The Effect of Caffeine Deprivation on Decisions about Future Events in Humans

A thesis

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Abstract

The current study used the stimulant model, caffeine, to assess the effects of stimulant deprivation on impulsivity in humans. Previous research has found substance abusers express greater preference for immediate outcomes and this effect is increased with deprivation from the substance. A delay discounting method was used to examine the effects of stimulant deprivation on caffeine-dependents and non-dependents.

Experiment 1 looked at the effects of 12 hour's abstinence from caffeine on High and Low caffeine consumers' decision making, using a pen-and-paper delay discounting method. Experiment 1 produced area under the curve values which showed the largest effect in the Low caffeine consumers, Low caffeine consumers increased discounting when under the influence of caffeine.

Experiment 2 used a well supported computer-based, hypothetical monetary, delay discounting task in hope of generating a magnitude effect. Experiment 2 was used to determine the task mode in Experiment 1 was not responsible for the unexpected pattern of results. A magnitude effect was found between the \$1000 and \$10,000 tasks in the delay discounting procedure.

Experiment 3 used the established computer-based, hypothetical monetary amounts, delay discounting task from Experiment 2 to assess the effects of 24 hours abstinence from caffeine in High and Low caffeine consumers. The *k* values revealed a significant increase in discounting when participants were caffeine deprived for all groups except the High caffeine group in the \$10,000 condition. These mixed results were discussed in terms of weaknesses revealed about the common mathematical measures used to analyse delay discounting data. Most importantly, the practice regularly employed by delay discounting researchers to exclude data which does not conform to discounting functions. The exponential, hyperbolic, extended hyperbolic models and the area under the curve measure were compared. The area under the curve was found to be the only measure to not exclude data, and sub-sequentially was preferred. Further research is required to establish if the area under the curve behaved in similar ways to other measures of discounting data as correlations in this study are not clear.

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Everyday humans and animals make behaviour choices, a choice between acts which have consequences. Consequences can be positive, negative, immediate and delayed. Behaviour economics studies the principles of psychology and economics to understand the transactions individuals make with the world (MacKillop, 2010). The field of psychology has used the label s*elf-control* to describe the processes which allows individuals to engage in behaviours with long-term positive consequences (Mitchell, 2004); these self-controlled choices can also be described as choosing the larger, more delayed option. The opposite of self-controlled behaviour is known as *impulsive behaviour.* Impulsivity is the failure to delay gratification and an impulse is often described as preference for the small, short-term gain over large, delayed gain (Ainslie, 1974). Factors contributing to whether an individual exhibits self-control include; the time horizon present, the passage of time, precommitment to a choice, uncertainty, survival and cognitive capacity (Logue, 1998). The behavioural processes underlying the effect of these mental struggles have been systematically studied (Madden & Bickel, 2010). Delay decreases the reinforcers effectiveness which results in a steep, negatively accelerated curve where subjective value is plotted as a function of the delay (Ainslie, 1974). These curves are often referred to as discounting curves, they suggest small, immediate reinforcement may be valued greater than larger, delayed reinforcement if the delay is significant enough (Ainslie, 1974). These curves can be predicted by mathematical discounting equations, the most accurate function for discounting data is continually being debated (Ainslie, 1974). The current thesis intended to investigate the delay discounting methods performance at measuring impulsivity when stimulant dependent participants were deprived of their stimulant drug. Caffeine was the drug dependence considered.

In the following, impulsivity and delay discounting are introduced. This is followed by a look at previous research investigating stimulant-dependants and delay discounting. Next, some known behavioural and cognitive effects of caffeine are presented. Caffeine is a suitable model for the current study because it is a widely consumed stimulant drug. And finally, the delay discounting method is examined and critiqued with a particular interest in the roles of the mathematical discounting functions.

Control & Impulsivity

Self-control is a term with widespread and common usage; in the field of behavioural science self-control is viewed as the ability to delay gratification for a more positive long-term outcome. Examples of conflicts between a self-controlled choice and an impulsive choice are evident in human daily activity, for example, a university student may have a test to study for but is given the option to go to the movies with their friends, or, Logue (1998) describes a vice president in charge of a physical plant having the choice between the latest technology or necessary building maintenance. Self-control and impulsivity provide descriptions of behaviour which is of interest to many academic fields, including; sociology, economics and psychology (Ainslie, 1974). Ainslie (1975) suggests the maladaptive behaviour of humans choosing the smaller, more impulsive alternative when both options are familiar could be explained by one of the following; people have not learned the consequences of following their impulses, the consequences are known but people are compelled to obey their impulses, or, finally, the perception of consequences is innately distorted.

Within behavioural sciences, experimental manipulations are used to measure self-control and impulsivity. If the experimental manipulation has the same effect on different kinds of outcomes it indicates the process underlying decision making is the same, and if not this would indicate different processes are involved (Green & Myerson, 2010). If the underlying process of decision making for different outcomes is found to be the same through experimental manipulation, this would indicate an impulsive trait with relative permanence and predictability within an individual (Green & Myerson, 2010). Previous research has indicated the permanence and predictability of impulsivity by comparing the subjective values of delayed and uncertain outcomes for patients with high and low impulsivity psychiatric diagnosis (Crean, deWit and Richards, 2000). Patients, with high-risk of displaying impulsive tendencies, displayed steeper decreases in value when delay till receipt of outcome increased. This experimental manipulation is commonly known as delay discounting.

Delay Discounting

Delay discounting is used to establish how future outcomes are subjectively devalued, also known as a measure of an individual's impulsive tendencies (Madden & Bickel, 2010). Economists pioneered the study of imperfect decision making by humans (Ainslie, 1974) and it was established a curve could illustrate discounting, the upward concavity suggesting utility falls off rapidly for relative short delays and declines gradually as delays increase (Strotz, 1956). Research on delay discounting has increased in the last decade, with searches on the PubMed database for the keyword *delay discounting* increasing from approximately zero in 1994 to over 40 in 2007 (Madden & Bickel, 2010).

The delay discounting paradigm looks at preference between smaller-sooner and larger-later consequences. Predominantly, positive reinforcers are used as consequences, although the paradigm has been used to study choices of aversive events also (Madden & Johnson, 2010). Green and Myerson (2004) suggest choices which involve more than one dimension can be examined from a discounting perspective, discounting assumes the perceived value of the reward is increasingly discounted as the delay increases and the chosen reward has the perceived higher (discounted) value. Figure 1 shows Green and Myerson's (2004) example of the discounting process, the rate at which the larger reward is discounted as a function of delay. A systematic set of findings from both non human and human literatures have established the discounting paradigm's relevance and social significance (Madden & Johnson, 2010).

Discounting research faces the problem that 'higher' processes are mediating the behaviour patterns observed. Animal research has played a significant role in an attempt to eliminate this criticism (Ainslie, 1975). Animal experimentation permits stronger manipulations so data is thorough, however, animal experimentation brings to question the influence of innate behavioural patterns specific to the species (Ainslie, 1975). Animal experimentation pioneered discounting research and was the first to predict reversals in preference would occur. Rachlin and Green (1972) predicted preference reversals would occur as the delay increases, they gave pigeons a choice between 2 s and 4 s access to a food magazine. The 2 s access was received immediately after pecking the red key and the 4 s access was received after a 4 s delay once the green key was pecked, the 2 s, immediate access was chosen on almost all trials (Rachlin & Green, 1972). The pigeons were then given two white keys to choose between, if the 25th peck was on the right key the pigeons were given the red and green keys as before, if the 25th peck was on the left key the pigeons were given the green key only (Rachlin & Green, 1972). Four of the pigeons displayed a commitment response by pecking the left key when the delay was long but not short – a reversal of preference (Rachlin & Green, 1972). Rachlin and Green (1972) provide evidence that behaviour is part of and responsive to changes in contingencies, a concept consistent with the modern discounting account. Evidence provided by discounting research indicates impulsivity can be measured and is responsive to change as a result of delay until receipt, evidence which is important to the many social implications of the failure to delay gratification.

Delay Discounting and Stimulant Abuse

The discounting paradigm provides a measure from which we can come to understand choices made by substance abusers (Yi, Mitchell & Bickel, 2010). Studies have compared substance abusers with non-abusing control populations and found that substance abusers have higher rates of discounting (Yi et al., 2010). Studies have also found reason to suggest the delayed costs of drug use may control behaviour more than the delayed benefits of drug abstinence (Odum, Madden & Bickel, 2002).

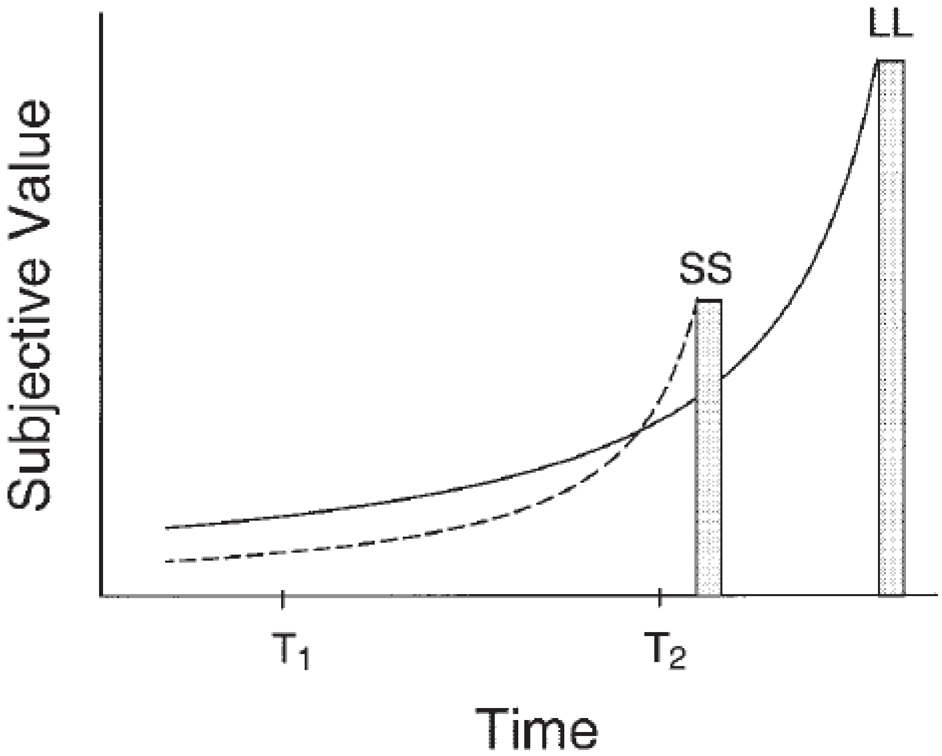

Figure 1. Displays the choice between a smaller, sooner (SS) reward and a larger, later (LL) reward. The curves show the subjective value of the rewards as a function of time. The bar height represents the actual reward amount. T_1 = Time 1: T_2 = Time 2. Reproduced from “A discounting framework for choice with delayed and probabilistic rewards” by Green, L. & Myerson, J. (2004) in *Psychological Bulletin,* 130 (5), 769-792.

Opioid dependent individuals were compared to non-drug using control participants and it was found that opioid dependent participants discounted hypothetical delayed monetary rewards significantly more than non-drug using control participants. It was also found the opioid rewards were discounted more than the monetary rewards (Madden, Petry, Badger & Bickel, 1997). Opioid-dependent participants have also been studied in a state of deprivation to assess impulsivity. Opioid deprivation increased discounting of both opioid and monetary rewards (Giordano et al., 2002). The findings by Madden et al. (1997) and Giordano et al. (2002) are consistent with the perspective that substance abusers express greater preference for immediate outcomes and this effect is increased with deprivation from the substance (Yi et al., 2010).

Abusers of the drug nicotine are some of the most examined using delay discounting procedures (Yi et al., 2010). Health gains and losses were examined in current cigarette smokers, participants who had never smoked cigarettes, and ex-smokers of cigarettes using this method (Odum et al., 2002). Current smokers discounted health gains and losses more steeply than never-smokers (with ex-smokers in the middle of the two). This indicates cigarette smokers show steep discounting for delayed health outcomes and suggests that nicotine treatments should control for this (Odum et al., 2002). Deprivation has also been found to affect the impulsive decision making of nicotine users (Mitchell, 2004). Cigarette deprivation has been found to increase impulsive decision making for drug-related rewards but not monetary rewards using a delay discounting method (Mitchell, 2004).

Discounting research provides evidence that the processes underlying substance abuse are also responsible for a failure to delay gratification. Discounting research helps increase the understanding of, and consequential ability to assist, stimulant abusers' decision making.

Caffeine

Cognitive Effects

Caffeine is the most widely consumed psychostimulant in the world (Dager et al., 1999). It is not commonly viewed as a drug of abuse and the understanding of the addictive behavioural effects of caffeine are limited.

The cognitive benefits of caffeine have been thoroughly examined by previous research. Caffeine alone was found to show improvements in the simple reaction times of participants (Adan & Serra-Grabulosa, 2010) and caffeine significantly improved attention on a switch task as compared to the placebo in a randomized, placebo-controlled, double-blind, cross-over experiment (Einöther, Martens, Rycroft & De Bruin, 2010).

The effects of caffeine on human information processing and cognitive performance have been found to have an inverted U shaped effect in dose-response; this indicates that excessive consumption can have a detrimental effect on performance (Fredholm, Bättig, Holmén, Nehlig, Zvartau, 1999). Childs and de Wit (2006) found acute doses of caffeine increased the number of hits and decreased reaction times in a vigilance task for light consumers of caffeine. The effects of caffeine on alertness were examined in a double-blind, randomized, 37 hour deprivation study (Kilpeläinen, Huttunen, Lohi & Lyytinen, 2010). Sleep deprivation was found to decrease performance on the vigilance test, however, participants who had consumed caffeine reported no decline in subjective opinion of performance (Kilpeläinen et al., 2010).

Behavioural Effects of Caffeine

From a behavioural perspective, caffeine has been well documented to delay the onset of sleep and increase performance in exercise. Performances while driving and on night shift have been found to significantly improve with caffeine intake, while caffeine is known to; shorten overall sleep time, prolong sleep latency and decrease overall sleep quality (Fredholm et al., 1999). The effects of caffeine on exercise performance were assessed in highly trained cyclists. Ingestion of caffeine was double-blind and randomized, it was found that the caffeine ingestion significantly increased the time to exhaustion recorded by cyclists (Simmonds, Minahan & Sabapathy, 2010).

With well documented behavioural and cognitive benefits of the stimulant drug caffeine, it is inevitable drug dependence will occur amongst its users. Drug dependence is the result of the substance being more satisfying than the withdrawal effects, maintaining dependence and increasing tolerance. Drug dependence is defined by Fredholm et al. (1999) as when administration of the drug is sought compulsively and the drug continues to be used despite adverse psychological and physical effects. Drug dependence is also considered all nonmedical and regular use of a psychoactive substance (Fredholm et al., 1999).

Withdrawal and Tolerance Effects of Caffeine

Withdrawal symptoms from caffeine include; weariness, apathy, weakness, drowsiness, anxiety, decreases motor behaviour, headaches, nausea and flu-like symptoms. To help characterize caffeine's' physical dependence in humans, Evans and Griffiths (1999) conducted four double-blind experiments. Caffeine withdrawal symptoms confirmed previous research and included; headaches, poor mood, fatigue and decreased alertness (Evans & Griffiths, 1999). A caffeine dose of one per day is enough to produce physical dependence and the magnitude of caffeine dose is positively correlated with increases in withdrawal symptoms (Evans & Griffiths, 1999).

Tolerance is when the consumption of the stimulant has to increase in order to gain the reinforcing effects once obtained from a smaller consumption rate. A study examined the difference in brain metabolic responses between heavy caffeine consumers and caffeine-intolerant individuals at baseline and one-hour following caffeine ingestion (Dager et al., 1999). Psychological and physiological distress, as well as increase in global and regionally specific brain lactate, was seen in intolerant participants but not in heavy consumers following caffeine ingestion (Dager et al., 1999). Heavy consumers were then re-examined after 1-2 months abstinent from caffeine (Dager et al., 1999). Re-exposure to caffeine after the 1-2 months of abstinence saw significant increases in brain lactate, similar to that seen in the caffeine-intolerant individuals (Dager et al., 1999). Tolerance to caffeine is apparent although it appears to be relatively short-lived after caffeine consumption ceases. Caffeine is a stimulant drug which, like all stimulant drugs, has reinforcing aspects that increase dependency and negative effects upon its removal.

Caffeine and Delay Discounting

Of interest to the current study, delay discounting methods have been applied to a limited number of caffeine studies. Diller, Saunders and Anderson (2008) examined the effects of acute and repeated caffeine administration on temporal discounting in rats. It was found that with administration of caffeine came a decrease in impulsive decision making, the larger, delayed reinforcer was chosen more often (Diller et al., 2008). Kingston (2010) completed an honours dissertation on, what is thought to be the first discounting research looking at the effects of caffeine on impulsivity in humans. Kingston (2010) compared the choices of caffeine consumers and non-consumers on a hypothetical monetary task and a hypothetical commodity task when deprived and exposed to caffeine. The withdrawal effects of caffeine were found to increase delay discounting in human participants (Kingston, 2010).

Delay Discounting Procedures

Providing a systematic procedure to investigate discounting of both human and nonhuman subjects has been a substantial part of the challenge in establishing an accurate measure of impulsivity.

Adjusting-delay Procedure

As previously mentioned, much of the pioneering work in discounting research was done in the animal laboratory on nonhuman subjects; most human procedures were an adaptation of these nonhuman studies (Madden & Johnson, 2010). One of the first procedures used to assess discounting was the adjusting-delay procedure (Madden & Johnson, 2010). The adjusting-delay procedure involves subjects choosing between a large food reward available after an adjusting delay, and a smaller amount of food available after a fixed, smaller delay (Madden & Johnson, 2010). Mazur, Stellar and Waraczynski (1987) pioneered this procedure; they gave rats the choice between a low frequency of electrical stimulation of the brain and a higher frequency of electrical stimulation of the brain available after a delay (electrical stimulation served as a reward for rats). The indifference points were estimated as the point in which the two alternatives were chosen equally often, these indifference points were then used to establish the discounting curve; these discounting curves had positive y-intercepts and slopes greater than 1.0 (Mazur et al., 1987).

To transition the adjusting delay procedure into research on human participants the reward on offer must be altered. A widely used reward for human participants in the studies is a hypothetical outcome (Madden & Johnson, 2010). The hypothetical amounts procedure uses hypothetical monetary amounts to provide participants with choices; smaller amounts of money available immediately versus large amounts of money available after a variable delay (Madden & Johnson, 2010). Rachlin, Raineri and Cross (1991) pioneered the hypothetical outcomes approach by offering human participants the choice between a hypothetical $1000 reward available with various probability or delays, and a variable hypothetical amount of money available immediately. When the hypothetical outcomes were presented to human participants the researchers found indifference points best described by a hyperbolic discounting function. They had the same general shape as Mazur (1987) had found with pigeon subjects (Rachlin et al., 1991). Rachlin et al. (1991) provided evidence that there is interspecies continuity in the process of discounting delayed outcomes, however, the hypothetical nature of the outcomes has raised concerns (Madden & Johnson, 2010).

Research has shown that the discounting patterns of humans presented with hypothetical rewards and with real rewards are both well represented by a hyperbolic discounting function (Madden & Johnson, 2010). Madden, Begotka, Raiff and Kastern (2003) used an adjusting amounts procedure in a within-subjects design to assess the subjective value of real and hypothetical rewards at each delay. Twenty college students were presented with a range of monetary amounts ($0.01 to $10) and delays (6 hours to 1 year), firstly in hypothetical form and then in real-life form (Madden et al., 2003). The hyperbolic discounting function provided the best fit for both the hypothetical reward and real reward conditions (Madden et al., 2003). The ease and lack of cost for using hypothetical rewards in human discounting studies is further supported by the notion that it does not affect the discounting patterns observed for participants.

Comparison of Instruments Used for Data Collection

As delay discounting is increasingly being viewed as an operational definition of impulsivity, its methodological protocols increase in importance (Smith & Hantula, 2008). Instruments used in the collection of discounting data are often compared to establish consistency, of interest to this particular study are the differences observed between modes in which these tasks are presented to human participants. Studies which compare modes are limited; Smith and Hantula (2008) assessed the difference in presenting human participants with a computer-based delay discounting task and a paper-and-pencil version of the delay discounting task. The computer-based delay discounting task and the paper-and-pencil delay discounting task showed no significant difference in discounting rates, these results remained stable with different task types and reward magnitudes (Smith & Hantula, 2008).

Analysing Delay Discounting Data

Discounting is best measured by studying the preference between smaller-sooner and larger-later consequences, the findings are amenable to quantification and replication (Madden & Johnson, 2010). Investigating the decline in reinforcer value as a result of delay can be predicted by mathematical functions and is commonly described by a negative curve shape

The Matching Law

Chung and Herrnstein (1967) had pigeons choose between equal reinforcers which varied on delay to delivery. Chung and Herrnstein (1967) were the first to find evidence for effects of delay of reinforcement being similar to those of rate of reinforcement on the distribution of responses – the matching law. It has been claimed that all animal's behaviour is distributed across choices according to the matching principle (Herrnstein, 1974). The matching law describes an animal's responses to choices as:

$$\frac{P_1}{P_1 + P_2 + \cdots + P_N} = \frac{R_1}{R_1 + R_2 + \cdots + R_N} \tag{1}$$

where P is total responses and R is total reinforcements (Herrnstein, 1974). The matching law has been found to describe choice behaviour even when responses and reinforcements differ quantitatively and qualitatively (Herrnstein, 1974).

The matching law describes the relation between alternatives which vary on one dimension, however, it cannot describe discounting when more than one dimension is varied (Church, 1997). Within a naturalistic environment decisions are made between choices which vary in more than one dimension, indicating the need for a more accurate descriptor.

The Exponential Model

An economic point of view assumes future value is discounted exponentially with delay, the present value decreases by a fixed proportion per unit of time until reward delivery (Kirby, 1997). Normative, exponential discounting can be expressed as:

$$V = Ae^{-kD} \tag{2}$$

where *V* is the present, discounted value of the delayed reward, *A* is the amount of the reward, *D* is the delay until reward is received, and *k* is the discounting rate (Kirby, 1997).

The exponential model assumes *k* is the same for both alternatives and that the present value of the small reinforcers is equal to the present value of the large reinforcers at the indifference point (Mazur et al., 1987). The exponential model predicts a linear indifference curve with a positive y-intercept and a slope equal to

1.0 – this is to be true regardless of reinforcer size (Mazur et al., 1987). Rationally, the exponential model appears a reasonable descriptor for the relation between delay and value, although, there are large amounts of empirical evidence which find this equation inconsistent (Mazur et al., 1987). There are well documented deviations from the exponential model in animal laboratories and with human participants (including those with drug addictions) regardless of whether the reward was hypothetical or real, or gains or losses (Madden & Johnson, 2010). Madden, Bickel and Jacobs (1999) examined the ability of discounting functions to describe the monetary and heroin reward delay discounting of 18 human heroin-dependent participants. The exponential model was found to account for significantly less variation and produce significantly smaller sums of squared error values than its rival discounting function (Madden et al., 1999).

Evidence suggests the exponential model is inadequate for describing discounting because indifference curves obtained in numerous studies have consistently had slopes greater than 1.0 and preference reversals (Mazur et al., 1987).

The Hyperbolic Model

The hyperbolic discounting function provides a more accurate descriptor for the discounting data as it hinges on the possibility that the discounting curves for different future rewards can cross (Kirby, 1997). The hyperbolic function is described by Mazur (1987) as:

$$V = \frac{A}{1 + kD} \tag{3}$$

where V is the present, discounted value of the delayed reward, A is the amount of the reward, D is the delay until reward is received, and k is the discounting rate (Mazur, 1987).

Like the exponential model, the hyperbolic model predicts a linear indifference curve with a slope greater than 1.0 (Mazur, 1987). Unlike the exponential model, the hyperbolic model predicts the y-intercept will be positive (Mazur, 1987). The well-established matching law (Chung & Herrnstein, 1967) had already implied hyperbolic discounting in its prediction of the discounting rate and delay being related, however, predictions of preference reverses are far from the normative model of discounting (Kirby, 1997). The exponential model assumes discounting is independent of the size of the reward so preference reversals should not occur (Kirby, 1997). Empirical research has found these preference reversals, although straying far from normative assumptions, do occur (Kirby, 1997). Evidence of preference reversals have been found using a range of non-human and human models, including; rats, pigeons, adult humans, and children (Kirby, 1997). Richards, Mitchell, deWit and Seiden (1997) offered eight Sprague-Dawley rats the choice between a varying amount of water available immediately and a fixed amount of water available after a delay. Indifference points were found in all trials and had discounting curves greater than 1.0 with positive y-intercepts, the hyperbolic model provided the best fit for the discounting data (Richards et al., 1997). Bickel, Yi, Kowal and Gatchalian (2008) found cigarette smokers discount future outcomes more than non-smokers. A computerized assessment of discounting was used and the hyperbolic model accurately described all participants' data (Bickel et al., 2008). This indicates cigarette smokers and non-smokers displayed preference reversals and had discounting curves with slopes greater than 1.0.

The Extended Hyperbolic Model

There is some support the notion that adding a free parameter to the hyperbolic discounting model will result in a better fit for discounting data. Rachlin (1989) suggested raising the hyperbolic equations' denominator to a power; the extended hyperbolic function has the form:

$$V = \frac{A}{(1 + kD)^s} \tag{4}$$

where *V* is the present, discounted value of the delayed reward, *A* is the amount of the reward, *D* is the delay until reward is received, and *k* is the discounting rate (Mazur, 1987). The exponent *s* stands for subjective sensitivity of value to amount and is generally equal to or less than 1.0 (Green & Myerson, 2004).

Rachlin (1989) proposed the addition of the *s* parameter to increases the accuracy of measuring sensitivity to delay. An *s* value of 1.0 indicates the subjective value is directly proportional to amount (Rachlin, 1989) and The extended hyperbolic model reduces to the hyperbolic model (Green & Myerson, 2004). Like the hyperbolic model, if the extended hyperbolic model provides the best fit for discounting data then choices between rewards available at different times are really choices between different rates of rewards (Green & Myerson, 2004).

Green and Myerson (2004) compared group median indifference points established for the exponential, hyperbolic and extended hyperbolic models on a discounting task. The exponential model provided the poorest fit for the data by over predicting the subjective values at smaller delays and under predicting values at larger delays (Green & Myerson, 2004). The hyperbolic model provided a more accurate fit than The exponential model but still over predicted the subjective values at smaller delays and under predicted at larger delays (Green & Myerson, 2004). The extended hyperbolic model provided the best fit for the data, this supports adding a free parameter to a model to increase the proportion of variance accounted for (Green & Myerson, 2004).

The Area Under the Curve

The most recent addition to measures of discounting is the Area Under the Curve (AUC). Myerson, Green and Warusawtharana (2001) proposed a measure of discounting which uses the area under the empirical discounting function (actual data points) as this would eliminate many issues which arise from the traditional measures. The AUC measure is theoretically neutral so can be applied to a variety of procedures and data groups (Myerson et al., 2001). To calculate the AUC, the indifference points are plotted on a graph against the investigated function with a line between each point (the result is a discounting curve), trapezoids are then used to calculate the total area under this discounting curve.

The AUC value can range between 0.0 to 1.0 – 0.0 represents extremely steep discounting and 1.0 represents no discounting shown (Myerson et al., 2001). The AUC measure is theoretically neutral and circumvents the statistical problems created by skewed distributions (Myerson et al., 2001). The AUC provides a combination of multiple measures of discounting obtained at different delays.

Odum (2011) reports the AUC as more normally distributed than *k* values derived from other discounting models, which allows for it to be evaluated by parametric statistics. Odum (2011) used the AUC measure to analyse archival data on delay discounting. It was found that AUC measures replicated conclusions resulting from different measures and positive correlations were found between discounting for multiple items (Odum, 2011).

Aims of Current Research

The current study used the stimulant model, caffeine, to assess the effects of stimulant deprivation on impulsivity in humans. A delay discounting method was used to examine the effects of stimulant deprivation on caffeine-dependents and non-dependents.

It was predicted that the caffeine dependent participants would discount future events more steeply when they were in a state of deprivation compared to their regular state of caffeine consumption, and caffeine non-dependents were expected to display the least amount of discounting on the delay discounting tasks.

The stimulant deprivation model was used to assess the accuracy of commonly used predictors of discounting rates. The exponential, hyperbolic, extended hyperbolic models and the AUC were compared to assess which described the discounting patterns of participants with the most accuracy. The AUC analysis was expected to provide the most accurate and useable analysis of the discounting data.

Experiment 1

1.1 Introduction

Impulsiveness is often discussed as a preference for the risky or negative outcome and can be referred to as failure to delay gratification (Ainslie, 1974). As discussed previously, impulsivity can be measured using the Discounting paradigm. The decrease in value to increase in delay effect is known as delay or temporal discounting (Mazur et al., 1987). When an individual displays a preference for the smaller, more immediate option they are displaying impulsive behaviour (Diller et al., 2008). Choosing the larger, more delayed option is defined as the individual displaying self-control (Diller et al., 2008). Typical delay discounting patterns can be described by a steep, negatively accelerated curve (Ainslie, 1974). Delay discounting procedures present a number of options and the participant has to choose between a smaller consequence which is immediately available and a larger, more delayed consequence (Kollins, 2003). A popular method for human discounting experimentation is the choice between a small hypothetical amount of money available immediately (e.g., $50 now) and a large hypothetical amount of money available after a delay (e.g., $1000 in 6 months).

Although consequences used in human discounting studies are commonly hypothetical monetary amounts, some research has looked at the discounting of other commodities. Weatherly, Terrell and Derenne (2010) found that different commodities were discounted differently depending on the domain they belonged to. Methods for collecting delay discounting data vary significantly; Smith and Hantula (2008) compared the use of a computer-based delay discounting task and a paper-and-pencil version of the delay discounting task. The computer-based delay discounting task and the paper-and-pencil delay discounting task showed no significant difference in discounting rates, these results remained stable over different task types and reward magnitudes (Smith & Hantula, 2008). Pen and paper administration provides a quick, easy and inexpensive method of obtaining discounting data. Beck and Triplett (2009) found the pen and paper method to have good reliability and validity using a test-retest procedure. Another potential benefit of the pen and paper method is that the respondents can view the whole range of answers allowing them to quickly scan all choices and make their choices accordingly (Beck & Triplett, 2009).

Delay discounting research has addressed the effect of stimulant drugs on discounting behaviour. Stimulant drugs can have a weakening effect on the reinforcing value of an outcome, effecting choice behaviour (Diller et al., 2008). Previous research has found that depriving dependent-users of the stimulant drug increases their impulsive behaviour. Mitchell (2004) asked nicotine-dependents to complete two delay discounting tasks, choice was given between small, immediate cigarettes or money and large, delayed cigarettes or money. For one session, cigarette consumption prior to participating remained the same, for the other session, participants were asked to abstain from smoking for 24hours prior (Mitchell, 2004). The deprivation of cigarettes increased impulsive decision making for the drug-related rewards but not the monetary rewards (Mitchell, 2004).

A stimulant which has had less attention by discounting research is caffeine. Caffeine is the most commonly consumed stimulant drug world-wide, it is readily available and without any form of control. As a result of this liberal availability, caffeine provided a suitable model to further assess the effects of deprivation of stimulants on impulsive behaviour. Caffeine has known effects on attention, vigilance, reaction time, and alertness (Einöther et al., 2010). Many caffeine consumers are dependent on its consumption and, as with all drug-dependencies, there are detrimental withdrawal effects of caffeine. Withdrawal symptoms of caffeine include; weakness, drowsiness, anxiety, headaches and nausea (Fredholm et al., 1999). The same as other stimulant drugs, caffeine is known to have an effect on impulsive choices. Diller et al. (2008) found that impulsive choice decreased in rats while they were under the influence of caffeine, which provides evidence that caffeine has similar underlying effects as other drugs of abuse.

Previous research on the effects of caffeine on impulsive behaviour in humans is limited. Kingston (2010) completed research for her honours dissertation on the effects of caffeine on delay discounting trends in humans. Kingston (2010) compared caffeine consumers and non consumers' performance on a computerised, hypothetical money and caffeine related rewards, delay discounting task. Caffeine consumers were found to discount monetary and commodity rewards significantly higher when abstinent from caffeine consumption (Kingston, 2010). Non consumers were found to discount less than caffeine consumers on the hypothetical monetary task. Kingston (2010) had a group of caffeine consumers in the study who consume between 100-200mg of caffeine per day, this is a relatively low level of caffeine, indicating the need for research that investigates caffeine users of large amounts.

Discounting data is typically described by negative curve shapes which are well predicted by mathematical discounting functions (Ainslie, 1974). Using the stimulant deprivation model, mathematical predictors of discounting will be compared. Economic theory suggested discounting should be best described by the exponential model. The exponential model assumes the subjective value decreases by a fixed proportion per unit of time (Kirby, 1997). Evidence has since shown the exponential model is inadequate for describing discounting data as the indifference curves obtained by numerous studies have slopes greater than 1.0 and the exponential model fails to predict preference reversals (Mazur et al., 1987). The hyperbolic model is supported by much research as accurately describing discounting patterns. The hyperbolic model has been found to provide the best fit to the discounting data of rats (Mitchell et al., 1997), cigarette smokers (Bickel et al., 2008), pigeons and children (Kirby, 1997). It accounts for reversals in preference, discounting slopes greater than 1.0 and predicts that y-intercepts will be positive (Mazur, 1987). It has also been suggested that raising the denominator to a power in the extended hyperbolic model will increase the accuracy of measuring sensitivity to delay (Green & Myerson, 2010). A limitation of the extended hyperbolic model is the assumption that measures are normally distributed, where individual parameter estimates tend to be positively skewed for discounting functions (Myerson & Green, 2001). The AUC measure uses empirical discounting data to calculate trapezoids, these trapezoids are totalled to establish the total AUC value (Myerson et al., 2001). The AUC is theoretically neutral so can be applied to a variety of procedure and data groups (Myerson et al., 2001). However, the AUC has been criticised for the failure to describe discounting direction.

It was expected that the high caffeine consumers would discount future events more steeply when they are in a state of deprivation compared to when they consume caffeine as usual. Low caffeine consumers were expected to display less discounting compared to high caffeine consumers on the delay discounting tasks. Both high and low caffeine consumers were expected to discount the value of hypothetical caffeine related outcomes more than hypothetical monetary rewards in both a non-abstinent and an abstinent state of consumption. To compare and evaluate the predictions made by popular discounting functions, four models were used to describe the data. Applying these functions provided comparison for the most accurate descriptor of the discounting trends, it was expected that the hyperbolic model would provide the most accurate fit for the data.

1.2 Method

Participants

Twenty participants were recruited from the University of Waikato (4 male:16 female, mean age 25.21years). The research was approved by the Psychology Research and Ethics Committee at the University of Waikato, Appendix A is a copy of the ethics application and approval (ref 29). Table 1 shows the demographic characteristics of the participants. Participants were recruited by advertising posted around the campus of the University of Waikato and on the internal internet system. Participants were all University of Waikato students. Students of a first year psychology class in the B semester of the University of Waikato academic year were offered a 1% course credit for completing the study. Interested participants contacted the researcher via email. The information sheet was sent via email and participants were instructed to familiarize themselves with the method and indicate an appropriate time to complete the first session.

Apparatus/Materials

Pre-experimental materials included; the information sheet (Appendix B), the University of Waikato Research Consent Form (Appendix C), the Caffeine Consumption Questionnaire (Appendix D) (Kingston, 2010) and the demographic questionnaire (Appendix E). The Caffeine Consumption Questionnaire provided information regarding the participant's usual consumption and dictated whether they were to complete the Hypothetical Caffeine Reward Task or the Hypothetical Beverage Reward Task. To calculate the participants average caffeine consumption, a reference list which was developed by the Australian Institute of Sport (2007) (Appendix F) was used. The experiment consisted of two delay discounting tasks as a measure of impulsivity. Both delay discounting tasks were pen and paper tests with 126 questions presented. For each condition 7 pages of questions were presented.

For the Hypothetical Monetary Reward Task each page had a table of questions which presented a hypothetical amount of money available immediately and hypothetical $1000 available after a delay. The Hypothetical Caffeine/Beverage Task consisted of a hypothetical voucher for a beverage, each page had a table of questions which presented a voucher of varying value available now and a voucher worth $1000 available after a delay. Beck and Triplett (2009) found gathering delay discounting data using a paper-pencil procedure had test-retest reliability of r >.60 for both k and AUC calculations. The correlations between discounting rates and BIS-11 scores were evidence of validity for Beck and Triplett's (2009) paper-pencil procedure. Beck and Triplett (2009) provide evidence of the current pen and paper procedure's reliability and validity.

Table 1.

Demographic characteristics of participants.

Age	Mean (years)	25.21
	Standard Deviation	9.32
Gender	Males : Females (ratio)	4:16
Caffeine Consumption	Low Caffeine Consumers average caffeine consumption per week	426mg
	High Caffeine Consumers average caffeine consumption per week	1469mg
	Mean hours since caffeine consumption before non-abstinent session	1423.6
	Mean hours since caffeine consumption before abstinent session	1368.3
Drug use in last 24 hours	Psychiatric Medication	No (20)
		Yes (0)
	Illegal Drugs	No (19)
		Yes (1)
	Nicotine	No (19)
		Yes (1)
	Alcohol	No (16)
		Yes (4)

Note. Table of demographic characteristics of the participants, including the average number of hours since last caffeine consumption for both the non-abstinent and abstinent conditions.

Procedure

Participants emailed the researcher and indicated an interest in participating. They were emailed a copy of the information sheet and instructed to familiarise themselves with the method before indicating a suitable time to complete the study. Individual participants arrived at the pre-determined research room which contained a computer, two desks, and two chairs. Participants were provided with a pen to complete the tasks. Only the participant and the researcher were present within the room. Upon arriving at the first session, informed consent was obtained.

The participants then completed the pre-experimental questionnaires. The Caffeine Consumption Questionnaire provided information regarding the participant's usual consumption and dictated whether they were to complete the Hypothetical Caffeine Reward Task or the Hypothetical Beverage Reward Task. Participants attended two sessions, each lasting approximately half an hour.

Hypothetical Monetary Reward Task.

After completing the Caffeine Consumption Questionnaire and the Demographic Details sheet, all the participants were asked to complete the Hypothetical Monetary Reward Task. The Hypothetical Monetary Reward task was a delay discounting task which asked participants decisions regarding hypothetical money.

The participants were given a choice between an amount of money ($1, $2, $10, $20, $50, $100, $200, $500, & $1000) available immediately and $1000 available after varying delays (1 month, 6 months, 1 year, 2 years, 4 years, 8 years, & 16 years). The options were listed in order of delay and amount, each delay was listed on a separate sheet of paper. See Figure 2 for an example of the page used for the 4 year delay. Participants were asked to indicate which option they would prefer for all 63 choice scenarios.

The Hypothetical Beverage/Caffeine Reward Tasks.

After completing the Hypothetical Monetary Reward Task, participants were asked to complete the Hypothetical Beverage/Caffeine Reward Task. The Hypothetical Beverage/Caffeine Reward Tasks were delay discounting tasks similar to the monetary task, with the exception of the monetary amounts being swapped for a voucher for a beverage. The commodities offered depended on the participants' response to the caffeine consumption questionnaire. If the participants indicated they consumed more than one coffee/100mg of caffeine per day (indicating they consumed over seven coffees per week on the caffeine consumption questionnaire), they completed The Hypothetical Caffeine Reward Task. If the participants indicated they consumed less than a coffee per day/100mg of caffeine per day (less than seven coffees per week on the caffeine consumption questionnaire) they completed The Hypothetical Beverage Reward Task. The vouchers were presented as an amount available in credit at a cafe of their choice to only purchase coffee/beverages (1 item, $4, $10, $20, $50, $200, $500, & $1000) available now, or $1000 credit for coffee/beverages at a cafe of their choice available after varying delays (1 month, 6 months, 1 year, 2 years, 4 years, 8 years, & 16 years).

Please tick the corresponding box beside the alternative you prefer

	Tick			Tick
Would you prefer $1 now	☐	OR	Would you prefer $1000 in 4 years	☐
Would you prefer $2 now	☐	OR	Would you prefer $1000 in 4 years	☐
Would you prefer $10 now	☐	OR	Would you prefer $1000 in 4 years	☐
Would you prefer $20 now	☐	OR	Would you prefer $1000 in 4 years	☐
Would you prefer $50 now	☐	OR	Would you prefer $1000 in 4 years	☐
Would you prefer $100 now	☐	OR	Would you prefer $1000 in 4 years	☐
Would you prefer $200 now	☐	OR	Would you prefer $1000 in 4 years	☐
Would you prefer $500 now	☐	OR	Would you prefer $1000 in 4 years	☐
Would you prefer $1000 now	☐	OR	Would you prefer $1000 in 4 years	☐

Figure 2. An example of the Hypothetical Monetary Reward Task.

Data Analysis

The amount of money available immediately, judged to be equal in subjective value as the large delayed amount of money ($1000 & $10,000), was expressed as a proportion of the corresponding objective amount. These subjective values were fitted to the data using nonlinear least-squares regression in Microsoft Excel. The Microsoft Excel SOLVER utility was used to fit the three discounting functions to the subjective values (y coordinate) and the time until receipt (x coordinate) to establish the parameter estimates of each function. The three discounting functions included the exponential model, the hyperbolic model, and the extended hyperbolic model. AUC and derived *k* values were used to conduct statistical significance comparisons. To establish an AUC measure, Myerson and Green (2001) describe a step-by-step process:

- Data was normalized. Subjective value was divided by the actual, delayed amount.
- Normalized data was used to construct a graph.
- Vertical lines were drawn from each data point to the *x* axis. The graph was subdivided into a series of trapezoids.
- The area of each trapezoid was equal to:

$$(x_2 - x_1)\ [(y_1 + y_2) / 2] \qquad (5)$$

- The area under the empirical discounting function was equal to the sum of all the trapezoids.

The AUC values were further analysed using the PASW statistics 18 software by performing a 2 x 2 x 2 repeated measures analysis of variance (ANOVA). To assess how well the individual analysis correlated with one and other, all *k* values and area under the curve statistics were assessed in PASW statistics 18 to establish a correlation matrice.

1.3 Results

The data was analysed to assess the hypothesis that caffeine consumers discounted the value of the delayed hypothetical $1000 monetary and caffeine related rewards at a higher rate when they were caffeine deprived compared to when they were not caffeine deprived. The hypothesis also predicted all participants would discount the commodity condition more steeply than the monetary condition.

Each participant's self- reported caffeine consumption was calculated using the Australian Institute of Sports (2007) caffeine content list (Appendix F), the total estimated caffeine consumed by each participant before each lab session was totalled and averaged. A median split was used to establish the two groups; High and Low caffeine consumers. Two reward conditions were used; Monetary and Commodity. Each condition presented 126 choices between small amounts of the reward available immediately, and $1000 worth of the reward available after a delay. Delay systematically increased from 1 month to 16 years. All participants received the same ordering of choices. AUC values were calculated for each participant and averaged to compare group performance. Nonlinear least square regression analyses were used to fit the discounting functions, the exponential, hyperbolic and extended hyperbolic models. Each analysis yielded a R^2 and k value for each participant.

Some participants' discounting functions did not form monotonic discounting trends; preference was indifferent (regardless of delay to receive reward) or showed reversals (indicating decisions were random as the choices are indifferent). The fits of all models to all individuals are given in Appendix H. On the occasions when the discounting functions did not conform, the resulting estimations of R^2 were very small. Making a comparison of the parameter estimates, across models and across conditions, meaningless. Following Kirby's (1997) method, when fits of the discounting models were very low, participants' data was excluded from any further comparison of the three discounting models. The criterion for excluding data was set at $R^2 < .01$, and this resulted in 5 participants' data being excluded from the Monetary task and 9 participants' data being excluded from the Commodity task.

Figure 3 shows the grouped average AUC for participants in both the non-abstinent state and abstinent caffeine consumption state. The top row represents the AUC values when all the data was included while the bottom row displays grouped averages when those who failed to reach the discounting criteria were excluded. The abstinent state was expected to show a steep increase in discounting, resulting in a smaller AUC value.

The AUC values for the top row (including all data) were subjected to a 2 (Non-abstinent vs. Abstinent) x 2 (Monetary vs. Commodity tasks) x 2 (High vs. Low) repeated measures analysis of variance (ANOVA), which revealed a significant interaction between the groups (High and Low) and the delay discounting tasks F (1, 9) = 7.59, p <.02, η^2 = .46. No other significant effects were observed.

The AUC values for the bottom row in Figure 4 (excluding data) were subjected to a 2 (Non-abstinent vs. Abstinent) x 2 (Monetary vs. Commodity tasks) x 2

(High vs. Low) repeated measures ANOVA, which revealed no significant differences. As the number of participants in each group varied as a result of the exclusion criteria, a repeated measures t test was conducted on each pair (High and Low in a non abstinent and abstinent state). Again, no significant differences were found between the pairs.

When all the data was included, the Low caffeine group in the monetary condition's AUC was greater in the abstinent state (0.24) than in the non-abstinent state (0.15). The High caffeine group in the monetary condition's AUC was greater in the non-abstinent (0.15) than in the abstinent condition (0.14). In the commodity condition, the Low caffeine group's AUC was greatest in the abstinent condition (0.15) compared to the non-abstinent condition (0.12). For the High caffeine group in the commodity condition, the AUC was greater in the non-abstinent state (0.16) compared to the abstinent state (0.05). Excluding the data of those who did not reach the discounting criterion changed the average AUC values. When excluded, the Low caffeine group in the monetary condition's AUC was greater in the abstinent state (0.30) than in the non-abstinent state (0.22). The High caffeine group in the monetary condition's AUC was greater in the non-abstinent (0.16) than in the abstinent condition (0.14). In the commodity condition, the Low caffeine group's AUC was greatest in the abstinent condition (0.23) compared to the non-abstinent condition (0.17). For the High caffeine group, the AUC was greater in the non-abstinent state (0.24) than in the abstinent state (0.07).

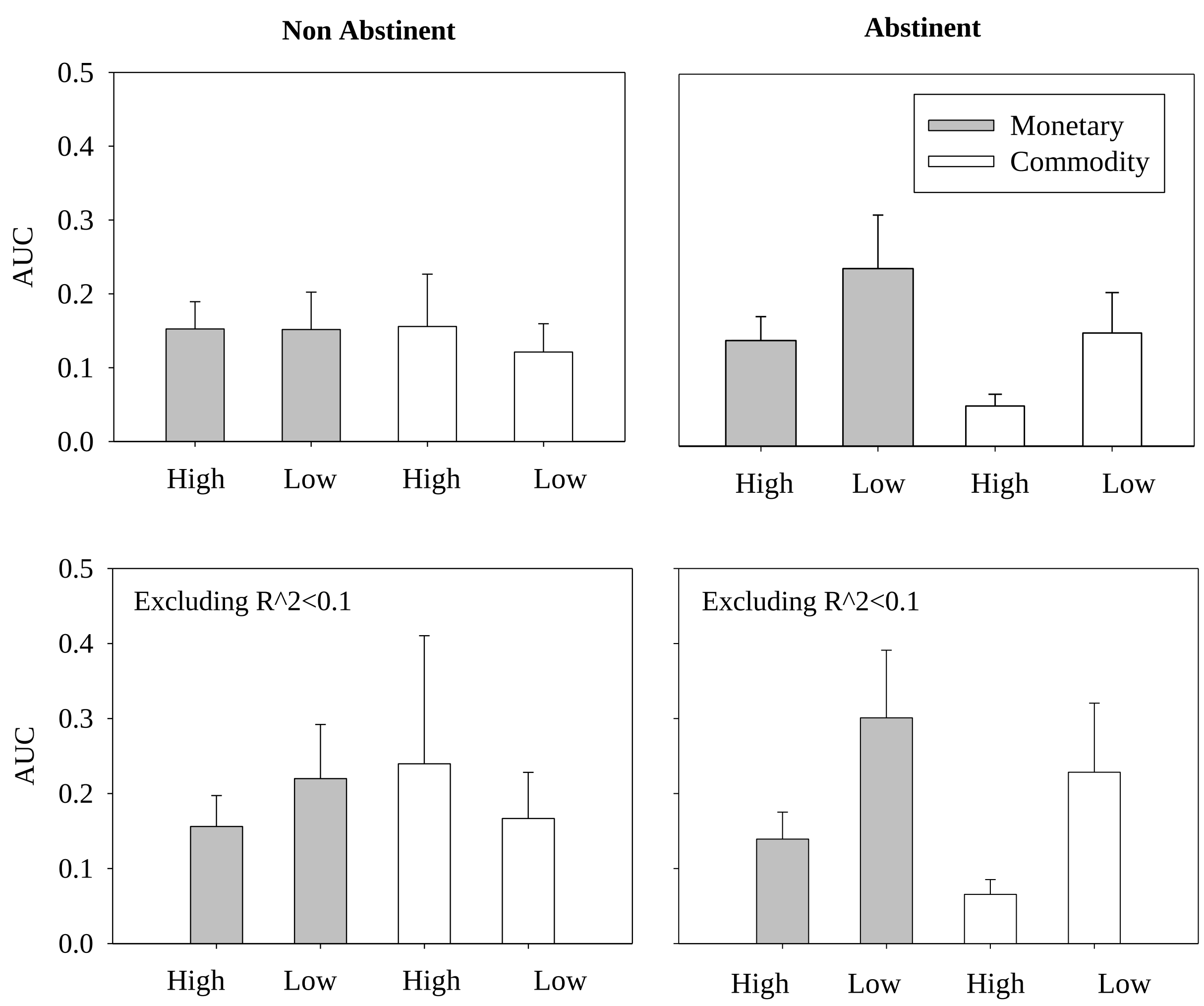

Figure 3. Average AUC for the monetary and commodity conditions in a Non-Abstinent state (left panel) and an Abstinent state (right panel) for the High caffeine and the Low caffeine groups. The top row represents the AUC values when all the data is included; the bottom row represents the AUC values when those who failed to meet the discounting criteria were excluded.

Table 2.

Grouped Averages of model analysis for data excluding R^2 <0.01.

		Monetary Task				Commodity Task			
		Non Abstinent		Abstinent		Non Abstinent		Abstinent	
		High	Low	High	Low	High	Low	High	Low
Exponential	$\boldsymbol{K}$	0.13	0.15	0.16	0.05	0.12	0.36	0.11	0.17
	$\boldsymbol{R^2}$	0.71	0.85	0.66	0.69	0.75	0.82	0.81	0.89
Hyperbolic	$\boldsymbol{K}$	0.23	0.24	0.27	0.11	0.26	0.69	0.24	0.10
	$\boldsymbol{R^2}$	0.79	0.90	0.79	0.75	0.75	0.86	0.80	0.85
Extended Hyperbolic	$\boldsymbol{K}$	13.35	0.26	0.96	0.97	0.32	2.90	0.28	0.12
	$\boldsymbol{s}$	192.62	22.71	485.17	134.58	24.65	119.05	136.52	24.53
	$\boldsymbol{R^2}$	0.85	0.92	0.85	0.83	0.78	0.91	0.84	0.91

Note. The grouped averages for the discounting models of the K and R^2 values. High = High caffeine group, Low = Low caffeine group.

Excluding the data of those who did not meet the discounting criterion impacted the performance of the mathematical models; analysis including the data which violated discounting theory is meaningless. Table 2 shows the grouped averages for the model analysis, excluding the data of participants whose R^2 values did not reach the discounting criterion.

Table 2 shows the extended hyperbolic model had the largest average R^2 values which indicated the model accounted for the most variance, all *s* values are larger than 1.0. The hyperbolic model performed the second best with average R^2 values of above 0.74. The exponential model was the worst performing model with two conditions having average R^2 of less than 0.70. A repeated measures t test was calculated for the *k* values in each model, no significant t values were found.

To establish if the different measures of discounting behaved in similar ways, the AUC measure and parameter estimates from the best fits of the exponential, hyperbolic and extended hyperbolic for the non abstinent state were compared using Pearson's correlations (a correlation matrices is shown in Table 3). Correlations vary as a function of both the discounting measure and impulsivity task. The AUC criterion was positively correlated in both tasks, indicating the AUC measure showed participants discounted in the same direction in both tasks and the correlation was significant ($r = .46$, $p = .02$). Negative correlations were found between the AUC and the discounting functions, indicating the *k* values increased as the AUC decreased. The hyperbolic model's results showed a significant positive correlation in both the monetary and commodity tasks, indicating the hyperbolic model's results found participants discounted in the same direction (r = .50, p = .01). The hyperbolic model's results had the smallest correlations with other functions. The correlations have limited significance after visual inspection of scatter plots revealed outliers are responsible for many significant correlations.

Table 3.

Correlation Matrices of Area Under the Curve (AUC) and k Values in the Hypothetical, Exponential and Extended Hypothetical discounting functions for the Monetary and Commodity Condition in the Non Abstinent sessions (all data included).

		AUC Commodity	Exponential Monetary *k*	Exponential Commodity *k*	Hyperbolic Monetary *k*	Hyperbolic Commodity *k*	Extended hyperbolic Monetary *k*	Extended hyperbolic Commodity *k*
AUC Monetary	Correlation Coefficient	.46[a]	-.47	-.20	-.41*	-.36	-.20	-.38
	Sig (2 tailed)	.02	.01	.20	.04	.06	.20	.05
AUC Commodity	Correlation Coefficient		-.31	-.30	-.27	-.42*	-.12	-.39*
	Sig (2 tailed)		.10	.10	.13	.03	.31	.05
Exponential Monetary *k*	Correlation Coefficient			.08	.95**	-.45*	.47*	.72**
	Sig (2 tailed)			.37	.00	.06	.02	.00
Exponential Commodity *k*	Correlation Coefficient				.09	.53*	.00	.59**
	Sig (2 tailed)				.36	.02	.49	.00
Hyperbolic Monetary *k*	Correlation Coefficient					.50*	.32	.67**
	Sig (2 tailed)					.01	.08	.00
Hyperbolic Commodity *k*	Correlation Coefficient						.01	.75**
	Sig (2 tailed)						.48	.00
Extended hyperbolic Monetary *k*	Correlation Coefficient							.43*
	Sig (2 tailed)							.03

Note.[a] * indicates correlation is significant at the 0.05 level, ** indicates correlation is significant at the 0.01 level (2 tailed).

1.4 Discussion

The hypothesis predicted high caffeine consumers would discount future events more steeply when deprived of caffeine than when they consume caffeine as they regularly would. The AUC values indicate caffeine deprivation increased discounting slightly in the monetary condition and increased discounting greatly in the commodity condition for the high caffeine consumers. The *k* values from the mathematical discounting models found no significant effects. In all conditions the *s* parameter, from the extended hyperbolic model, varied from 1.0.

The hypothesis predicted the commodity condition would be discounted more steeply for both the high and low caffeine consumers. According to the AUC values, the commodity task was discounted at a steeper rate for all states and groups except the High caffeine group when not deprived of caffeine. The *k* values for the extended hyperbolic model reveal steeper discounting rates on the monetary condition for the High caffeine group in a deprived state and the Low caffeine group not deprived of caffeine. The extended hyperbolic model found the High caffeine group when not deprived of caffeine and the Low caffeine group when deprived of caffeine had steeper discounting rates on the monetary condition compared to the commodity condition.

Interestingly, the AUC values indicate the Low caffeine group discount less steeply when they were deprived of caffeine for both the monetary and commodity tasks. The *k* values reveal this pattern existed in all but the extended hyperbolic model's analysis of the monetary task. The data reveals the Low caffeine group had a pattern of discounting which varied from that previously seen in stimulant research. The effect of caffeine deprivation on discounting in humans in the current study varied from previous research on stimulant deprivation and delay discounting. Kingston (2010) used a similar method to examine the effects of caffeine on discounting in humans. It was found that caffeine deprivation increased discounting in humans, indicating caffeine deprivation increases impulsive behaviour (Kingston, 2010).

A potential explanation for the unexpected pattern of results may be the tolerance effect in caffeine consumers. The current research had participants who consumed small amounts of caffeine (Low caffeine group) and participants who consumed large amounts of caffeine (High caffeine group). As found by Dager et al. (1999), caffeine can have a tolerance effect with heavy consumption. Measured at baseline and one hour after caffeine consumption, caffeine intolerant participants displayed psychological and physiological distress (Dager et al., 1999). Measured under the same conditions, heavy consumers showed no signs of distress or effect of any kind after caffeine consumption (Dager et al., 1999). The findings of the current research indicate that caffeine consumption had a increasing effect on the discounting of the Low caffeine group suggests that Dager et al. (1999)'s finding in caffeine intolerant participants may also follow to low caffeine consumers.

Caffeine deprivation had a positive effect on the discounting patterns displayed by the Low caffeine group. The Low caffeine group had a decrease in discounting when caffeine deprived. This effect may be explained by no withdrawal effects in low caffeine consumers. It is likely that there were no withdrawal effects acting on the low caffeine consumers' behaviour in the abstinent condition, instead, their behaviour was influenced by caffeine in the non-abstinent condition. It has been found that nondependent caffeine consumers had a ‘high’ feeling, impaired memory and decreased reaction times created by caffeine consumption (Child & de Wit, 2006) and that impulsivity is positively correlated with caffeine consumption (Jones & Lejuez, 2005). The current findings suggest that the low caffeine consumers decrease in discounting when deprived of caffeine is directly related to the increasing effect caffeine has on impulsive behaviour.

The commodities reward condition was, predominantly, discounted greater than the monetary rewards condition by both the High caffeine group and the Low caffeine group. This effect was consistent with Mitchell’s (2004) findings, nicotine deprived smokers would discount the value of cigarettes significantly more when in a deprived state, but that deprivation had no effect on the choices made in a monetary task. Deprivation of the drugs on which individuals are dependent has been found to decrease the subjective value of the drug (Mitchell, 2004). It is possible that caffeine consumers must have consumed caffeine for a long period of time before their impulsivity on non-caffeine-related tasks is influenced, however, more research is required. Future research should assess the effects of caffeine deprivation in caffeine and non-caffeine-related tasks on heavy, long-term caffeine consumers.

The present study compared three prominent models of discounting. Subsequent to the inclusion of the discounting criterion, the extended hyperbolic model was found to most accurately describe the group averaged data as it accounted for the most variance in all conditions. This supported findings by Myerson and Green

(1995), which compared the exponential, hyperbolic and extended hyperbolic. It was found that the extended hyperbolic model to account for the most variance (Myerson & Green, 1995). By adding the free parameter to the extended hyperbolic model it would be expected that the variance accounted for or R^2 value would be greater. The *s* parameter value in the extended hyperbolic model in both the monetary and commodity condition varied notably from 1.0 on all occasions. The variation from 1.0 indicates the data requires a more general form of hyperbolic discounting. The finding that the *s* parameter is greater than 1.0 is unexpected. Theoretically, the *s* parameter in the extended hyperbolic model represents the exponent of the power function scaling time divided by the exponent of the power function scaling amount (McKercher, Green, Myerson, Pickford, Hill & Stout, 2009). The *s* parameter being greater than 1.0 indicates that the exponent of the power function scaling time is greater than the exponent of the power function scaling amount. Indicating the delay until receipt of the reward was more powerful than the amount of the reward.

To further analyse the various discounting measures, correlations between them were examined. Considering the AUC measure, statistically significant correlations were found between the measure from the two task types. This positive correlation appears to have provided evidence for convergent validity of the AUC measure and the impulsivity tasks (Smith & Hantula, 2008). This indicates the same processes which underlie the monetary discounting task may also be responsible for the responses in the commodity discounting task. The hyperbolic model also provides a significantly positive correlation between task types, indicating the tasks were investigating the same process. The exponential model and the extended hyperbolic model had less defined results. Other significant correlations between task type and measures appear relatively random. This may indicate that the models are not measuring the same aspect of impulsivity, however, after visual inspection of scatter plots it was revealed outliers are responsible for many significant correlations.

The current study had limitations; no pure control group was established as no participants never consumed any form of caffeine, the participants were always given the monetary task prior to the beverage task which may have resulted in a bias towards increasing discounting on the beverage task, and participants were only deprived of caffeine for 12 hours prior to completing the abstinent session, which may not be a substantial enough time to change impulsivity. Many caffeine consumers discontinue consuming prior to sleeping; it is likely, for many participants, 12 hours is a regular period to go without caffeine consumption. Participants' data was excluded from the analysis when their R^2 values were below 0.01. Excluding data decreases sample size and results in making establishing significance difficult.

In conclusion, caffeine deprivation had the most surprising effect on low caffeine consumers; the Low caffeine group showed steeper discounting when influenced by caffeine, a finding which requires further investigation. The current study supports the use of the AUC analysis. The AUC provides a measure which is not theoretically based. The AUC measure was significantly correlated between discounting tasks, which indicates strong validity. Of the mathematical discounting models, the extended hyperbolic model was found to provide the most accurate description of group data, although no significant correlations were found between discounting tasks or other models. This supports the findings of previous research which support the use of hyperbola over exponential models (Myerson & Green, 1995).

Experiment 2

2.1 Introduction

Delay discounting is used to measure the subjective value of a reinforcer when a delay has been applied, the subjective value decreases as the delay until delivery increases. Temporal decision making has been studied in animal laboratories and in human research to gain a better understanding of impulsive behaviour. As explained in Experiment 1, impulsive behaviour has been linked to psychiatric disorders, pathological gambling and substance abuse.

To increase our understanding of impulsivity, experimental manipulations are used to establish the underlying processes of decision making (Green & Myerson, 2010). In Experiment 1 it was found that the discounting patterns of low caffeine consumers were more affected by the presence of caffeine than discounting patterns of high caffeine consumers, this result was unexpected. Furthermore, Experiment 1 had a number of participants whose data contradicted the predicted pattern of discounting. A potential explanation for the non-predicted results is the pen and paper method which was utilised. Smith and Hantula (2008) compared mode types on a discounting task, they found no significant difference between a computerized and paper-and-pencil mode. However, based on the difference in results between Kingston's (2010) study and Experiment 1, it is fair to suggest the difference may be a result of the difference in mode of presentation.

It is well supported that small rewards are discounted more steeply than large rewards. The magnitude effect has been observed in discounting research using consumable rewards (Mitchell & Rosenthal, 2003), heroin-rewards in opioid-dependent individuals (Madden & Rosenthal, 2003), and hypothetical monetary rewards (Smith & Hantula, 2008). With this well supported effect, the following study intended to assess the effectiveness of a computer-based discounting program. As in Experiment 1, the discounting patterns were analysed using the exponential, the hyperbolic, the extended hyperbolic model and the AUC.

The current study intended to provide evidence that the method is, in part, responsible for the contradictory pattern of results found in Experiment 1. It was expected that the smaller amount of money ($1000) would be discounted more steeply than the larger amount of money ($10,000) in the delay discounting task. Four common discounting measures were compared. Smith and Hantula (2008) found the *k* value of the hyperbolic and exponential functions to be better supported psychometrically than the AUC. It was also found that the hyperbolic discounting construct better described the discounting data than the exponential function (Smith & Hantula, 2008). According to previous research on magnitude effects, the current research expected the hyperbolic to best describe the discounting data.

2.2 Method

Participants

Twelve participants were recruited from the Styx and Stone Restaurant in Christchurch, New Zealand (7 female, 5 male, mean age 27.4years). 18 participants were recruited from the University of Waikato (9 female, 9 male, mean age 22.3years). The 22-2-2011 earthquake interrupted further data collection in Christchurch. Table 9 shows the demographic characteristics of the participants. Participants from the restaurant were recruited by management advertising for volunteers during a staff meeting and the researcher approaching staff members. Participants from the University of Waikato were recruited by advertising posted around the campus and on the internal internet system. Students of a first year psychology class in the A semester of the University of Waikato academic year were offered 1% course credit for completing the study. Ethics approval was granted by the Psychology Research and Ethics Committee at the University of Waikato, the ethics application and letter of approval are in Appendix H (Ethics Approval Application – 10/50).

Apparatus/Materials

An information sheet was presented to each participant (Appendix I). A pre-experimental questionnaire (Appendix J) asked for demographic information including; age, gender, occupation, ethnicity and living circumstance. The experimental tasks were presented on a HP Pavilion laptop computer and included 126 questions.

Procedure

Participants from the restaurant indicated their interest by approaching the researcher and organising a suitable time to complete the experiment. Participants attended the experimental session individually. Upon arrival at the experimental session, the participants were given time to read the information sheet and ask any questions required before informed consent was obtained.

For Waikato students, participants emailed the researcher expressing an interest in participating in the research. The information sheet was then sent, via email, and participants were instructed to familiarise themselves with the method and indicate an appropriate time to complete the first session.

For restaurant participants, the experiment was conducted in a quiet office above the facility which contained two computers, two desks, and two chairs. Only the participant and the researcher were present within the room. For the Waikato participants, the research room contained two desks, two computers, and two chairs.

Table 4.

Demographic characteristics of participants.

		Restaurant	The University of Waikato
Participants	Age mean (years)	27.4	22.3
	Male: Female ratio	5:7	9:9
Occupation	Student	5	18
	Hospitality	7	0
Ethnicity	NZ European	10	14.5
	Maori	1	1.5
	Other	1	2
Living Circumstance	Home Owner	4	0
	Renting	6	12
	Boarding	2	6

Note. Table of demographic characteristics of the participants from both the restaurant and The University of Waikato.

After the demographic questionnaire was completed, participants were presented with the experimental tasks. The experiment consisted of two delay discounting tasks. Each screen in the first condition presented a choice between a hypothetical amount of money available immediately and hypothetical $1000 available after a delay. The second condition was similar except the amounts were multiplied by 10. The questions were counterbalanced and in random order. Figure 4 shows the first screen participants were presented.

Figure 5 shows an example of a screen in the first experimental condition. The participant had been told that pressing the left arrow on the keyboard would indicate a choice of $100 now and by pressing the right key would indicate a choice of $1000 in one month. Participants attended one session, which lasted approximately half an hour.

Condition 1. The participants were given choices between an amount of money ($1, $2, $10, $20, $50, $100, $200, $500, & $1000) available immediately and $1000 available after varying delays (1 month, 6 months, 1 year, 2 years, 4 years, 8 years & 16 years) randomly. Participants were asked to indicate which option they would prefer for all 63 choice scenarios.

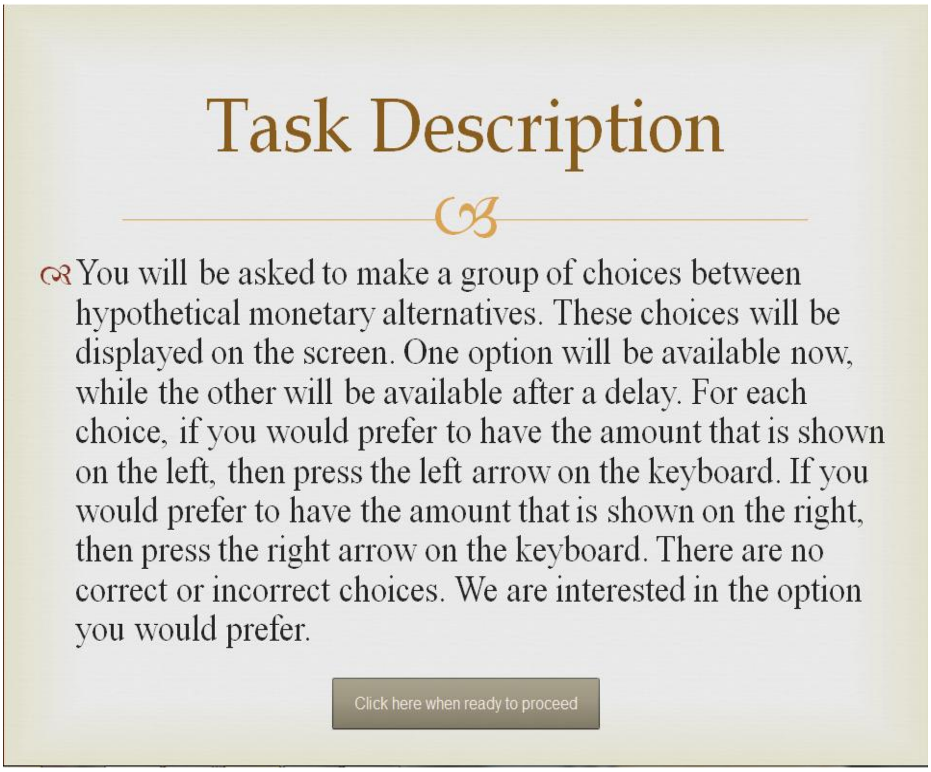

Figure 4. Task Description presented to participants at prior to beginning the task.

Figure 5. Example of a screen in the $1000 condition.

Condition 2. After completing Condition 1, the researcher set the computer to the beginning of the second condition. The participants were given the choice between a larger amount of money ($10, $20, $100, $200, $500, $1000, $2000, $5000, & $10,000) available immediately and $10,000 available after varying delays (1 month, 6 months, 1 year, 2 years, 4 years, 8 years, & 16 years) randomly. Participants were asked to indicate which option they would prefer for all 63 choice scenarios.

Data Analysis

As in Experiment 1, the subjective values were fit to the data using nonlinear least-squares regression in Microsoft Excel (see Experiment 1 for calculating the subjective values). Three discounting functions were applied to the subjective values and the AUC measure was used for statistical comparisons, these are described in detail in Experiment 1.

2.3 Results

Data was analysed to test the hypothesis that the small reward condition ($1000) would be discounted more steeply than the large reward condition ($10,000). Two reward amounts were used; $1000 and $10,000. Each condition presented 126 choices between small amounts of the reward available immediately and $1000 worth available after a delay, delay systematically increased from 1 month to 16 years. Choices were presented randomly and individually. AUC values were calculated for each participant and averaged to compare group performance. Nonlinear least square regression analysis was used to fit the discounting functions, the exponential, the hyperbolic and the extended hyperbolic models. Each analysis yielded a R^2 and k value for each participant.

As found in Experiment 1, some participants' discounting functions did not conform to the expected shape of a monotonically discounting function. Some participants showed reversal in preferences for the amount at different points in time which is something none of the discounting models are able to accommodate when fitted to the data, and result in parameter estimates that are not well determined. The fits of all models to all individual participants' data is given in Appendix K. A criterion for excluding was set at $R^2 < .01$, and resulted in 7 participants' data being excluded.

Figure 6 shows the average AUC for both conditions, the left panel includes data from all participants, and the right only includes data from participants that met the discounting criterion. In both panels, the $10,000 condition was discounted less steeply than the $1000 condition. With all data included, the $1000 condition had an average AUC of 0.49 and the $10,000 condition had an average AUC of 0.61. With only those who met the discounting criterion included, the $1000 condition (*M* = 0.42, *SD* = 0.23) was discounted significantly more steeply than the $10,000 condition (*M* = 0.56, *SD* = 0.32) ($t(21) = 3.14$, $p < 0.01$, one-tailed, $d = 1.37$).

Excluding the data from those who did not meet the discounting criterion, as in Experiment 1, impacted the performance of the mathematical models; analysis including the data which violated discounting theory is meaningless. Table 4 shows the grouped averages for the model analysis, excluding the data from participants who did not reach the discounting criterion.

Table 5 shows the extended hyperbolic model had the largest average R^2 values which indicated the model accounted for the data well. The exponential model was the next best performing model with R^2 values of above 0.70. The hyperbolic model was the worst performing model with the $10,000 condition with an average R^2 value of 0.65.

A repeated measures t test was calculated for the derived *k* values in each model. Significant effects on estimates of *k* derived from fits of the various discounting models on the delay discounting data for individual participants for the exponential model ($t(22) = 2.29$, $p < 0.02$, one tailed, $d = 0.98$), for the hyperbolic model ($t\ (22) = 1.32$, $p < 0.10$, one tailed, $d = 0.56$) and for the extended hyperbolic model ($t\ (22) = 1.55$, $p < 0.07$, one tailed, $d = 0.66$), indicated the *k* value were significantly greater in the $10,000 condition than the $1000 condition.

To establish if the different measures of discounting behaved in similar ways, the AUC measure and parameter estimates from the best fits of the exponential, the hyperbolic and the extended hyperbolic models in the non abstinent states were compared using Pearson's correlations (a correlation matrices is shown in Table 6). Correlations which were significant at the 0.01 level are shown with ** and those significant at a 0.05 level are shown with *. The AUC analysis was positively correlated in both tasks, this indicates a trend in the same direction and the correlation was significant (r = .73, p =0.00). No other correlations were significant across the tasks. The AUC measure in the $1000 condition was positively correlated with all other measures except for the $10,000 conditions for the exponential model and the extended hyperbolic model. Other correlations appear rather random. The correlations have limited significance after visual inspection of scatter plots revealed outliers are responsible for many significant correlations.

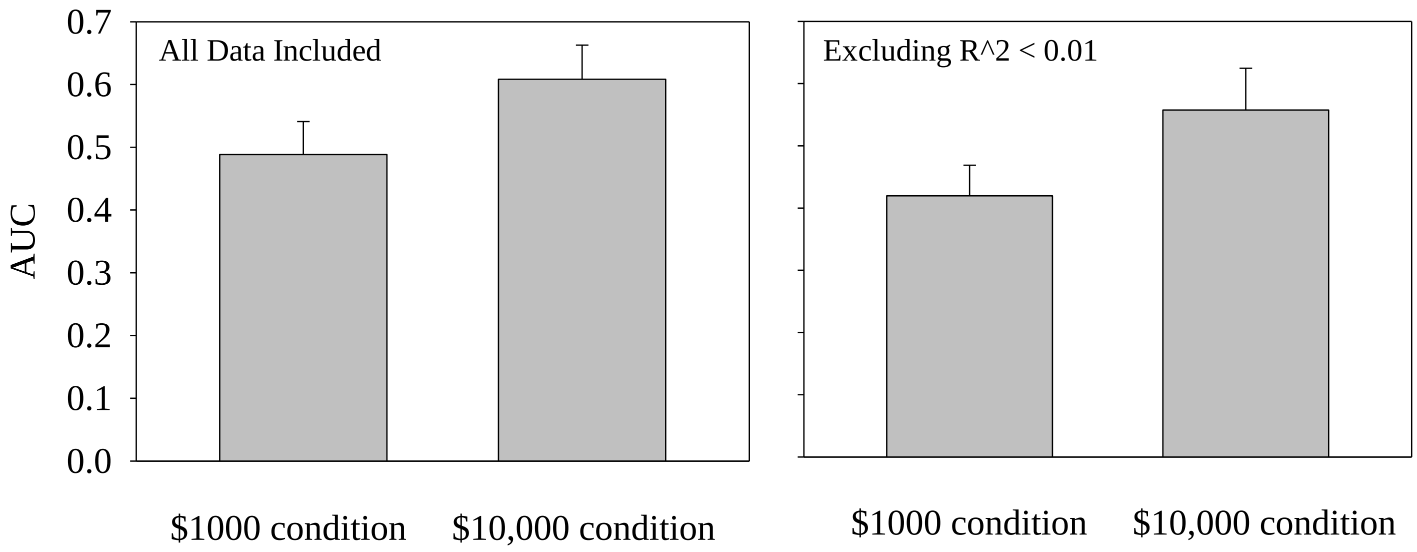

Figure 6. Average AUC on the $1000 and $10,000 Discounting Tasks. The left panel represents the average AUC when all the data is included, the right panel represents the average AUC when the data is excluded which did not reach the discounting criterion.

Table 5.

Grouped Averages of model analysis for data excluding R^2 <0.01.

		$1000	$10,000
Exponential	***K***	0.16	0.49
	$\boldsymbol{R^2}$	0.72	0.80
Hyperbolic	***K***	0.87	2.60
	$\boldsymbol{R^2}$	0.71	0.65
Extended Hyperbolic	***K***	1.00	2.83
	s	75.94	38.61
	$\boldsymbol{R^2}$	0.77	0.82

Note. The grouped averages for the discounting models of the *K* and R^2 values.

Table 6.

Correlation Matrices of k Values in the Hypothetical, Exponential and Extended Hypothetical Discounting Functions for the $1000 and $10,000 Conditions.

		AUC $10,000	Exponential $1000 *k*	Exponential $10,000 *k*	Hyperbolic $1000 *k*	Hyperbolic $10,000 *k*	Extended hyperbolic $1000 *k*	Extended hyperbolic $10,000 *k*
AUC $1000 *k*	Correlation Coefficient	*0.73***	*0.15*	*0.14*	*0.19*	*0.35**	*0.20*	*-0.18*
	P value	*0.00*	*0.22*	*0.24*	*0.15*	*0.03*	*0.15*	*0.17*
$10,000 *k*	Correlation Coefficient		*0.52***	*0.02*	*0.56***	*-.28*	*0.57***	*-0.33**
	P value		*0.02*	*0.47*	*0.00*	*0.07*	*0.00*	*0.04*
Exponential $1000 *k*	Correlation Coefficient			*0.14*	*1.00***	*0.15*	*0.99***	*0.01*
	P value			*0.24*	*0.00*	*0.21*	*0.00*	*0.49*
Exponential $10,000 *k*	Correlation Coefficient				*0.08*	*0.67***	*0.08*	*0.62***
	P value				*0.34*	*0.00*	*0.34*	*0.00*
Hyperbolic $1000 *k*	Correlation Coefficient					*0.06*	*1.00***	*-0.03*
	P value					*0.39*	*0.00*	*0.43*
Hyperbolic $10,000 *k*	Correlation Coefficient						*0.05*	*0.36**
	P value						*0.40*	*0.03*
Extended hyperbolic $1000 *k*	Correlation Coefficient							*-0.04*
	P value							*0.42*

Note .Correlation Matrices for all the data. Correlations significant at the 0.01 level are shown with ** and those significant at a 0.05 level are shown with *.

2.4 Discussion

The current research investigated the magnitude effect, an effect established in previous discounting studies. Using the AUC values, the smaller condition ($1000) was found to be discounted significantly more steeply than the larger ($10,000) condition, according to the repeated measures t test.

Smith and Hantula (2008) had participants of a similar age group (20.37 years) complete a binary choice task with a $1000 condition and a $10,000 condition. The current study aimed to replicate and extend the findings of Smith and Hantula (2008) by using a similar method. The data in both studies was analysed using the AUC measure. In Smith and Hantula (2008) it was found that comparing discounting and reward magnitude was statistically significant $F(1,52) = 13.43$, $p = .01$ with an effect size of $r = .45$, indicating a magnitude effect occurred. The residual-least squares analysis found significant magnitude effects for average k values in all discounting models, again, this effect was a replication of Smith and Hantula (2008); $F(1,52) = 5\ 51.57$, $p = 5\ .00$ with an effect size of $r = 5\ .71$. The current study provided further evidence to support a reward magnitude effect.

A residual-least squares analysis found some participants discounting functions did not conform to the expected monotonically decreasing discounting function, on the occasions when the discounting functions did not conform, the resulting estimations of R^2 were very small. When fits of the discounting models derived very low R^2 values further comparisons of models were meaningless. Following Kirby's (1997) method, a criterion for excluding was set at $R^2 < .01$, (Appendix K). It was established that 7 participants had R^2 values which did not meet the discounting criterion. The exclusion of this data from the analysis brings into question the scientific integrity of the study. Parameter estimates derived from discounting models are not applicable to the decision making patterns expressed by human beings if some choice behaviour is not able to be analysed. Models that can not accurately describe ALL animal behaviour should not be included in scientific studies.

A difference between the current study and Smith and Hantula's (2008) study was the performance of the hyperbolic model. Smith and Hantula (2008) found the hyperbolic model fit the data better than the exponential model in all but two of their data fields. The performance of the discounting functions was based on their R^2 values or variance accounted for. In the current study, the hyperbolic model performed the worst on both tasks, accounting for the least variance in the \$10,000 condition ($R^2 = 0.65$). The exponential model and the extended hyperbolic model performed in a similar manner, accounting for between 72% and 82% of variance. The extended hyperbolic model was expected to account for more variance as a result of adding the *s* parameter, it is when the *s* value varies significantly from 1.0 that it indicates its worth as a good descriptor of the data. In both conditions the *s* parameter varied from 1.0 (s = 75.94 and 38.61). As described in Experiment 1, the *s* value being greater than 1.0 was unexpected, however, this indicates the exponent of the power function scaling time is greater than the exponent of the power function scaling amount. The delay till receipt had a larger effect than the amount of the reward. The dramatically large *s* value in the \$1000 condition provides reason to question the hyperbolic model and the extended hyperbolic model's accuracy at describing the current data.

The hypothesis stated the hyperbolic model was expected to describe the data most accurately. The finding that, unlike most of the previous discounting literature, the exponential model provided a better fit for the discounting data is a point of interest. The exponential model assumes *k* is the same for both alternatives provided in a binary choice task and the subjective value of the smaller alternative is equal to the subjective value of the large alternative at the point of indifference (Mazur et al., 1987). The rational for the exponential model's lack of popularity and empirical support is the assumption the discounting curve is equal to 1.0 and its inability to predict preference reversals (Mazur et al., 1987). The current data, however, indicate the exponential model was not always the lesser measure for assuming a discounting curve of 1.0, which suggests participants made their choices in a manner predicted by the exponential model.

Within the study, four measures of delay discounting were compared. Correlations were found with the AUC in both the $1000 and the $10,000 conditions. The positive correlations appear to have provided evidence for convergent and divergent validity of the AUC and the impulsivity tasks as both had values which correlated in the same direction indicating both are measuring a similar process (Smith & Hantula, 2008). This indicates the same processes which underlie the $1000 discounting task also are responsible for the responses in the $10,000 discounting task.

The current study, however, had limitations. Every participant completed the $1000 condition prior to completing the $10,000 condition, this allowed for a possible practice effect. If the conditions had been counterbalanced it is possible that the results, in particularly for the $10,000 condition, may have altered. It is possible the choices made in the $10,000 condition were based on a comparison to the impulsive tendencies displayed on the previous condition. It is a possibility that the delay till receipt of the $10,000 reward was not large enough to dictate discounting patterns in some participants. Both conditions had delay periods ranging from one month to sixteen years. After completing the $1000 condition participants may have believed that sixteen years was not a long period to wait for a $10,000 reinforcer. To provide a comprehendible analysis of the discounting functions, data had to be excluded, limiting the scientific integrity of the study (this is discussed further in the general discussion).

Future research should address issues raised from this research; the conditions should be counterbalanced to limit the practice effect. Potentially the most startling finding in this research is the place of decay functions in discounting research. Further research is required to establish the place of the discounting functions when data presents extreme values. Although the extended hyperbolic model was established as the most accurate descriptor of the data when outliers were excluded, it is unscientific in nature to exclude participants' data on the basis of it not being as predicted. The only measure in which no data was required to be excluded was the AUC measure.

In conclusion, the present findings support the magnitude effect. A significant finding was that the \$10,000 condition was discounted less steeply than the \$1000 condition. The current study also established that the AUC provided the most accurate and unbiased measure for the discounting data, as no data was required to be excluded.

Experiment 3

3.1 Introduction

Impulsive behaviour is commonly referred to as giving in to temptation, seduction (Ainslie, 1974), or a result of a lack of self-control. As discussed in Experiment 1, the importance of increasing our understanding of impulsive behaviour stems from the behaviour's relevance to psychiatric disorders, pathological gambling and substance abuse. Viewing impulsivity as an inability to delay gratification has lead to many impulsivity studies both within the animal laboratory and with humans (Evenden, 1999).

Delay discounting methods and caffeine (for more information on delay discounting and caffeine see General Introduction) give a method to measure impulsivity and the effects of drug deprivation. To extend the findings of Experiment 1 and Experiment 2, the current study used a computer-based discounting task to measure the effects of caffeine deprivation. Based on Experiment 1's findings, it was expected that caffeine consumers who reached the Low caffeine groups criteria would show steeper discounting when they were influenced by caffeine compared to when they are deprived of caffeine. As previous drug deprivation research has found, it is expected the caffeine consumers that meet the High caffeine group criteria which show steeper discounting patterns when they were deprived of caffeine, compared to when they have consumed caffeine. As Experiment 2 found, it was expected that a magnitude effect would be found between the discounting conditions. The $1000 task was expected to have steeper discounting than the $10,000 condition.

As in Experiment 1 and 2, analysis of the discounting patterns was done and compared using the exponential, the hyperbolic, the extended hyperbolic model and the AUC measure. Based on previous discounting research, it was expected the hyperbolic model would provide the most accurate analysis of the data (Smith & Hantula, 2008).

3.2 Method

Participants

Twenty-eight participants were recruited from the University of Waikato (8 Male and 20 Female, mean age 23 years). The research was approved by the Psychology Research and Ethics Committee at the University of Waikato (ref 29/11), as an extension of Experiment 1, a request for minor changes to the method was sent and approved (Appendix L). Table 7 shows the demographic characteristics of the participants. Participants were recruited by advertising on posters around the campus and through the internal internet system. Participants were all University of Waikato students and those students enrolled in a first year psychology class received up to 2 % course credit for participating in the study.

Apparatus/Materials

Pre-experimental materials included the approved University of Waikato consent form (Appendix D), a demographic questionnaire (Appendix M), and the Caffeine Consumption Questionnaire (Appendix E) (Kingston, 2010). The demographic questionnaire asked for participant's age, gender, contact telephone number, stimulant consumption in the previous twenty-four hours, and the time of last caffeine consumption. The Caffeine Consumption questionnaire was the same as Experiment 1. The experiment consisted of computer-based delay discounting tasks, see Experiment 2 for details.

Table 7.

Demographic characteristics of participants.

		High Caffeine Consumers	Low Caffeine Consumers
Age	Mean (years)	25.6	20.6
	Standard Deviation	4.7	3.2
Gender	Males : Females (ratio)	5:9	3:11
Caffeine Consumption	Average caffeine consumption per week	1515.1mg	152mg
	Mean hours since caffeine consumption before non-abstinent	2.2 hours	17.3
	Mean hours since caffeine consumption before abstinent	27.4 hours	67.4
Drug use the last 24hours	Psychiatric Medication	No (14)	No (13)
		Yes (0)	Yes (1)
	Illegal Drugs	No (14)	No (14)
		Yes (0)	Yes (0)
	Nicotine	No (14)	No (13)
		Yes(1)	Yes(1)
	Alcohol	No (8)	No (13)
		Yes (6)	Yes (1)

Note. Table of demographic characteristics of the participants, including the average number of hours since last caffeine consumption for both the non-abstinent and abstinent conditions.

Procedure

Participants contacted the researcher via email and were instructed to familiarise themselves with the information sheet. After a session room and time were established, some participants were contacted via email and instructed to withhold caffeine consumption for 24 hours prior to the experiment, attached to the email was the caffeine content questionnaire (Appendix E). While other participants were instructed to consume caffeine as they usually would prior to arriving at the first session. Participants completed the experiment individually; within the room were two desks, two computers and two chairs. Only the researcher and participant were present in the room. Informed consent was collected and the pre-experimental questionnaires were completed. Participants then completed the computer-based delay discounting tasks which are described in Experiment 2.

Approximately 24 hours prior to arriving for the second session, participants were contacted by text message and reminded of the session. Participants who were non-abstinent for the first session were instructed to stop consuming all caffeinated products until the second session was completed. Those who were abstinent for the first session were instructed to consume caffeine as they usually would. On arrival of the second session, participants were asked to complete the pre-experimental questionnaires. Following this, participants were instructed to complete the computer-based delay discounting tasks again.

Data Analysis

As in Experiment 1, the subjective values were fit to the data using nonlinear least-squares regression in Microsoft Excel (see Experiment 1 for calculating the subjective values). Three discounting functions were applied to the subjective values and the AUC measure was used for statistical comparisons, these are described in detail in Experiment 1.

3.3 *Results*

The data was analysed to assess the hypothesis that caffeine consumers will discount the value of the delayed hypothetical \$1000 and \$10,000 rewards at a higher rate when they are caffeine deprived compared to when they are not, and that all participants would discount the \$1000 condition more steeply than the \$10,000 condition.

As in Experiment 1, the self-reported weekly caffeine consumption was totalled and averaged (see Appendix G for caffeine content list). A median split was used to establish the two groups; High caffeine group and Low caffeine group. Two reward conditions were used; \$1000 and \$10,000. Each condition presented 126 choices between small amounts of money available immediately and \$1000 or \$10,000 available after a delay, delay systematically increased from 1 month to 16 years. Choices were presented in random order. AUC values were calculated for each participant and averaged to compare group performance. Nonlinear least square regression analysis was used to fit the discounting functions, the exponential, the hyperbolic and the extended hyperbolic models. Each analysis yielded a R^2 and k value for each participant.

As in Experiment 1, some participants discounting functions did not conform to the expected monotonically decreasing discounting function. Some participants showed reversal in preferences for the amount of money at different points in time which is something none of the discounting models is able to accommodate when fit to the data and resulted in parameter estimates that were not well determined. The fits of all models to all individual participants' data is given in Appendix K.

A criterion for excluding data was set at $R^2 < .01$, and resulted in 2 participants' data being excluded from the $1000 condition and 1 participants' data being excluded from the $10,000 condition.

Figure 7 shows the grouped average AUC for participants in both the non-abstinent state and abstinent state. The abstinent state was expected to show the steepest delay discounting trends. One predicted discounting trend was true, the $1000 condition had smaller AUC values than the $10,000 condition for all states and groups. Excluding data using the discounting criterion, in this case, had minor effect on the AUC values.

The AUC values, excluding those who did not meet the discounting criterion, were subjected to a 2 (Non-abstinent vs. Abstinent) x 2 (Monetary vs. Commodity tasks) x 2 (High vs. Low) repeated measures analysis of variance (ANOVA), which revealed a condition effect (F (1, 12) = 91.67, p <.00, η^2 =.88). The ANOVA revealed that the AUC values were significantly larger for the $10,000 than for the $1000 condition. No other significant effects were established.

Table 8 shows the extended hyperbolic model had consistently the largest R^2 values, with only two values falling below 0.70, which indicated the model accounted for the data well. The exponential model performed the second best of the equations by having four R^2 values above 0.80. The hyperbolic model was the worst performing model with only two R^2 values of over 0.80.

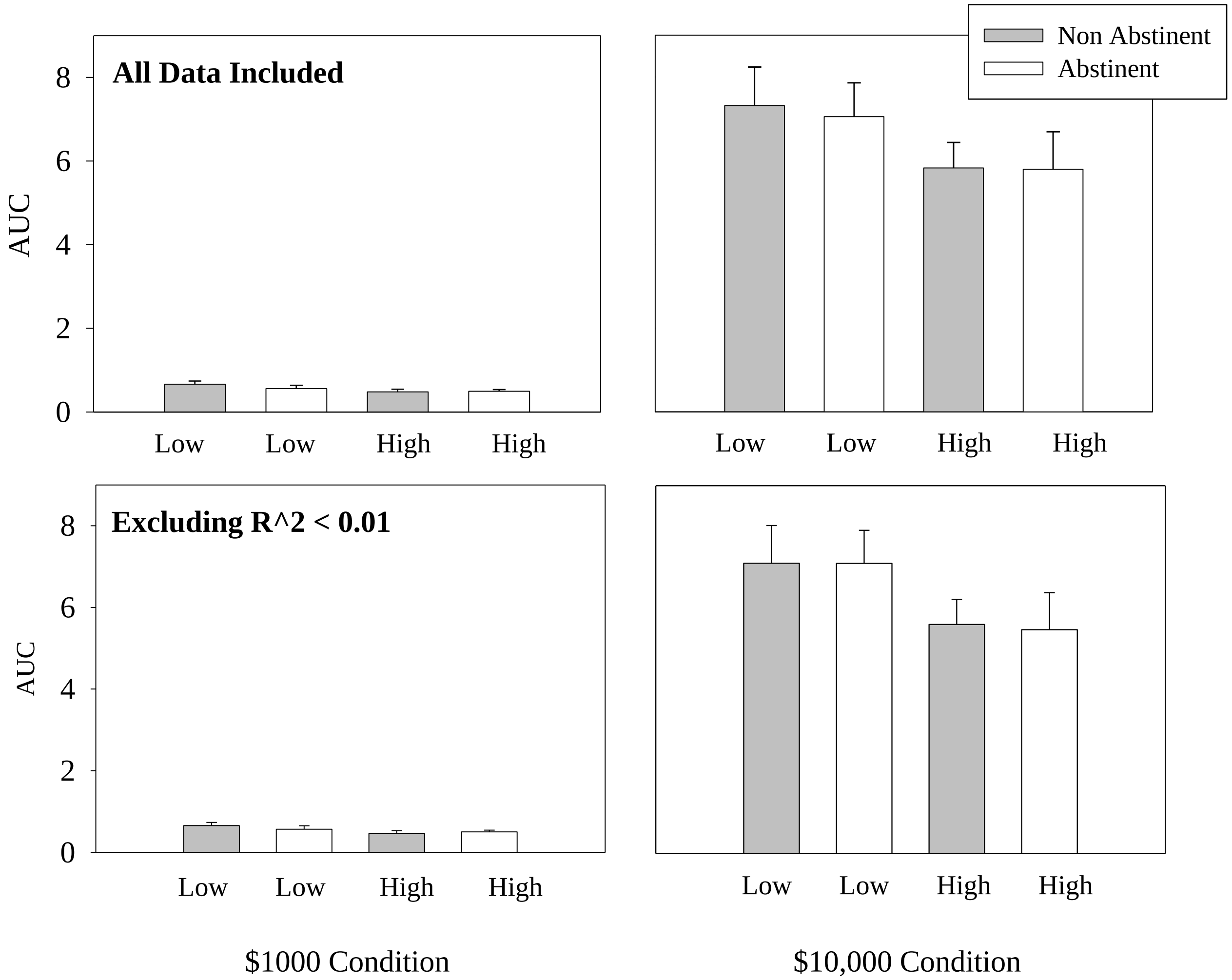

Figure 7. Average area under the curve for the \$1000 (left panel) and \$10,000 (right panel) conditions in a Non-Abstinent state and Abstinent state for both High and Low caffeine groups. The tope row represents the mean AUC when all data is included and the bottom row represents the mean AUC when participants who did not meet the discounting criterion were excluded.

Table 8.

Grouped Averages of model analysis for data from participants when fits of any model where R^2 <0.01.

		$1000 Task				$10,000 Task			
		Non Abstinent		Abstinent		Non Abstinent		Abstinent	
		High	Low	High	Low	High	Low	High	Low
Exponential	***K***	0.66	2.13	0.12	0.68	0.01	0.90	0.56	0.64
	$\boldsymbol{R^2}$	0.82	0.80	0.63	0.67	0.66	0.87	0.84	0.84
Hyperbolic	***K***	0.28	1.51	0.19	0.31	0.01	0.97	0.59	0.67
	$\boldsymbol{R^2}$	0.77	0.78	0.61	0.63	0.63	0.84	0.81	0.79
Extended Hyperbolic	***K***	0.10	0.37	0.07	0.11	0.01	2.66	1.64	1.90
	s	241.33	95.06	58.71	86.10	56.51	150.68	53.16	66.51
	$\boldsymbol{R^2}$	0.82	0.81	0.69	0.72	0.67	0.89	0.85	0.84

Note. The grouped averages for the discounting models of the *K* and R^2 values. High = High caffeine group, Low = Low caffeine group.

A repeated measures t test was calculated for the *k* values in each model. Significant effects were found for the $1000 condition. The Low caffeine group had a significant effect that caffeine deprivation increased discounting in the exponential model ($t(12) = 1.66$, $p < 0.06$, $d = 0.96$), in the hyperbolic model ($t(12) = 1.63$, $p < 0.06$, $d = 0.94$), and in the extended hyperbolic model ($t(12) = 1.88$, $p < 0.04$, $d = 1.09$). The High caffeine group showed a significant increase in discounting when deprived of caffeine when the hyperbolic model was used (t(12) = 1.02, $p < 0.16$, $d = 0.59$).

For the $10,000 condition., the Low caffeine group showed a significant effect that caffeine deprivation on estimates of *k* derived from fits of the various discounting models on the delay discounting data for individual participants for the exponential model ($t(13) = 1.59$, $p < 0.07$, $d = 0.88$), for the hyperbolic model ($t(13) = 1.65$, $p < 0.06$, $d = 0.92$), and for the extended hyperbolic model ($t(13) = 1.48$, $p < 0.08$, $d = 0.82$).The High caffeine group also showed significant effect of caffeine deprivation on estimates of *k* derived from fits of the various discounting models on the delay discounting data for individual participants for the exponential model ($t(12) = 2.36$, $p < 0.02$, $d = 1.36$), for the hyperbolic model ($t(12) = 2.40$, $p < 0.02$, $d = 1.38$), and for the extended hyperbolic model ($t(12) = 2.33$, $p < 0.02$, $d = 1.34$).

To establish if the different measures of discounting behaved in similar ways, the AUC measure and parameter estimates from the best fits of the exponential, the hyperbolic and the extended hyperbolic models, correlations were calculated for all the data (these are shown in Table 9). Correlations that were significant at the

0.01 level are shown with ** and those significant at a 0.05 level are shown with *. The exponential model in the $10,000 condition was significantly correlated with five other measures, the most correlations for a single measure and condition. Measures that are significantly correlated with four other measures include; AUC $1000, the exponential model $1000 and the extended hyperbolic model in the $10,000 condition. The extended hyperbolic model in the $1000 condition was the only measure to have no significant correlations. The parameter values for the exponential model were positively correlated for both tasks, this indicates a trend in the same direction and the correlation was significant. No other measures were significantly correlated across tasks. The correlations have limited significance after visual inspection of scatter plots revealed outliers are responsible for many significant correlations.

Table 9.

Correlation Matrices of k Values in the Hypothetical, Exponential and Extended Hypothetical Discounting Functions for the Non Abstinent $1000 and $10,000 Conditions.

		AUC $10,000	Exponential $1000 *k*	$10,000 *k*	Hyperbolic $1000 *k*	$10,000 *k*	Extended hyperbolic $1000 *k*	$10,000 *k*
AUC $1000	Correlation Coefficient	*0.29*	*0.30*	*0.43**	*-0.15*	*0.41**	*0.11*	*0.45***
	P value	*0.17*	*0.06*	*0.01*	*0.22*	*0.02*	*0.28*	*0.01*
$10,000	Correlation Coefficient		*0.39*	*0.70***	*-0.11*	*0.69***	*-0.31*	*0.73***
	P value		*0.02*	*0.00*	*0.30*	*0.00*	*0.05*	*0.00*
Exponential $1000 *k*	Correlation Coefficient			*0.41**	*0.63***	*0.41**	*0.09*	*0.40**
	P value			*0.02*	*0.00*	*0.02*	*0.32*	*0.02*
$10,000 *k*	Correlation Coefficient				*0.19*	*1.00***	*-0.06*	*1.00***
	P value				*0.17*	*0.00*	*0.38*	*0.00*
Hyperbolic $1000 *k*	Correlation Coefficient					*0.22*	*0.07*	*0.13*
	P value					*0.13*	*0.36*	*0.25*
$10,000 *k*	Correlation Coefficient						*-0.06*	*1.00***
	P value						*0.38*	*0.00*
Extended hyperbolic $1000 *k*	Correlation Coefficient							*-0.06*
	P value							*0.38*

Note .Correlation Matrices for all the data. Correlations significant at the 0.01 level are shown with ** and those significant at a 0.05 level are shown with *.

3.4 *Discussion*

The current study found that caffeine deprivation increased discounting by low caffeine consumers in both a $1000 discounting task and a $10,000 discounting task. This was found to be significant for the derived *k* values from the discounting models but not for the AUC values. The Low caffeine consumers when deprived of caffeine made more impulsive decisions, characterised by steeper discounting on a delay discounting task. Caffeine deprivation increased discounting for the high caffeine consumers in the $1000 condition significantly from the average *k* values of the hyperbolic model but not for any other measure. According to the derived *k* values, the High caffeine consumers when derived of caffeine made less impulsive decisions, characterised by steeper discounting on the $10,000 delay discounting task.

Previous research has found stimulant deprivation increases discounting in both drug related and monetary discounting tasks (Giordano et al., 2002). Diller et al. (2008) found that acute and repeated caffeine administration to rat's decreased discounting behaviour. The present study provides evidence of caffeine decreasing impulsive behaviour in low consumers.

The disagreements between Experiment 1 and the current study may be a result of methodological differences. The current study used a computer-based, monetary reward, delay discounting task, while Experiment 1 used a pen and paper, monetary and commodity rewards, delay discounting task. Previous research has found no significant difference in discounting rates between a computer-based task and a pen and paper task (Smith & Hantula, 2008), however, the current research found AUC values in the computer-based task that were smaller than those found in Experiment 1's pen and paper task. Although different samples were used, the AUC value for the low caffeine consumers in the $1000, non abstinent condition was 0.67. Using the same delay and monetary value as the current study, Experiment 1 found the AUC value for the low caffeine consumers in the $1000, non abstinent condition was 0.15. This notable variation brings to light the need for further comparisons of instruments used in delay discounting tasks.

High caffeine consumers were found to discount in the expected direction on the $1000 condition and showed discounting trends towards less steep discounting in an abstinent state for the $10,000 condition. It was predicted that high caffeine consumers would show significantly steeper discounting when they were deprived of their dependent drug of choice, caffeine. As found previously by Giordano et al. (2002), opioid deprivation increased discounting of both heroin and monetary rewards. The current study and Experiment 1 found caffeine deprivation effects discounting patterns but the direction of the effect was less predictable. Further research is required, however, Mitchell (2004) found that nicotine dependents that were deprived of nicotine showed steeper discounting on nicotine related rewards and not on monetary related rewards. The current research further supports Mitchell's (2004) suggestion that increased impulsive responding was driven by the increased value of the stimulant drug and not accompanied by the increased impulsivity towards all delayed rewards.

As in Experiment 2, a magnitude effect was found between the $1000 discounting task and the $10,000 discounting task. This further supports Smith and Hantula's (2008) finding that the discounting of delayed monetary rewards is steeper when the hypothetical reward is smaller.

A residual-least squares analysis found some participants discounting functions did not conform to the expected monotonically decreasing discounting function, on the occasions when the discounting functions did not conform, the resulting estimations of R^2 values were very small. When fits of the discounting models were very low further comparisons of models were meaningless. Following Kirby's (1997) method, a criterion for excluding data was set at $R^2 < .01$, (Appendix N). As a result of many discounting studies having participants who did not display monotonically decreasing discounting, the requirement to exclude data in delay discounting studies is becoming common practice, excluding data from the analysis brings to question the scientific integrity and relevance of any scientific research (see Experiment 2).

The extended hyperbolic model accounted for the most variance than either the exponential model or the hyperbolic model. This supported findings by Myerson and Green (1995), which compared the exponential, hyperbolic and extended hyperbolic models and found the extended hyperbolic model to account for the most variance. With adding the free parameter, the extended hyperbolic model, it was expected that the variance accounted for or the R^2 value would be greater. The *s* parameter value in the extended hyperbolic model varied notably from 1.0 on all but one occasion, the variation from 1.0 indicates this data needs a more general form of hyperbolic discounting. As described in Experiment 1, the *s* parameter having a value greater than 1.0 (as it is in all conditions and states) is unexpected. The *s* parameter being greater than 1.0 indicates that the exponent of the power function scaling time is greater than the exponent of the power function scaling amount. This means the delay till receipt of the reward has more effect than the amount of the reward.

Correlations have limited significance as a result of extreme outliers. With the exclusion of outliers the correlations, when measures are compared to their equivalent in the opposing task, trend in a negative direction. The negative trend is consistent with the magnitude effect. It is expected the AUC and the *k* values would be negatively correlated. When outliers are excluded, the negative correlations between AUC and *k* values increased from 1/7 to 2/7. Experiment 1 and 2 both found the AUC measure to be significantly correlated between tasks, which may indicate the same underlying processes are responsible for discounting of tasks of different delayed rewards and tasks of different sized delayed rewards. The current study, however, found the AUC measure to not be significantly correlated between discounting tasks. This indicates more research is required to justify the use of the current measures as valid and reliable tools, if the same processes are being measured it would be expected more significant correlations would be present.

The current study was not without limitations. As in Experiment 2, the possibility of a practice effect was not accounted for as each participant completed the $1000 condition prior to completing the $10,000 condition. Like Experiment 1 and 2, the delay period until receipt of reward may not have been substantial enough to warrant discounting by some participants, especially in the $10,000 condition. Deprivation of caffeine was un-controllable and relied on participant's self-report responses.

Future research should address issues raised from this research. The conditions should be counterbalanced to limit the practice effect. Like Experiment 1 and 2, the current study again found the residual-least regression analysis required the exclusion of data. This finding brings into focus the place of decay functions in discounting research. Further research is required to establish the place of the discounting functions when data presents extreme values. The only measure in which no data was required to be excluded was the AUC measure.

In conclusion, the present study findings support the existence of a magnitude effect when using hypothetical monetary values in delay discounting research. It provides a base from which future research could examine the effects of deprivation from the popular stimulant drug, caffeine, on impulsive decisions in humans. Most significantly, the current research highlights the exclusion of data in the mathematical models commonly used for analysis in delay discounting research and provides support for the AUC measure, which does not exclude data.

General Discussion

Experiment 1 and Experiment 3 attempted to apply a common methodology, the deprivation of a stimulant drug, to a delay discounting procedure in order to increase knowledge of the effects of the commonly consumed stimulant, caffeine, on self-control in humans. Previous research on stimulant deprivation had found a positive correlation between stimulant-dependents deprivation and increased impulsivity (Giordano et al., 2002, Mitchell, 2004). An honours research paper found a positive correlation between caffeine deprivation and increased impulsive decisions in humans (Kingston, 2010), however, the effects of caffeine were not significant in Experiment 1. Several possible accounts that may be responsible for the results were discussed, including, the control group were low caffeine consumers as oppose to not consuming caffeine at all, tasks were not counterbalanced which may have created a practice effect, and the stimulant deprivation was uncontrolled and relied on self-report.

To ascertain the task mode in Experiment 1 was not responsible for the unexpected pattern of results, Experiment 2 used a well supported computer-based mode to examine the magnitude effect (Smith & Hantula, 2008). As predicted, the computer-based mode of administration showed a significant magnitude effect, providing confidence that the mode of administration was not responsible for the possible failure to show discounting behaviour in Experiment 3.

Experiment 3 used the established computer-based mode of administration to present caffeine consumers with a delay discounting task both in a state of caffeine deprivation and in a state of caffeine influence. Discounting trends of low caffeine consumers showed steeper discounting when caffeine consumption was deprived. This was only significant for the *k* values established by the discounting models in both caffeine related experiments and trends in both experiments indicate contradictory results. Common to both Experiment 1 and Experiment 3 was the finding that caffeine appears to have the greatest effect on the decision making of those who are not caffeine dependent. It was suggested that low caffeine consumers were more affected by caffeine as a result of stimulant tolerance, previous research has found heavy caffeine consumers showed no psychological or physical distress, compared to their caffeine-intolerant control, after ingesting caffeine (Dager et al., 1999).

Experiment 3 agreed with previous research on stimulant deprivation. Previous research has found stimulant deprivation increased discounting trends on delay discounting tasks for stimulant dependents (Madden et al., 1997, Giordano et al., 2002, Odum et al., 2002, Mitchell, 2004). This effect has been found in delay discounting tasks with various outcomes, including; health gains and losses, drug-related rewards and monetary rewards. The findings of previous stimulant deprivation discounting research appears to agree that drug-related rewards are discounted more steeply than monetary amounts and discounting increases with stimulant deprivation. The research on caffeine deprivation, specifically, is less clear-cut. Kingston (2010) found caffeine deprivation increased discounting trends in humans, this agrees with previous stimulant deprivation findings. The current study found, using a reputable computer-based method, caffeine deprivation increased impulsivity for Low caffeine consumers more consistently than for High caffeine consumers. Caffeine is the most widely consumed stimulant drug in the world, its prominence may be responsible for the findings in the High caffeine consumers. Unlike previous studies of stimulant deprivation which used stimulants that have age restrictions (e.g. nicotine) or are illegal (e.g. opioid), caffeine's prominent use may be responsible for the unexpected behaviour patterns, like tolerance.

The finding that stimulant deprivation had an unexpected effect on caffeine consumers in Experiment 1 may be due to methodological issues. Experiment 1 used a pen and paper method, which presented all options to participants in order of delay and amount. Smith and Hantula (2008) found no significant difference between modes of administration when comparing discounting on a pen and paper task and a computer-based task. Participants in Experiment 1 (pen and paper mode) had a greater magnitude of discounting patterns which did not conform to discounting functions, resulting in small R^2 values, five in the Monetary task and nine in the Commodity task. Participants in Experiment 3 (computer-based mode) only had two participants in the \$1000 condition and one participant in the \$10,000 condition which had R^2 values too small to be included. An increase in useable data, in my opinion, increases the validation of the computer-based mode, over pen and paper mode, to present delay discounting tasks. The current study provides evidence of a difference in the discounting patterns found between a pen and paper mode and a computer-based mode of presenting delay discounting tasks, a finding in opposition to previous research and requires further investigation.

In Experiment 3, the high caffeine consumers had *k* values that were significantly more varied than the low caffeine consumers; caffeine deprivation increased impulsivity in the $1000 condition and decreased impulsivity in the $10,000 condition. It is a possibility that $10,000 is too large to be influenced by caffeine consumption. It is also possible the decrease in discounting for the high consumers in the $10,000 condition may be explained by the effects of excessive caffeine on human information processing and cognitive performance. Fredholm et al. (1999) found excessive consumption can have a detrimental effect on performance which suggests the high caffeine consumers decision making may have been negatively impacted in a non-abstinent state.

In the current research, one prominent discussion is related to the mathematical discounting functions in delay discounting research. The area under the curve, the exponential model, the hyperbolic model and the extended hyperbolic model were all used to analyse the discounting data in each experiment. The derived *k* values assume animals discount in a regular decline trend as delay lengthens. As a result of *k* values assuming the participants discount systematically, it has become common practice for delay discounting research to exclude the data from participants who did not show the expected discounting pattern (Beck & Triplett, 2009; Kirby & Guastello, 2001). Beck and Triplett (2009) discuss the exclusion of participants from their study with relevance to other prominent discounting studies; Myerson et al. (2001) excluded 9% of participants, Madden et al. (2004) dropped 15% of outliers, and Ohmura, Takahashi, Kitamura and Wehr (2006) dropped 9% of their participants at the second test in their reliability study. Of concern to research that refers to past delay discounting studies is the claim it is becoming common-place to not report the exclusion of data in discounting research (Beck & Triplett, 2009). It is irresponsible for scientists to exclude data on the basis that the behaviour did not take the expected form. Excluding participants' data on the basis that their decision making was unexpected by the mathematical functions used for analysis could be considered a distortion of the results.

It has been suggested the AUC scores need to be restricted to the same discounting criteria as its theoretically-based counterparts, Beck and Triplett (2009) suggest that because the AUC scores are insensitive to the form of the function that they should be guided by the criteria set by the mathematical discounting functions. The benefits of the AUC measure seem to out-weigh its insensitivity to the form of the function, these include; the AUC measure is theoretically neutral (Myerson et al., 2001), the statistical problems created by skewed distributions are circumvented (Myerson et al., 2001) and it allows for evaluation by parametric statistics as it is more normally distributed than *k* values (Odum, 2011). The AUC scores have been found to replicate findings from different measures in archival discounting research (Odum, 2011), however, in the current research it was not correlated with the discounting functions on many occasions. The lack of correlation found in the current study is possibly the result of methodological limitations and requires further research to assess AUC's reliability as a discounting measure. An empirical concern is raised as to whether it is justifiable to exclude data from reporting when a measure with established construct validity, and that is theoretically neutral, is available for use.

The current research had limitations, many of which are discussed within Experiment 1, 2 and 3. Additionally, self- report measures were used to assess previous caffeine consumption of participants within Experiment 1 and 3; the researcher had limited control over caffeine form, amount or time of delivery. Other caffeine related studies have used double-blind procedures using caffeine or placebo capsules to control caffeine consumption (Kilpeläinen et al., 2010). As previous research suggests, stimulant dependents increase impulsive decision making when deprived, which brings to question the self-control practiced by caffeine-deprived dependents when required to not consume for between 12 and 24hours. Such controls were not possible within the resources available for the current study and future research should address this issue.

A concerning issue for delay discounting research was raised in the current study. The practice of excluding data is becoming common place within delay discounting research, a concerning method for a facet of psychological research steadily gaining in prevalence and standing. Assessment and critique of discounting research's validity and reliability is required.

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Appendix B

Information

My name is Rosanna Frankish; I am a student in the Masters of Applied Behaviour Analysis programme at the University of Waikato's Psychology department. I would like to invite you to participate in my research to examine the effects of caffeine on simple decision making tasks.

It has been claimed caffeine is the most commonly used drug in the world, it has physiological effects which effect attention and energy. The form caffeine is consumed in has grown substantially; with energy drinks, tea, some carbonated beverages and, of course, coffee, the choices for consuming caffeine are close to endless. This study intends to look at the effects of caffeine withdrawal on decision-making involving future events. It is thought that caffeine consumers will display more impulsive decision-making when they are in a state of withdrawal, compared to non-caffeine consumers and those not in a state of withdrawal.

You will be required to:

- Attend 2 lab sessions - one week apart
- If you regularly consume caffeine: 1 lab session will require no caffeine consumption at least 12 hours prior and the other will require you to maintain your regular caffeine consumption prior.
- If you do not consume caffeine you will be required to attend two laboratory sessions remaining caffeine free.
- In lab 1 you will be asked to provide demographic details and answer a short questionnaire regarding caffeine consumption.
- Both lab sessions will include pen and paper delay discounting tasks, this requires you to choose between two options in hypothetical money and commodity tasks. The choice made provides information regarding individual Self-control tendencies. The laboratory sessions are expected to take approximately 30 minutes.

May experience mild discomfort:

Large amounts and regular caffeine consumers may feel some mild discomfort abstaining from caffeine for at least 12 hours before one laboratory session, I will try to limit discomfort by having laboratory sessions in the morning. If you experience discomfort or distress at any stage of the research process, feel free to contact Healthline. This is a free service provided to New Zealanders who require health advice, it is a 24 hour service.
Contact Healthline on: 0800 611 116 or www.healthline.govt.nz

Data will remain anonymous and confidential:
Contact details and your name will only be required for scheduling experimental sessions, after completing the sessions your identifying details will be destroyed. Demographic details will remain anonymous and used for analytic purposes only. Voluntary and informed consent is required before participating in this study, consent forms and data will be kept securely at the University of Waikato for a period of three years at which point they will be destroyed. Any further use of the data will only be reported as group data.

Participation in this study is entirely voluntary:
You are not required to participate and are free to withdraw at any time without question or negative consequence. Participants are required to restrain from consuming psychiatric drugs, illegal drugs, nicotine or alcohol in the past 24hrs before participating.
If you have any enquires regarding your participation in the study feel free to contact the researcher or supervisor:

Researcher: Rosanna Frankish
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Appendix C

University of Waikato

School of Psychology

CONSENT FORM

PARTICIPANT'S COPY

Research Project: Replication and Extension of 'Caffeine Withdrawal: Does it cause caffeine consumers to behave more impulsivity?'

Name of Researcher: Rosanna Frankish

Name of Supervisor (if applicable): Dr Lewis Bizo and Prof Mary Foster

I have received an information sheet about this research project or the researcher has explained the study to me. I have had the chance to ask any questions and discuss my participation with other people. Any questions have been answered to my satisfaction.

I agree to participate in this research project and I understand that I may withdraw at any time. If I have any concerns about this project, I may contact the convenor of the Research and Ethics Committee (Dr Robert Isler, phone: 838 4466 ext. 8401, e-mail r.isler@waikato.ac.nz)
I would like to receive a summary of the findings at the completion of the research:

☐YES

☐NO

Participant's
Name:______________________Signature:_________________Date:_______

===

University of Waikato
School of Psychology

CONSENT FORM

RESEARCHER'S COPY

Research Project: Replication and Extension of 'Caffeine Withdrawal: Does it cause caffeine consumers to behave more impulsivity?'

Name of Researcher: Rosanna Frankish

Name of Supervisor (if applicable): Dr Lewis Bizo and Prof Mary Foster

I have received an information sheet about this research project or the researcher has explained the study to me. I have had the chance to ask any questions and discuss my participation with other people. Any questions have been answered to my satisfaction.

I agree to participate in this research project and I understand that I may withdraw at any time. If I have any concerns about this project, I may contact the convenor of the Research and Ethics Committee.

I would like to receive a summary of the findings at the completion of the research:

☐YES

☐NO

Participant's Name: ______________________Signature:_______________ Date:_______

Appendix D

Kingston (2010)

CAFFEINE CONSUMPTION QUESTIONNAIRE				
Please answer the following questions as completely and honestly as you can.				
This information is confidential do not write your name anywhere on this page.				
Thank you for your co-operation.				
Please answer the following questions about your caffeine consumption in the past week				
Respond to items that you consumed **at least once in the past week**				
COFFEE (number of cups in the past week)	MORNING 6am-midday	AFTERNOON Midday-6pm	EVENING 6pm-2am	NIGHT 2am-6am
Espresso (café style)				
Drip-brewed				
Plunger style				
Instant				
Decaffeinated				
Other: Please Specify				
TEA (caffeinated not herbal) (number of cups in the past week)				
HOT CHOCOLATE (number of cups in the past week)				
SOFT DRINK (number of cups or cans in the past week)				
Coca-cola				
Pepsi				
Other: Please Specify				
ENERGY DRINKS (number of cans in the past week)				
Red bull				
V				
Other: Please Specify				
OVER THE COUNTER DRUGS CONTAINING CAFFEINE (number of tablets in the past week)				
NoDoz				
Guarana				
Other: Please Specify				
CHOCOLATE (number of bars in the past week)				

Appendix E

Demographic Details

Please fill in the following questions:

1. Age ____________________

2. Gender ____________________

3. Have you consumed any of the following in the last 24hours: (*circle your answer*)

Session 1	Psychiatric Medication	*Yes* *No*
	Illegal Drugs	*Yes* *No*
	Nicotine	*Yes* *No*
	Alcohol	*Yes* *No*
Session 2	Psychiatric Medication	*Yes* *No*
	Illegal Drugs	*Yes* *No*
	Nicotine	*Yes* *No*
	Alcohol	*Yes* *No*

4. Number of minutes/hours since you last consumed caffeine

Session 1 _________________

Session 2 _________________

Appendix F

Caffeine content of food and beverages developed by the Australia Institute of Sport (2007)

Food or Drink	Serve	Caffeine Content (mg)
Instant coffee	250 ml cup	60 (12-169)*
Brewed coffee	250 ml cup	80 (40-110)*
Short black coffee/espresso	1 standard serve (commercial purchase)	107 (25-214)*
Decaffeinated Coffee		7
Tea	250 ml cup	27 (9-51)*
Hot chocolate	250 ml cup	5-10
Chocolate -milk	60 g	5-15
Chocolate - dark	60 g	10-50
Viking chocolate bar	60 g	58
Coca Cola	375 ml can	49
Pepsi Cola	375 ml can	40
Musashi E Shot Cola	300 ml	95
Jolt soft drink	375 ml can	75
Red Bull energy drink	250 ml can	80
Monster Energy	16oz	160
Red Eye Power energy drink	250 ml can	50
V Energy drink	250 ml can	50
Smart Drink - Brain fuel	250 ml can	80
Lift Plus energy drink	250 ml can	36
Lipovitan energy drink	250 ml can	50
Black Stallion energy drink	250 ml can	80
PowerBar caffeinated sports gel	40 g sachet	25
PowerBar double caffeinated sports gel	40 g sachet	50
Gu caffeinated sports gel	32 g sachet	20
PowerBar Performance bar with Acticaf	65 g bar	50

Appendix G

The parameter estimates from the best fits of the exponential, hyperbolic and extended hyperbolic models to individual data from the discounting tasks/individual delay discounting data, Experiment 1.

The Monetary Condition

Exponential (HighNonAbstinent)			
Participant	A	k	R^2
Par 21	1000	0.065	0.815
Par 7	1000	0.071	0.825
Par 17	1000	0.137	0.107
Par 6	1000	0.033	0.926
Par 20	1000	0.146	0.389
Par 11	1000	0.011	0.798
Par 19	1000	0.107	0.923
Par 23	1000	0.033	0.845
Par 25	1000	0.070	0.941
Par 28	1000	0.586	0.766
Mean		**0.126**	**0.733**

Exponential (HighAbstinent)			
Participant	A	k	R^2
Par 21	1000	0.043	0.720
Par 7	1000	0.247	0.917
Par 17	1000	0.078	0.914
Par 6	1000	0.013	0.879
Par 20	1000	0.580	0.580
Par 11	1000	0.051	0.377
Par 19	1000	0.146	0.269
Par 23	1000	0.082	0.302
Par 25	1000	0.580	0.000
Par 28	1000	0.213	0.945
Mean		**0.203**	**0.590**

Exponential (LowNonAbstinent)			
Participant	A	k	R^2
Par 4	1000	0.008	0.889
Par 3	1000	1.609	0.000
Par 14	1000	2.303	0.235
Par 30	1000	1.609	0.442
Par 29	1000	0.078	0.944
Par 26	1000	0.043	0.628
Par 27	1000	0.656	0.871
Par 5	1000	0.021	0.821
Par 22	1000	2.303	0.000
Par 31	1000	0.079	0.948
Mean		**0.871**	**0.578**

Exponential (LowAbstinent)			
Participant	A	k	R^2
Par 4	1000	0.008	0.889
Par 3	1000	0.586	0.628
Par 14	1000	6.908	0.000
Par 30	1000	2.996	0.000
Par 29	1000	0.137	0.341
Par 26	1000	0.006	0.840
Par 27	1000	0.048	0.903
Par 5	1000	0.016	0.916
Par 22	1000	1.605	0.000
Par 31	1000	0.081	0.237
Mean		**1.239**	**0.475**

Note. The parameter estimates from the best fits of the exponential model to individual data from the monetary condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Hyperbolic (HighNonAbstinent)				Hyperbolic (HighAbstinent)				Hyperbolic (LowNonAbstinent)				Hyperbolic (LowAbstinent)			
Participant	A	k	R^2	Participant	A	k	R^2	Participant	A	k	R^2	Participant	A	k	R^2
Par 21	1000	0.098	0.785	**Par 21**	1000	0.076	0.875	**Par 4**	1000	0.011	0.853	**Par 4**	1000	0.011	0.853
Par 7	1000	0.107	0.777	**Par 7**	1000	0.413	0.828	**Par 3**	1000	3.067	0.000	**Par 3**	1000	0.856	0.938
Par 17	1000	0.318	0.505	**Par 17**	1000	0.133	0.923	**Par 14**	1000	8.944	0.335	**Par 14**	1000	314.285	0.000
Par 6	1000	0.054	0.893	**Par 6**	1000	0.018	0.802	**Par 30**	1000	3.535	0.787	**Par 30**	1000	14.978	0.000
Par 20	1000	0.368	0.645	**Par 20**	1000	0.801	0.914	**Par 29**	1000	0.138	0.935	**Par 29**	1000	0.338	0.624
Par 11	1000	0.017	0.842	**Par 11**	1000	0.097	0.629	**Par 26**	1000	0.073	0.826	**Par 26**	1000	0.007	0.765
Par 19	1000	0.176	0.942	**Par 19**	1000	0.359	0.574	**Par 27**	1000	1.029	0.979	**Par 27**	1000	0.073	0.863
Par 23	1000	0.049	0.775	**Par 23**	1000	0.185	0.487	**Par 5**	1000	0.036	0.874	**Par 5**	1000	0.024	0.887
Par 25	1000	0.124	0.955	**Par 25**	1000	0.664	0.000	**Par 22**	1000	6.400	0.000	**Par 22**	1000	0.037	0.000
Par 28	1000	0.894	0.985	**Par 28**	1000	0.373	0.860	**Par 31**	1000	0.140	0.929	**Par 31**	1000	0.178	0.463
Mean		**0.221**	**0.810**	**Mean**		**0.312**	**0.689**	**Mean**		**2.337**	**0.652**	**Mean**		**33.079**	**0.539**

Note. The parameter estimates from the best fits of the hyperbolic model to individual data from the monetary condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Ext. Hyperbolic (HighNonAbstinent)					Ext. Hyperbolic (HighAbstinent)					Ext. Hyperbolic (LowNonAbstinent)					Ext. Hyperbolic (LowAbstinent)				
Partici-pant	A	k	s	R^2	Partici-pant	A	k	s	R^2	Partici-pant	A	k	s	R^2	Partici-pant	A	k	s	R^2
Par 21	1000	112.532	0.443	0.723	**Par 21**	1000	0.236	0.530	0.909	**Par 4**	1000	0.000	125.705	0.888	**Par 4**	1000	0.000	125.705	0.888
Par 7	1000	0.000	828.096	0.825	**Par 7**	1000	0.000	2213.945	0.917	**Par 3**	1000	633.971	0.244	0.628	**Par 3**	1000	2.083	0.624	0.987
Par 17	1000	3.803	0.361	0.790	**Par 17**	1000	0.078	1.436	0.926	**Par 14**	1000	75.573	0.546	0.374	**Par 14**	1000	100.000	1.305	0.000
Par 6	1000	0.000	293.585	0.926	**Par 6**	1000	0.000	313.103	0.879	**Par 30**	1000	21.720	0.510	0.977	**Par 30**	1000	100.000	0.539	0.203
Par 20	1000	2.376	0.447	0.778	**Par 20**	1000	1.951	0.626	0.964	**Par 29**	1000	0.037	2.624	0.949	**Par 29**	1000	2.469	0.431	0.772
Par 11	1000	0.020	0.909	0.843	**Par 11**	1000	0.452	0.435	0.707	**Par 26**	1000	0.328	0.442	0.896	**Par 26**	1000	0.000	184.890	0.840
Par 19	1000	0.115	1.334	0.945	**Par 19**	1000	3.101	0.401	0.773	**Par 27**	1000	1.133	0.945	0.980	**Par 27**	1000	0.000	494.591	0.903
Par 23	1000	0.000	607.578	0.845	**Par 23**	1000	2.906	0.347	0.649	**Par 5**	1000	0.040	0.939	0.875	**Par 5**	1000	0.026	1.534	0.933
Par 25	1000	0.068	1.498	0.960	**Par 25**	1000	16.686	0.273	0.779	**Par 22**	1000	100.000	0.314	0.000	**Par 22**	1000	100.000	0.013	0.000
Par 28	1000	1.305	0.809	0.993	**Par 28**	1000	0.000	1835.682	0.945	**Par 31**	1000	0.016	5.617	0.948	**Par 31**	1000	3.295	0.329	0.664
Mean		**12.022**	**173.506**	**0.863**	**Mean**		**12.022**	**173.506**	**0.863**	**Mean**		**83.282**	**13.789**	**0.752**	**Mean**		**30.787**	**80.996**	**0.619**

Note. The parameter estimates from the best fits of the extended hyperbolic model to individual data from the monetary condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Commodity Condition

Exponential (HighNonAbstinent)				Exponential HighAbstinent)				Exponential (LowNonAbstinent)				Exponential (LowAbstinent)			
Partici-pant	A	k	R*2	Partici-pant	A	k	R*2	Partici-pant	A	k	R*2	Partici-pant	A	k	R*2
Par 21	1000	0.175	0.846	**Par 21**	1000	0.071	0.836	**Par 4**	1000	0.016	0.924	**Par 4**	1000	0.016	0.916
Par 7	1000	0.005	0.592	**Par 7**	1000	0.071	0.836	**Par 3**	1000	1.608	0.000	**Par 3**	1000	1.608	0.000
Par 17	1000	0.115	0.970	**Par 17**	1000	0.115	0.970	**Par 14**	1000	2.996	0.000	**Par 14**	1000	6.908	0.000
Par 6	1000	0.032	0.914	**Par 6**	1000	2.996	0.000	**Par 30**	1000	2.996	0.000	**Par 30**	1000	2.996	0.000
Par 20	1000	0.080	0.953	**Par 20**	1000	0.589	0.790	**Par 29**	1000	0.237	0.881	**Par 29**	1000	0.657	0.954
Par 11	1000	0.031	0.883	**Par 11**	1000	0.078	0.000	**Par 26**	1000	0.021	0.821	**Par 26**	1000	0.008	0.769
Par 19	1000	13.039	0.000	**Par 19**	1000	2.303	0.000	**Par 27**	1000	1.609	0.518	**Par 27**	1000	0.238	0.907
Par 23	1000	2.996	0.000	**Par 23**	1000	2.996	0.000	**Par 5**	1000	0.031	0.883	**Par 5**	1000	0.016	0.916
Par 25	1000	1.000	0.044	**Par 25**	1000	2.303	0.000	**Par 22**	1000	0.065	0.000	**Par 22**	1000	0.083	0.442
Par 28	1000	0.195	0.576	**Par 28**	1000	0.188	0.580	**Par 31**	1000	0.247	0.915	**Par 31**	1000	0.067	0.890
Mean		**1.767**	**0.578**	**Mean**		**1.171**	**0.401**	**Mean**		**0.982**	**0.494**	**Mean**		**1.260**	**0.579**

Note. The parameter estimates from the best fits of the exponential model to individual data from the commodity condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Hyperbolic (HighNonAbstinent)				Hyperbolic (HighAbstinent)				Hyperbolic (LowNonAbstinent)				Hyperbolic (LowAbstinent)			
Partici-pant	A	k	R*2	Partici-pant	A	k	R*2	Partici-pant	A	k	R*2	Partici-pant	A	k	R*2
Par 21	1000	0.275	0.872	**Par 21**	1000	0.109	0.781	**Par 4**	1000	0.025	0.883	**Par 4**	1000	0.024	0.887
Par 7	1000	0.005	0.516	**Par 7**	1000	0.109	0.781	**Par 3**	1000	2.724	0.000	**Par 3**	1000	2.835	0.000
Par 17	1000	0.199	0.939	**Par 17**	1000	0.199	0.939	**Par 14**	1000	16.441	0.000	**Par 14**	1000	811.405	0.000
Par 6	1000	0.051	0.904	**Par 6**	1000	15.751	0.135	**Par 30**	1000	14.945	0.000	**Par 30**	1000	15.708	0.000
Par 20	1000	0.143	0.925	**Par 20**	1000	0.158	0.000	**Par 29**	1000	0.036	0.832	**Par 29**	1000	0.010	0.836
Par 11	1000	0.048	0.902	**Par 11**	1000	0.158	0.230	**Par 26**	1000	0.036	0.874	**Par 26**	1000	0.010	0.700
Par 19	1000	8.165	0.000	**Par 19**	1000	6.651	0.000	**Par 27**	1000	3.571	0.832	**Par 27**	1000	0.391	0.836
Par 23	1000	15.044	0.000	**Par 23**	1000	14.950	0.000	**Par 5**	1000	0.048	0.902	**Par 5**	1000	0.024	0.887
Par 25	1000	3.979	0.993	**Par 25**	1000	6.586	0.000	**Par 22**	1000	0.050	0.000	**Par 22**	1000	0.199	0.553
Par 28	1000	0.571	0.684	**Par 28**	1000	0.552	0.692	**Par 31**	1000	0.411	0.827	**Par 31**	1000	0.114	0.951
Mean		**2.848**	**0.674**	**Mean**		**4.522**	**0.356**	**Mean**		**3.829**	**0.515**	**Mean**		**83.072**	**0.565**

Note. The parameter estimates from the best fits of the hyperbolic model to individual data from the commodity condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Ext. Hyperbolic (HighNonAbstinent)					Ext. Hyperbolic (HighAbstinent)					Ext. Hyperbolic (LowNonAbstinent)					Ext. Hyperbolic (LowAbstinent)				
	A	k	s	R*2		A	k	s	R*2		A	k	s	R*2		A	k	s	R*2
Par 21	1000	0.197	1.258	0.875	**Par 21**	1000	0.001	129.075	0.836	**Par 4**	1000	0.001	17.453	0.923	**Par 4**	1000	0.002	9.565	0.917
Par 7	1000	0.000	76.891	0.591	**Par 7**	1000	0.001	129.075	0.836	**Par 3**	1000	100.000	0.258	0.570	**Par 3**	1000	586.625	0.239	0.789
Par 17	1000	0.006	19.726	0.970	**Par 17**	1000	0.000	287.229	0.970	**Par 14**	1000	100.000	0.563	0.000	**Par 14**	1000	100.000	1.472	0.000
Par 6	1000	0.014	2.706	0.919	**Par 6**	1000	100.000	0.572	0.609	**Par 30**	1000	100.000	0.538	0.249	**Par 30**	1000	100.000	0.566	0.466
Par 20	1000	0.012	6.954	0.953	**Par 20**	1000	1.212	0.859	0.980	**Par 29**	1000	0.001	303.316	0.881	**Par 29**	1000	0.549	1.582	0.998
Par 11	1000	0.028	1.462	0.906	**Par 11**	1000	6.129	0.262	0.681	**Par 26**	1000	0.040	0.939	0.875	**Par 26**	1000	0.000	79.605	0.768
Par 19	1000	100.000	0.294	0.041	**Par 19**	1000	100.000	0.370	0.303	**Par 27**	1000	17.314	0.547	0.971	**Par 27**	1000	0.005	45.953	0.906
Par 23	1000	100.000	0.547	0.000	**Par 23**	1000	100.000	0.539	0.284	**Par 5**	1000	0.028	1.462	0.906	**Par 5**	1000	0.002	9.565	0.917
Par 25	1000	3.968	1.001	0.993	**Par 25**	1000	100.000	0.371	0.377	**Par 22**	1000	100.000	0.314	0.000	**Par 22**	1000	1.890	0.413	0.629
Par 28	1000	1.071	0.732	0.695	**Par 28**	1000	1.109	0.710	0.706	**Par 31**	1000	0.001	390.576	0.915	**Par 31**	1000	0.130	0.919	0.952
Mean		**20.530**	**11.157**	**0.694**	**Mean**		**40.845**	**54.906**	**0.658**	**Mean**		**41.738**	**71.597**	**0.629**	**Mean**		**78.920**	**14.988**	**0.734**

Note. The parameter estimates from the best fits of the extended hyperbolic model to individual data from the commodity condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Appendix I

Information

<u>The Effect of Delay and Expected Outcomes on Choices for Future Events</u>

My name is Rosanna Frankish; I am a student in the Masters of Applied Behaviour Analysis programme at the University of Waikato's Psychology School. I would like to invite you to participate in my research to examine the effects of reward magnitude on simple decision making tasks. By participating in this research you automatically go in the draw to win a $50 grocery voucher.

It has been assumed that giving people choices which differ in terms of the delay to them happening and the magnitude of the future outcomes provides a measure of Self-control. This study intends to investigate the effects of reward magnitude on choices about future outcomes in human decision making.

You will be required to:

- Attend one session which will take approximately 30 minutes in duration.
- Before the session some demographic details will be required by filling out a questionnaire.
- The session will involve completing **two simple delay discounting tasks**, these requires you to choose between two options in hypothetical money and commodity tasks. The choice made provides information regarding individual Self-control tendencies.

Data will remain anonymous and confidential:

Contact details and your name will only be required for identifying the winner of the $50 grocery voucher, once the winner has been announced your identifying details will be destroyed. Demographic details will remain anonymous and used for analytic purposes only. Voluntary and informed consent will be asked for before participating in this study, consent forms and data will be kept securely at the University of Waikato for a period of three years at which point they will be destroyed. Any further use of the data will only be reported as group data.

Participation in this study is entirely voluntary:

You are free to withdraw from the research at any time without question or negative consequence. If you have any enquires regarding your participation in the study feel free to contact the researcher or supervisor:

Researcher: Rosanna Frankish
School of Psychology at the University of Waikato
rpjf2@students.waikato.ac.nz
Phone: 0275552554

Supervisor: Dr Lewis Bizo
School of Psychology at the University of Waikato
lbizo@waikato.ac.nz

This project has been approved by the School of Psychology Research and Ethics Committee and if you have any concerns about the research you may approach the convenor of the committee; Dr Robert Isler (phone 07 8384466 ext 8401, email: r.isler@waikato.ac.nz)

Appendix J

Demographic Details

Please fill in the following questions:

1. Age (years) ____________________

2. Gender (circle): Male Female

3. Occupation _________________

4. Ethnicity (circle): NZ European

   Maori

   Pacific Island

   Asian

   Indian

   Other, please specify -

   ____

5. Living Circumstance (circle):

   Home owner

   Renting

   Other, please specify

   ____

Appendix K

The parameter estimates from the best fits of the exponential, hyperbolic and extended hyperbolic models to individual data from the discounting tasks/individual delay discounting data, Experiment 2.

Exponential ($1000)				**Exponential ($10000)**			
Participant	A	k	R*2	Participant	A	k	R*2
1003	1000	0.004	0.603	**1003**	10000	1.768	1.000
1004	1000	0.007	0.807	**1004**	10000	0.006	0.826
1005	1000	8.458	1.000	**1005**	10000	0.004	0.788
1006	1000	0.114	0.964	**1006**	10000	2.302	0.000
1007	1000	8.458	1.000	**1007**	10000	0.003	0.422
1008	1000	0.008	0.769	**1008**	10000	0.012	0.901
1009	1000	0.049	0.832	**1009**	10000	0.031	0.883
1010	1000	0.008	0.889	**1010**	10000	0.009	0.000
1011	1000	0.000	0.000	**1011**	10000	1.768	1.000
1012	1000	0.006	0.840	**1012**	10000	0.002	0.655
1013	1000	0.006	0.826	**1013**	10000	0.006	0.840
1014	1000	0.009	0.648	**1014**	10000	0.004	0.788
1015	1000	0.004	0.788	**1015**	10000	0.006	0.840
1017	1000	0.009	0.084	**1017**	10000	0.016	0.924
1018	1000	0.006	0.840	**1018**	10000	0.007	0.463
1019	1000	0.146	0.183	**1019**	10000	0.031	0.883
1020	1000	0.012	0.901	**1020**	10000	0.006	0.840
1021	1000	0.032	0.925	**1021**	10000	0.016	0.916
1023	1000	0.012	0.842	**1023**	10000	0.006	0.826
1024	1000	2.996	0.944	**1024**	10000	3.912	0.949
1026	1000	0.006	0.712	**1026**	10000	1.768	1.000
1027	1000	8.458	1.000	**1027**	10000	1.768	1.000
1028	1000	0.004	0.429	**1028**	10000	1.768	1.000
1029	1000	0.011	0.798	**1029**	10000	0.004	0.788
1030	1000	0.006	0.826	**1030**	10000	1.768	1.000
1031	1000	0.151	0.486	**1031**	10000	0.115	0.799
1032	1000	0.050	0.927	**1032**	10000	0.012	0.855
1033	1000	0.065	0.827	**1033**	10000	0.027	0.205
1034	1000	0.010	0.749	**1034**	10000	0.002	0.655
1035	1000	0.022	0.893	**1035**	10000	0.003	0.422

Note. The parameter estimates from the best fits of the exponential model to individual data. Those in grey did not meet the discounting criterion.

Hyperbolic ($1000)				Hyperbolic ($10000)			
Participant	A	k	R*2	Participant	A	k	R*2
1003	1000	0.005	0.531	**1003**	10000	1.856	1.000
1004	1000	0.009	0.712	**1004**	10000	0.008	0.739
1005	1000	100.000	0.000	**1005**	10000	0.002	0.066
1006	1000	0.196	0.940	**1006**	10000	0.023	0.000
1007	1000	100.000	0.000	**1007**	10000	0.004	0.422
1008	1000	0.010	0.700	**1008**	10000	0.007	0.014
1009	1000	0.070	0.814	**1009**	10000	0.048	0.902
1010	1000	0.011	0.853	**1010**	10000	0.003	0.111
1011	1000	0.000	0.000	**1011**	10000	1.856	1.000
1012	1000	0.007	0.765	**1012**	10000	0.002	0.609
1013	1000	0.008	0.739	**1013**	10000	0.007	0.765
1014	1000	0.013	0.675	**1014**	10000	0.002	0.066
1015	1000	0.005	0.765	**1015**	10000	0.007	0.765
1017	1000	0.015	0.101	**1017**	10000	1.856	1.000
1018	1000	0.007	0.765	**1018**	10000	0.008	0.182
1019	1000	0.356	0.516	**1019**	10000	0.765	0.902
1020	1000	0.017	0.815	**1020**	10000	0.007	0.765
1021	1000	0.052	0.906	**1021**	10000	0.024	0.887
1023	1000	0.019	0.837	**1023**	10000	0.739	0.008
1024	1000	19.002	0.995	**1024**	10000	49.333	0.983
1026	1000	0.008	0.765	**1026**	10000	1.856	1.000
1027	1000	100.000	0.000	**1027**	10000	1.856	1.000
1028	1000	0.005	0.388	**1028**	10000	1.856	1.000
1029	1000	0.017	0.842	**1029**	10000	0.002	0.066
1030	1000	0.008	0.739	**1030**	10000	1.856	1.000
1031	1000	0.214	0.631	**1031**	10000	0.222	0.821
1032	1000	0.078	0.861	**1032**	10000	0.008	0.164
1033	1000	0.099	0.793	**1033**	10000	0.051	0.221
1034	1000	0.013	0.659	**1034**	10000	0.002	0.609
1035	1000	0.032	0.858	**1035**	10000	0.004	0.422

Note. The parameter estimates from the best fits of the hyperbolic model to individual data. Those in grey did not meet the discounting criterion.

Ext Hyperbolic ($1000)					Ext Hyperbolic ($10000)				
Participant	A	k	s	R*2	Participant	A	k	s	R*2
1003	1000	3.8E-05	1.1E+02	6.0E-01	**1003**	10000	5.307	0.485	1.000
1004	1000	4.1E-05	1.7E+02	8.1E-01	**1004**	10000	0.000	137.387	0.825
1005	1000	1.0E+02	3.1E-01	0.0E+00	**1005**	10000	0.000	22.557	0.787
1006	1000	1.8E-02	6.9E+00	9.6E-01	**1006**	10000	100.000	0.066	0.000
1007	1000	1.0E+02	3.1E-01	0.0E+00	**1007**	10000	0.004	0.948	0.422
1008	1000	5.0E-05	1.5E+02	7.7E-01	**1008**	10000	0.000	110.747	0.901
1009	1000	2.2E-04	2.2E+02	8.3E-01	**1009**	10000	0.028	1.462	0.906
1010	1000	3.2E-04	2.5E+01	8.9E-01	**1010**	10000	6.043	0.229	0.028
1011	1000	5.5E+00	7.2E-02	0.0E+00	**1011**	10000	5.307	0.485	1.000
1012	1000	4.8E-05	1.2E+02	8.4E-01	**1012**	10000	0.000	117.935	0.655
1013	1000	5.7E-05	1.1E+02	8.2E-01	**1013**	10000	0.000	80.726	0.839
1014	1000	1.6E-02	1.6E+00	7.1E-01	**1014**	10000	0.000	25.120	0.787
1015	1000	1.4E-04	2.9E+01	7.9E-01	**1015**	10000	0.000	80.726	0.839
1017	1000	8.9E-01	1.7E-01	1.3E-01	**1017**	10000	0.000	36.384	0.923
1018	1000	4.7E-05	1.2E+02	8.4E-01	**1018**	10000	0.075	0.331	0.732
1019	1000	3.6E+00	3.8E-01	7.6E-01	**1019**	10000	0.028	1.462	0.906
1020	1000	7.7E-05	1.6E+02	9.0E-01	**1020**	10000	0.000	80.726	0.839
1021	1000	9.2E-03	4.0E+00	9.3E-01	**1021**	10000	0.002	9.589	0.917
1023	1000	5.7E-03	2.6E+00	8.5E-01	**1023**	10000	0.000	150.013	0.825
1024	1000	1.8E+01	1.0E+00	9.9E-01	**1024**	10000	43.480	1.032	0.983
1026	1000	1.5E-02	6.5E-01	7.7E-01	**1026**	10000	5.307	0.485	1.000
1027	1000	1.0E+02	3.1E-01	0.0E+00	**1027**	10000	5.307	0.485	1.000
1028	1000	4.9E-05	8.6E+01	4.3E-01	**1028**	10000	5.307	0.485	1.000
1029	1000	2.0E-02	9.1E-01	8.4E-01	**1029**	10000	0.000	25.120	0.787
1030	1000	5.7E-05	1.1E+02	8.2E-01	**1030**	10000	5.307	0.485	1.000
1031	1000	5.6E-01	5.6E-01	6.6E-01	**1031**	10000	0.124	1.465	0.826
1032	1000	7.4E-04	6.7E+01	9.3E-01	**1032**	10000	0.000	56.278	0.855
1033	1000	2.2E-03	2.9E+01	8.3E-01	**1033**	10000	0.070	0.602	0.247
1034	1000	3.9E-05	2.5E+02	7.5E-01	**1034**	10000	0.000	117.935	0.655
1035	1000	2.3E-03	9.9E+00	8.9E-01	**1035**	10000	0.004	0.948	0.422

Note. The parameter estimates from the best fits of the extended hyperbolic model to individual data. Those in grey did not meet the discounting criterion.

Appendix M

Demographic Details

Please fill in the following questions:

6. Age ____________________

7. Gender ____________________

8. Have you consumed any of the following in the last 24hours: (*circle your answer*)

Session 1	Psychiatric Medication	*Yes* *No*
	Illegal Drugs	*Yes* *No*
	Nicotine	*Yes* *No*
	Alcohol	*Yes* *No*
Session 2	Psychiatric Medication	*Yes* *No*
	Illegal Drugs	*Yes* *No*
	Nicotine	*Yes* *No*
	Alcohol	*Yes* *No*

9. Number of minutes/hours since you last consumed caffeine

Session 1 ________________

Session 2 ________________

Appendix N

The parameter estimates from the best fits of the exponential, hyperbolic and extended hyperbolic models to individual data from the discounting tasks/individual delay discounting data, Experiment 3.

$1000 Condition

Exponential (,NonAbstinent)				Exponential (LowAstinent)				Exponential (High Abstinent)				Exponential (High Abstinent)			
Participant	**A**	**k**	**R*2**	**Participant**	**A**	**k**	**R*2**	**Participant**	**A**	**k**	**R*2**	**Participant**	**A**	**k**	**R*2**
1047	1000	0.008	0.889	**1047**	1000	0.012	0.898	**1049**	1000	0.004	0.788	**1049**	1000	0.010	0.677
1059	1000	0.006	0.712	**1059**	1000	0.002	0.655	**1050**	1000	0.011	0.834	**1050**	1000	0.004	0.119
1060	1000	0.004	0.617	**1060**	1000	0.002	0.655	**1051**	1000	0.006	0.840	**1051**	1000	0.011	0.753
1061	1000	0.010	0.747	**1061**	1000	0.036	0.805	**1054**	1000	0.053	0.847	**1054**	1000	0.011	0.878
1062	1000	0.003	0.422	**1062**	1000	0.003	0.000	**1055**	1000	0.007	0.816	**1055**	1000	0.013	0.526
1063	1000	8.458	1.000	**1063**	1000	0.001	0.069	**1057**	1000	0.011	0.798	**1057**	1000	0.021	0.751
1066	1000	0.012	0.586	**1066**	1000	0.011	0.878	**1058**	1000	0.013	0.867	**1058**	1000	0.009	0.785
1069	1000	8.458	1.000	**1069**	1000	0.006	0.553	**1065**	1000	0.004	0.788	**1065**	1000	0.006	0.712
1070	1000	2.303	0.999	**1070**	1000	0.271	0.907	**1067**	1000	0.039	0.821	**1067**	1000	0.005	0.025
1075	1000	0.006	0.840	**1075**	1000	0.010	0.138	**1068**	1000	0.005	0.587	**1068**	1000	0.010	0.645
1077	1000	0.004	0.788	**1077**	1000	0.034	0.878	**1071**	1000	0.012	0.898	**1071**	1000	0.009	0.889
1079	1000	8.458	1.000	**1079**	1000	8.458	1.000	**1072**	1000	0.010	0.740	**1072**	1000	0.004	0.617
1080	1000	0.004	0.603	**1080**	1000	0.006	0.712	**1076**	1000	8.458	1.000	**1076**	1000	0.010	0.743
1084	1000	0.004	0.603	**1084**	1000	0.006	0.503	**1048**	1000	0.047	0.000	**1048**	1000	0.007	0.807
Mean		**1.981**	**0.772**	**Mean**		**0.633**	**0.618**	**Mean**		**0.620**	**0.759**	**Mean**		**0.009**	**0.638**

Note. The parameter estimates from the best fits of the exponential model to individual data from the $1000 condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Hyperbolic (Low ,NonAbstinent)				Hyperbolic (Low Abstinent)				Hyperbolic (High NonAbstinent)				Hyperbolic (High Abstinent)			
Participant	**A**	**k**	**R*2**	**Participant**	**A**	**k**	**R*2**	**Participant**	**A**	**k**	**R*2**	**Participant**	**A**	**k**	**R*2**
1047	1000	0.011	0.853	**1047**	1000	0.016	0.827	**1049**	1000	0.005	0.765	**1049**	1000	0.015	0.643
1059	1000	0.008	0.765	**1059**	1000	0.002	0.609	**1050**	1000	0.019	0.844	**1050**	1000	0.006	0.169
1060	1000	0.004	0.550	**1060**	1000	0.002	0.609	**1051**	1000	0.007	0.765	**1051**	1000	0.016	0.726
1061	1000	0.013	0.659	**1061**	1000	0.052	0.744	**1054**	1000	0.076	0.817	**1054**	1000	0.015	0.829
1062	1000	0.004	0.422	**1062**	1000	0.005	0.000	**1055**	1000	0.008	0.724	**1055**	1000	0.026	0.710
1063	1000	3.356	1.000	**1063**	1000	0.001	0.086	**1057**	1000	0.017	0.842	**1057**	1000	0.036	0.724
1066	1000	0.019	0.708	**1066**	1000	0.015	0.829	**1058**	1000	0.018	0.788	**1058**	1000	0.011	0.696
1069	1000	3.356	1.000	**1069**	1000	0.009	0.544	**1065**	1000	0.005	0.765	**1065**	1000	0.008	0.765
1070	1000	9.438	0.957	**1070**	1000	0.460	0.794	**1067**	1000	0.058	0.734	**1067**	1000	0.009	0.117
1075	1000	0.007	0.765	**1075**	1000	0.013	0.158	**1068**	1000	0.007	0.541	**1068**	1000	0.014	0.574
1077	1000	0.005	0.765	**1077**	1000	0.052	0.878	**1071**	1000	0.016	0.827	**1071**	1000	0.013	0.823
1079	1000	3.356	1.000	**1079**	1000	3.356	1.000	**1072**	1000	0.013	0.648	**1072**	1000	0.004	0.550
1080	1000	0.005	0.531	**1080**	1000	0.008	0.765	**1076**	1000	3.356	1.000	**1076**	1000	0.013	0.650
1084	1000	0.005	0.531	**1084**	1000	0.008	0.368	**1048**	1000	0.095	0.000	**1048**	1000	0.009	0.712
Mean		**1.399**	**0.750**	**Mean**		**0.286**	**0.586**	**Mean**		**0.264**	**0.719**	**Mean**		**0.014**	**0.620**

Note. The parameter estimates from the best fits of the hyperbolic model to individual data from the $1000 condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Ext. Hyperbolic (Low NonAbstinent)					Ext. Hyperbolic (Low Abstinent)					Ext. Hyperbolic (High NonAbstinent)					Ext. Hyperbolic (High Abstinent)				
Parti-cipant	**A**	**k**	**s**	**R*2**	**Parti-cipant**	**A**	**k**	**s**	**R*2**	**Parti-cipant**	**A**	**k**	**s**	**R*2**	**Parti-cipant**	**A**	**k**	**s**	**R*2**
1047	1000	0.000	127.563	0.888	**1047**	1000	0.000	156.945	0.898	**1049**	1000	0.000	76.968	0.788	**1049**	1000	0.000	39.608	0.676
1059	1000	0.015	0.653	0.770	**1059**	1000	0.000	19.116	0.652	**1050**	1000	0.010	1.619	0.848	**1050**	1000	0.193	0.146	0.321
1060	1000	0.000	165.521	0.616	**1060**	1000	0.000	19.116	0.652	**1051**	1000	0.000	195.309	0.840	**1051**	1000	0.001	12.232	0.753
1061	1000	0.000	302.182	0.746	**1061**	1000	0.000	233.567	0.805	**1054**	1000	0.000	580.927	0.847	**1054**	1000	0.000	45.348	0.878
1062	1000	0.004	1.022	0.422	**1062**	1000	0.637	0.094	0.204	**1055**	1000	0.000	233.751	0.815	**1055**	1000	0.130	0.390	0.783
1063	1000	1.273	0.485	1.000	**1063**	1000	0.050	0.087	0.162	**1057**	1000	0.020	0.909	0.843	**1057**	1000	0.001	25.934	0.751
1066	1000	0.043	0.561	0.725	**1066**	1000	0.000	45.348	0.878	**1058**	1000	0.000	324.712	0.867	**1058**	1000	0.000	150.047	0.784
1069	1000	1.273	0.485	1.000	**1069**	1000	0.002	3.602	0.555	**1065**	1000	0.000	76.968	0.788	**1065**	1000	0.015	0.653	0.770
1070	1000	0.886	3.629	0.999	**1070**	1000	0.001	444.116	0.906	**1067**	1000	0.000	866.577	0.821	**1067**	1000	0.535	0.138	0.345
1075	1000	0.000	195.309	0.840	**1075**	1000	0.000	70.860	0.602	**1068**	1000	0.000	175.933	0.587	**1068**	1000	0.000	147.646	0.645
1077	1000	0.000	76.968	0.788	**1077**	1000	0.021	2.024	0.887	**1071**	1000	0.000	273.791	0.898	**1071**	1000	0.000	82.384	0.888
1079	1000	1.273	0.485	1.000	**1079**	1000	1.273	0.485	1.000	**1072**	1000	0.000	329.359	0.740	**1072**	1000	0.000	68.791	0.616
1080	1000	0.000	180.946	0.603	**1080**	1000	0.015	0.653	0.770	**1076**	1000	1.273	0.485	1.000	**1076**	1000	0.000	189.871	0.742
1084	1000	0.000	180.946	0.603	**1084**	1000	0.000	123.418	0.616	**1048**	1000	13.930	0.188	0.573	**1048**	1000	0.000	111.688	0.806
Mean		**0.340**	**88.340**	**0.786**	**Mean**		**0.143**	**79.959**	**0.685**	**Mean**		**1.088**	**224.107**	**0.804**	**Mean**		**0.063**	**62.491**	**0.697**

Note. The parameter estimates from the best fits of the extended hyperbolic model to individual data from the $1000 condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

$10,000 Condition

Exponential (Low NonAbstinent)				Exponential (Low Abstinent)				Exponential (High NonAbstinent)				Exponential (High Abstinent)			
Participant	**A**	**k**	**R*2**	**Participant**	**A**	**k**	**R*2**	**Participant**	**A**	**k**	**R*2**	**Participant**	**A**	**k**	**R*2**
1047	10000	0.006	0.840	**1047**	10000	0.009	0.893	**1049**	10000	1.768	1.000	**1049**	10000	2.303	0.000
1059	10000	1.768	1.000	**1059**	10000	1.768	1.000	**1050**	10000	0.002	0.655	**1050**	10000	1.768	1.000
1060	10000	1.768	1.000	**1060**	10000	1.768	1.000	**1051**	10000	0.004	0.788	**1051**	10000	0.004	0.788
1061	10000	0.036	0.794	**1061**	10000	0.026	0.900	**1054**	10000	0.004	0.617	**1054**	10000	0.006	0.840
1062	10000	0.007	0.463	**1062**	10000	0.005	0.616	**1055**	10000	0.001	0.069	**1055**	10000	1.768	1.000
1063	10000	1.768	1.000	**1063**	10000	1.768	1.000	**1057**	10000	0.021	0.856	**1057**	10000	0.107	0.936
1066	10000	0.004	0.617	**1066**	10000	0.006	0.826	**1058**	10000	0.004	0.429	**1058**	10000	0.016	0.924
1069	10000	1.768	1.000	**1069**	10000	0.002	0.655	**1065**	10000	0.011	0.798	**1065**	10000	1.768	1.000
1070	10000	0.278	0.896	**1070**	10000	0.042	0.791	**1067**	10000	0.007	0.465	**1067**	10000	1.768	1.000
1075	10000	1.768	1.000	**1075**	10000	0.004	0.617	**1068**	10000	0.008	0.769	**1068**	10000	0.019	0.692
1077	10000	1.768	1.000	**1077**	10000	1.768	1.000	**1071**	10000	0.008	0.889	**1071**	10000	0.005	0.471
1079	10000	1.768	1.000	**1079**	10000	1.768	1.000	**1072**	10000	0.006	0.840	**1072**	10000	0.004	0.788
1080	10000	0.009	0.762	**1080**	10000	0.006	0.840	**1076**	10000	0.010	0.742	**1076**	10000	0.010	0.750
1084	10000	0.009	0.755	**1084**	10000	0.006	0.547	**1048**	10000	0.002	0.655	**1048**	10000	0.009	0.760
Mean		**0.909**	**0.866**	**Mean**		**0.639**	**0.835**	**Mean**		**0.133**	**0.684**	**Mean**		**0.682**	**0.782**

Note. The parameter estimates from the best fits of the exponential model to individual data from the $10,000 condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Hyperbolic (Low,NonAbstinent)				Hyperbolic (Low Abstinent)				Hyperbolic (High NonAbstinent)				Hyperbolic (High Abstinent)			
Parti-cipant	**A**	**k**	**R*2**	**Parti-cipant**	**A**	**k**	**R*2**	**Parti-cipant**	**A**	**k**	**R*2**	**Parti-cipant**	**A**	**k**	**R*2**
1047	10000	0.007	0.765	**1047**	10000	0.012	0.836	**1049**	10000	1.856	1.000	**1049**	10000	7.782	0.000
1059	10000	1.856	1.000	**1059**	10000	1.856	1.000	**1050**	10000	0.002	0.609	**1050**	10000	1.856	1.000
1060	10000	1.856	1.000	**1060**	10000	1.856	1.000	**1051**	10000	0.005	0.765	**1051**	10000	0.005	0.765
1061	10000	0.051	0.737	**1061**	10000	0.038	0.828	**1054**	10000	0.004	0.550	**1054**	10000	0.007	0.765
1062	10000	0.013	0.639	**1062**	10000	0.007	0.606	**1055**	10000	0.001	0.086	**1055**	10000	1.856	1.000
1063	10000	1.856	1.000	**1063**	10000	1.856	1.000	**1057**	10000	0.030	0.844	**1057**	10000	0.179	0.947
1066	10000	0.004	0.550	**1066**	10000	0.008	0.739	**1058**	10000	0.005	0.388	**1058**	10000	0.025	0.883
1069	10000	1.856	1.000	**1069**	10000	0.002	0.609	**1065**	10000	0.017	0.842	**1065**	10000	1.856	1.000
1070	10000	0.465	0.786	**1070**	10000	0.063	0.703	**1067**	10000	0.010	0.506	**1067**	10000	1.856	1.000
1075	10000	1.856	1.000	**1075**	10000	0.004	0.550	**1068**	10000	0.010	0.700	**1068**	10000	0.029	0.629
1077	10000	1.856	1.000	**1077**	10000	1.856	1.000	**1071**	10000	0.011	0.853	**1071**	10000	0.007	0.504
1079	10000	1.856	1.000	**1079**	10000	1.856	1.000	**1072**	10000	0.007	0.765	**1072**	10000	0.005	0.765
1080	10000	0.012	0.670	**1080**	10000	0.007	0.765	**1076**	10000	0.013	0.651	**1076**	10000	0.013	0.658
1084	10000	0.012	0.673	**1084**	10000	0.007	0.474	**1048**	10000	0.002	0.609	**1048**	10000	0.012	0.672
Mean		**0.969**	**0.844**	**Mean**		**0.674**	**0.794**	**Mean**		**0.141**	**0.655**	**Mean**		**1.106**	**0.756**

Note. The parameter estimates from the best fits of the hyperbolic model to individual data from the $10,000 condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.

Ext. Hyperbolic (Low, NonAbstinent)					**Ext. Hyperbolic (Low Abstinent)**					**Ext. Hyperbolic (High, NonAbstinent)**					**Ext. Hyperbolic (High, Abstinent)**				
Parti-cipant	**A**	**k**	**s**	**R*2**	**Parti-cipant.**	**A**	**k**	**s**	**R*2**	**Parti-cipant**	**A**	**k**	**s**	**R*2**	**Parti-cipant**	**A**	**k**	**s**	**R*2**
1047	10000	0.000	103.953	0.840	**1047**	10000	0.000	86.027	0.892	**1049**	10000	5.307	0.485	1.000	**1049**	10000	100.000	0.419	0.000
1059	10000	5.307	0.485	1.000	**1059**	10000	5.307	0.485	1.000	**1050**	10000	0.000	81.437	0.654	**1050**	10000	5.307	0.485	1.000
1060	10000	5.307	0.485	1.000	**1060**	10000	5.307	0.485	1.000	**1051**	10000	0.000	23.993	0.787	**1051**	10000	0.000	10.758	0.787
1061	10000	0.000	79.320	0.794	**1061**	10000	0.000	83.503	0.900	**1054**	10000	0.000	90.810	0.616	**1054**	10000	0.000	111.434	0.840
1062	10000	0.075	0.331	0.732	**1062**	10000	0.001	3.963	0.617	**1055**	10000	0.050	0.087	0.162	**1055**	10000	5.307	0.485	1.000
1063	10000	5.307	0.485	1.000	**1063**	10000	5.307	0.485	1.000	**1057**	10000	0.008	2.937	0.861	**1057**	10000	0.093	1.579	0.953
1066	10000	0.000	90.810	0.616	**1066**	10000	0.000	137.387	0.825	**1058**	10000	0.000	73.356	0.428	**1058**	10000	0.000	36.384	0.923
1069	10000	5.307	0.485	1.000	**1069**	10000	0.000	54.157	0.654	**1065**	10000	0.020	0.909	0.843	**1065**	10000	5.307	0.485	1.000
1070	10000	0.000	1473.845	0.895	**1070**	10000	0.000	195.410	0.790	**1067**	10000	0.020	0.619	0.510	**1067**	10000	5.307	0.485	1.000
1075	10000	5.307	0.485	1.000	**1075**	10000	0.000	94.235	0.616	**1068**	10000	0.000	85.110	0.768	**1068**	10000	0.000	172.971	0.692
1077	10000	5.307	0.485	1.000	**1077**	10000	5.307	0.485	1.000	**1071**	10000	0.000	32.758	0.888	**1071**	10000	0.027	0.391	0.518
1079	10000	5.307	0.485	1.000	**1079**	10000	5.307	0.485	1.000	**1072**	10000	0.000	104.135	0.840	**1072**	10000	0.000	10.758	0.787
1080	10000	0.000	209.034	0.762	**1080**	10000	0.000	105.368	0.840	**1076**	10000	0.000	157.039	0.741	**1076**	10000	0.000	188.026	0.749
1084	10000	0.000	148.798	0.754	**1084**	10000	0.000	168.666	0.603	**1048**	10000	0.000	81.437	0.654	**1048**	10000	0.000	156.836	0.760
Mean		**2.659**	**150.677**	**0.885**	**Mean**		**1.896**	**66.510**	**0.838**	**Mean**		**0.386**	**52.508**	**0.697**	**Mean**		**8.668**	**49.393**	**0.786**

Note. The parameter estimates from the best fits of the extended hyperbolic model to individual data from the $10,000 condition. High = High caffeine group, Low = Low caffeine group. Those in grey did not meet the discounting criterion.