, Advanced Seminar on Cognitive Psychology, Advanced Seminar on Behavioral Economics, Seminar on Biological Basis of Behavior, Parametric Univariate Statistics, Multivariate Statistics, Methods of Reviewing Literature

University of North Texas Coursework

Introduction to Behavior Analysis, Observation and Measurement of Behavior, Experimental Analysis of Behavior, Techniques in Applied Behavior Analysis, Quantitative Analysis of Behavior, Verbal Behavior, Research Methods, Behavior Theory and Philosophy

University of Florida Coursework

Principles of Behavior Analysis, Introduction to Applied Behavior Analysis, Experimental Analysis of Behavior Lab, Behaviorism in Contemporary Society

Professional Service

Student Member, Executive Council, Association for Behavior Analysis, International — May 2013 – May 2016

Student Representative to Psychology Faculty for Experimental and Applied Psychological Science Students — June 2014 – May 2015

Professional Work Experience

Instructor Department of Psychology Utah State University Logan, UT, 84322	January 2014 – Present
Graduate Teaching Assistant Department of Psychology Utah State University Logan, UT, 84322	August 2013 – December 2013
Ad hoc Statistical Consultant Perio Protect, LLC St. Louis, MO, 63125	July 2013
Graduate Research Assistant Department of Psychology Utah State University Logan, UT. 84322	August 2011 – July 2013
Teaching Fellow Department of Behavior Analysis University of North Texas Denton, TX. 76203	June 2008 – July 2011
Behavior Principles I and II Course Coordinator Department of Behavior Analysis University of North Texas Denton, TX. 76203	August 2009 – July 2011
Teaching Assistant (Undergraduate Classes) Department of Behavior Analysis University of North Texas Denton, TX. 76203	January 2008 – May 2010
Teaching Assistant (Undergraduate Classes) Department of Behavior Analysis University of North Texas Denton, TX. 76203	August 2007 – May 2007
Undergraduate Teaching Assistant Department of Computer Information Science and Engineering University of Florida	July 2006 – May 2007

Professional Affiliations

Association for Behavior Analysis, Student Member, 2007 - present
Society for the Quantitative Analyses of Behavior, Student Member, 2007 - Present