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The effects of caffeine on risky decision making

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THE EFFECTS OF CAFFEINE ON RISKY DECISION MAKING

by

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A THESIS PRESENTED TO THE DEPARTMENT OF PSYCHOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE BACHELOR OF ARTS WITH HONOURS DEGREE IN APPLIED PSYCHOLOGY

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Abstract

Caffeine is one of the most ubiquitous drugs in the world, and is often consumed for its cognitive enhancing properties. The current research investigated the influence of caffeine on two commonly used measures of risky decision making (the Iowa Gambling Task and the Balloon Analogue Risk Task). Findings indicated that caffeine improved performance on the IGT but not on the BART. However, inclusion of individual differences on decision making style and impulsivity generated regression models that explained a significant proportion of variance in performance on the IGT and BART. Multiple significant correlations existed among a variety of individual difference trait measures of decision-making style, impulsive tendencies and risk-taking behaviour. Results and implications are discussed in terms of two prominent decision-making theories as well as prior research, and further research directions are suggested that may help elucidate the apparently contradictory effects of caffeine on two distinct measures of risky decision making.

Keywords: decision-making, caffeine, stimulant, gambling, risk

The effects of caffeine on risky decision making

Caffeine is one of the most ubiquitous drugs in the Western world. The effects of caffeine on cognition have been widely studied, resulting in the knowledge that caffeine (in the form of tea, capsules and coffee) acts as a cognitive enhancer, improving alertness, speed of processing information, short term recall, and mood, as well as lessening feelings of fatigue (for review see Ruxton, 2008; Arab, Khan, and Lam, 2013). These effects exist even in habitual users, showing a lack of tolerance for positive cognitive and mood affects of the drug (Ruxton, 2008; Attwood, Higgs, & Terry, 2007; Nehlig, 2005). Researchers have further demonstrated a negative correlation between caffeine consumption and aging-related cognitive decline (Arab et al., 2013). While much research has elucidated the cognitive impacts of caffeine, very little research has investigated the impact of caffeine on performance in tasks that require the application of higher cognitive functioning, such as complex decision making scenarios.

Decision making is a complicated construct to study, with many different conceptualizations. The current research is grounded in two influential theories: Kahneman's System 1 System 2 theory and Damasio's Somatic Marker Hypothesis. Kahneman (2011) explains decision making as the result of two types of thinking titled "System 1" and "System 2". System 1 represents reflexive and automatic processes, and System 2 represents effortful and purposeful processes. System 1 is based more on emotion, and System 2 based on logical reasoning. Damasio and colleagues formulated the Somatic Marker Hypothesis, which explains decision making as critically reliant on the physiological arousal caused by emotion (Bechara, Damasio, Damasio, and Anderson, 1994). This means that individuals respond to gut feelings to avoid long and effortful thinking when making a quick decision (Killgore, Grugle & Balkin, 2012). In this hypothesis, emotion is necessary for decision making, as a lack of emotional integration (e.g. as a result of ventromedial prefrontal cortex damage) results in disadvantageous decision making (Bechara et al, 1994). Both of these theories have empirical support and have led to fruitful lines of research, but they generate opposing predictions in terms of whether logic or emotion is more important and adaptive in decision making.

The present study seeks to address the impact of caffeine on decision making performance, and explore whether individual differences are related to the effects of caffeine on decision making. To the best of our knowledge, the only research testing caffeine effects on decision making did so in the context of severe sleep deprivation (Killgore, Grugle, & Balkin, 2012; Killgore, Kamimori, & Balkin, 2011; Killgore, Lipizzi, Kamimori, & Balkin, 2007). Killgore et al. (2011) found that when individuals were sleep deprived, they were more likely to make risky decisions, and that caffeine administration prevented risky decision making in those individuals. Other studies confirmed that sleep deprivation increased risky decision making, but reported that stimulants including caffeine failed to reduce risky decision making (Killgore et al., 2012; Killgore et al., 2007).

The purpose of this study was to investigate the ways in which caffeine can influence the decisions made by college-aged students. Not only is this an understudied topic, but it has practical application for a wide segment of the population. This study provides a better understanding of the effects of caffeine, a widely consumed drug, on cognitive skills such as the ability to resist risk in the context of decision making. The objectives of this study are as follows: (1) to understand how caffeine impacts risky decision making, and (2) to gain insight into individual difference profiles in caffeine effects as defined by decision making style, impulsivity scores, and risky behavior tendencies, along with participant variables such as age, gender, regular caffeine consumption, and sleep deprivation.

We hypothesized that caffeine would decrease risky decision making. Specifically, we predicted that caffeine consumption would result in more optimal choices and higher gains on the Iowa Gambling Task (IGT) and the Balloon Analogue Risk Task (BART), both commonly used measures of risky decision making. The IGT and the BART are significantly correlated with measures of risky decision making tendencies (Bechara, Damasio, Tranel, & Damasio, 1997; Lejuez, Aklin, Zvolensky, & Pedulla, 2003, respectively) and impulsivity (Xu, Korczykowski, & Zhu, 2013). We anticipated that caffeine's effects on IGT and BART performance may be moderated by individual difference variables such as decision making style, impulsivity, risk tendencies, age, gender, habitual caffeine consumption and sleep deprivation.

Methods

Participants

Participants were 112 college students, of whom 107 had usable data (86 female), age 18-48 (*Median*=20). The data from five participants were excluded due to disruptions in data collection. Participants enrolled in applicable psychology classes received course credit, and all participants received a small amount of money (between $1.00 and $5.00 in Canadian currency) reflecting their choices on two financial games.

Procedure and Measures

This study used an experimental, between groups design to measure the impact of caffeine on impulsivity and risk propensity in the context of economic decision making. We tested the effects of caffeine as compared to placebo on two commonly used measures of impulsive and risky decision making: the Iowa Gambling Task (IGT; Bechara et al., 1994) and the Balloon Analogue Risk Task (BART; Lejuez et al., 2002). Participants were instructed to arrive at the research session having fasted for 1 hour prior to the study, as carbohydrates combined with caffeine can have inconsistent effects on cognition (Maridakis, O'Connor, & Tomporowski, 2009).

After participants voluntarily completed a consent form, they completed a computerized version of the Stroop task (Stroop, 1935) to induce cognitive depletion (Fairclough & Houston, 2004), with the aim of ensuring all participants would start with a similar amount of cognitive resources. All questionnaires and tasks were run from an open-source software called Psychology Experiment Building Language (PEBL; Mueller & Piper, 2014).

Using a double blind experimental procedure, participants were given a capsule to swallow according to their randomly assigned condition: either an experimental group (200mg caffeine, a commonly used dosage in caffeine experiments; Ruxton, 2008) or a control group (placebo, identical capsules with inert contents). Participants answered a series of questions and then were permitted to draw on a blank sheet of paper over the following 15 minutes, allowing time for the caffeine to take effect (Adan, Prat, Fabbri, & Sànchez-Turet, 2008). Participants reported basic demographic information, caffeine consumption, average hours of sleep per night, and hours of sleep the previous night, to investigate the impact of previous caffeine exposure and sleep deprivation on decision making (Killgore, Balkin, & Wesensten, 2006; Killgore et al., 2011; see appendix B).

Participants completed the General Decision Making Style survey (GDMS; Scott & Bruce, 1995), which included statements such as "when I make a decision, I trust my inner feelings and reactions" rated on a 5 point likert scale. The GDMS measures the relative fit of individuals into five decision making styles: rational, intuitive, dependent, avoidant, and spontaneous (see appendix C). Participants then completed the Abbreviated Barratt Impulsiveness Scale (ABIS; Coutlee, Politzer, Hoyle, & Huettel, 2014), which used statements like “I do things without thinking” rated on a 4 point likert scale to assess trait impulsivity (see appendix D). Subsequently, participants completed the Domain-Specific Risk-Taking (DOSPERT; Blais, & Weber, 2006) scale to assess risk propensity and risk taking attitudes in five domains: ethical, financial, health/safety, social, and recreational. The DOSPERT used statements such as “revealing a friend’s secret to someone else” rated on a 7 point likert scale (see appendix E). Previous research has found that the GDMS R and I profiles are both positively correlated to various measures of emotional intelligence (Fabio & Kenny, 2012).

As a manipulation check for the subjective effects of caffeine, participants completed the Stanford Sleepiness Scale (SSS; see appendix F), a subjective measure of sleepiness that is sensitive to the effects of caffeine (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973; Lieberman, Wurtman, Emde, & Coviella, 1987).

The IGT was completed on computers (“Iowa” task included in PEBL battery; see appendix G for a screenshot). The goal of the IGT is for participants to gain money by discriminating between “bad” decks of cards (overall loss, high initial gains) and “good” decks (overall gain, modest gains and losses). Participants were instructed to try to maximize their winnings, and told they would receive a small proportion of their winnings on the IGT in cash. Higher gains on this task are related to risk aversion and lower impulsivity (Burdick, Roy, Raver, 2013; Xu et al., 2013; Buelow, & Suhrb, 2013). Participants completed 100 card choices.

The BART was also completed on computers to assess risk-taking behaviour (Lejuez et al., 2002; “BART” task included in PEBL battery; see appendix H for a screenshot). In this exercise participants gained money each time they clicked to fill a virtual balloon with air, but lost all of the money if the balloon popped. The exact point at which the balloon pops is random, but it becomes more probable with each click. Again, participants were instructed to try to maximize their winnings, and told they would receive a small proportion of their winnings on the BART in cash. Risky decision making is associated with low performance on the BART. Participants completed 90 balloons.

The IGT and BART were counter-balanced to prevent any order effects. Participants received 0.5% of their winnings on the IGT and BART as compensation (with a minimum of $1.00 and a maximum of $5.00). After completing all of the surveys and tasks participants were debriefed and thanked. All procedures were approved by the Douglas College Research Ethics Board.

Results

We measured outcomes on the IGT using two variables: total winnings and good deck choices minus bad deck choices (common analysis techniques; Turnbull, Evans, Bunce, Carzolio, & O'Connor, 2005). For the BART, we measured outcomes using four variables: total number of pumps, adjusted pumps (average number of pumps per trial when the balloon did not explode), number of balloon explosions, and winnings (all common analysis techniques; Lejuez et al., 2002; Xu et al., 2013; DeMartini et al., 2014; Killgore et al., 2011).

We also analyzed IGT outcomes in a novel way. Based on a modified version of the IGT that presents equal gain-loss frequencies of each deck, Chiu and Lin (2007) posit that it is gain-loss frequency, not overall gain, that influences participants' decisions on the IGT. They state that decks B and D are high frequency gain decks, whereas decks A and C are high frequency loss decks (relative to decks B and D). Thus, we calculated an IGT risk aversion score by subtracting the number of selections from the high frequency loss decks from the number of selections from high frequency gain decks (BD-AC).

To test the prediction that the caffeine group would perform better on the IGT and BART than the placebo group, separate one-tailed independent t-tests (caffeine vs. placebo) were performed on IGT and BART outcomes. Results indicated that relative to placebo, caffeine resulted in better performance on the IGT, both in terms of greater winnings (t(105)=1.67, p=0.049, Cohen’s d=0.32; Figure 1) and more advantageous deck choices (t(105)=1.69, p=0.047, Cohen’s d=0.33; Figure 2). However, relative to placebo, caffeine did not significantly impact BART pumps (t(105)=-0.22, p=0.41), adjusted BART pumps (t(105)=-0.26, p=0.40), BART explosions (t(105)=0.01, p=0.49), or BART winnings (t(105)=-0.13, p=0.45). Analysis of the SSS yielded no significant differences in subjective levels of behavioural arousal between the caffeine and placebo groups (t(103)=-0.26, p=0.40).

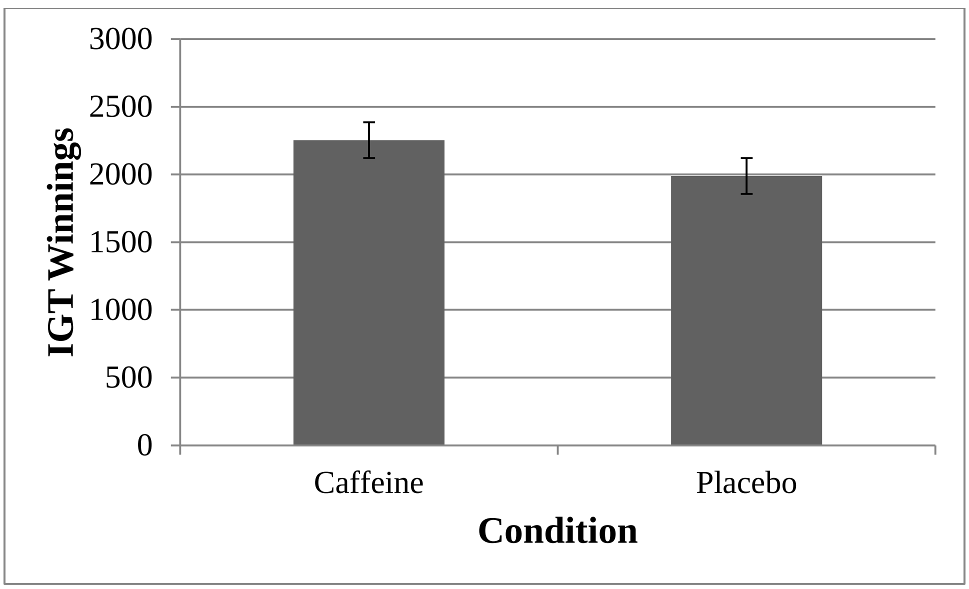

Figure 1. Mean IGT winnings by condition (error bars indicate ±SEM; p = 0.049).

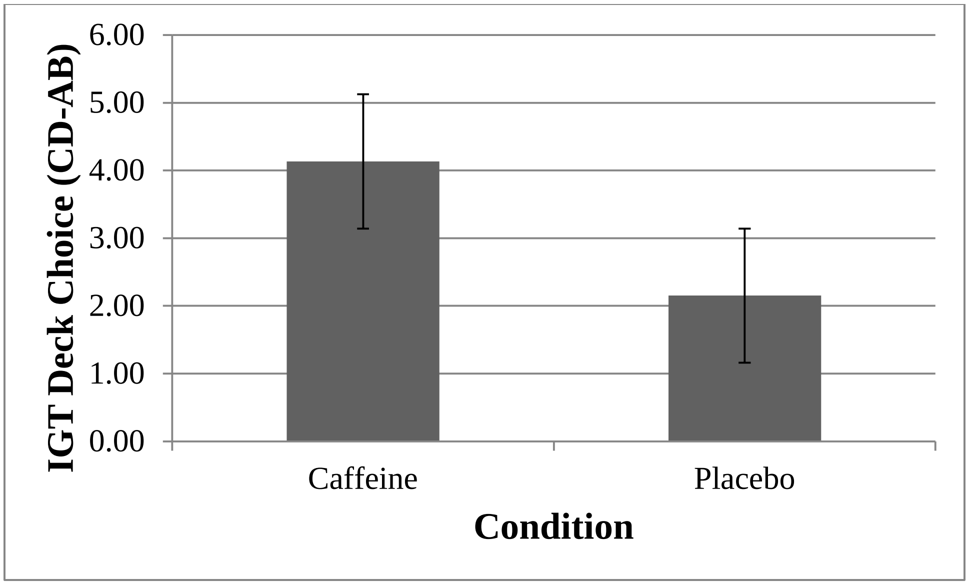

Figure 2. Mean IGT deck choices by condition (error bars indicate ±SEM; p=0.047)

Analysis of gender revealed significant differences on only IGT winnings, in that males won significantly more than females (Figure 3). We analyzed if deck choice differed by gender, as previous research has found that males choose more from advantageous deck choices than females (see van den Bos et al., 2013 for overview), but found non-significant results (t_{105}=0.65, p=0.52). Further analysis of gender illustrated that females were significantly less risky than males, both in general (t(105)=-1.98, p=0.025) and financially (t(105)=-1.67, p=0.049) as measured by the DOSPERT. Also, unsurprisingly, most of our participants scored quite high on the social riskiness scale of the DOSPERT (M=28, SD=5.5), probably because many of the questions may not seem particularly risky to college aged adults.

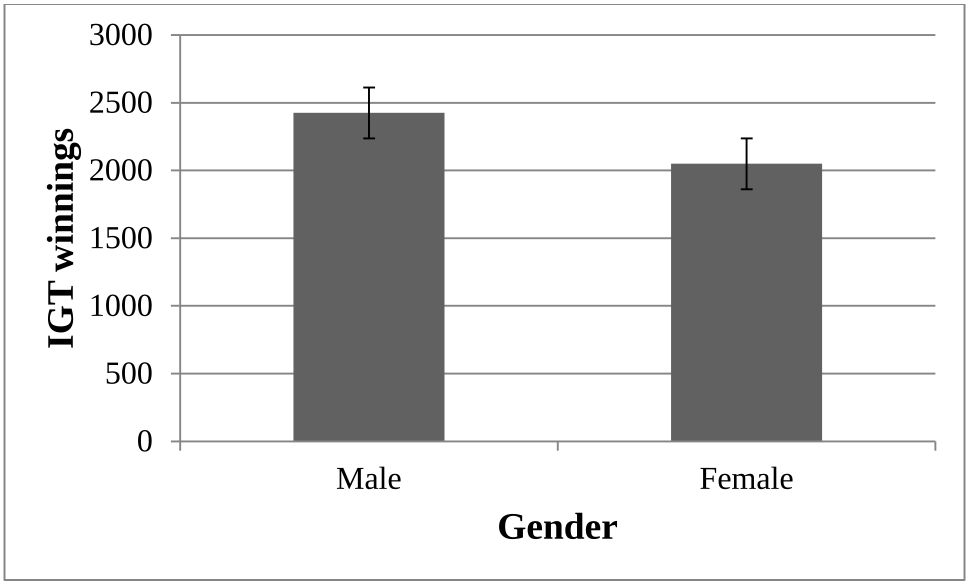

Figure 3. Mean differences on IGT winnings for males and females, regardless of experimental condition (error bars indicate ±SEM; p=0.03).

Analysis of task order revealed that participants who completed the BART first made significantly more advantageous deck choices on the IGT than participants who completed the IGT first (t(105)=2.95, p=0.002; see Figure 4). No other significant order effects were found. To address the possibility that caffeine had not reached full effect when participants completed the IGT and BART (as the SSS results suggest), further analyses of the IGT outcomes included task order as a possible moderator of caffeine effects. We completed a factorial ANOVA on IGT winnings including three factors: caffeine (two levels: caffeine, placebo), gender (two levels: male, female), and order (two levels: IGT first or BART first). This analysis revealed a significant caffeine x task order interaction (F(1,99)=4.23, p=0.042). A t-test comparing caffeine vs. placebo effects on IGT winnings for only those participants who completed the BART first was statistically significant (t(49)=2.51, p=0.008).

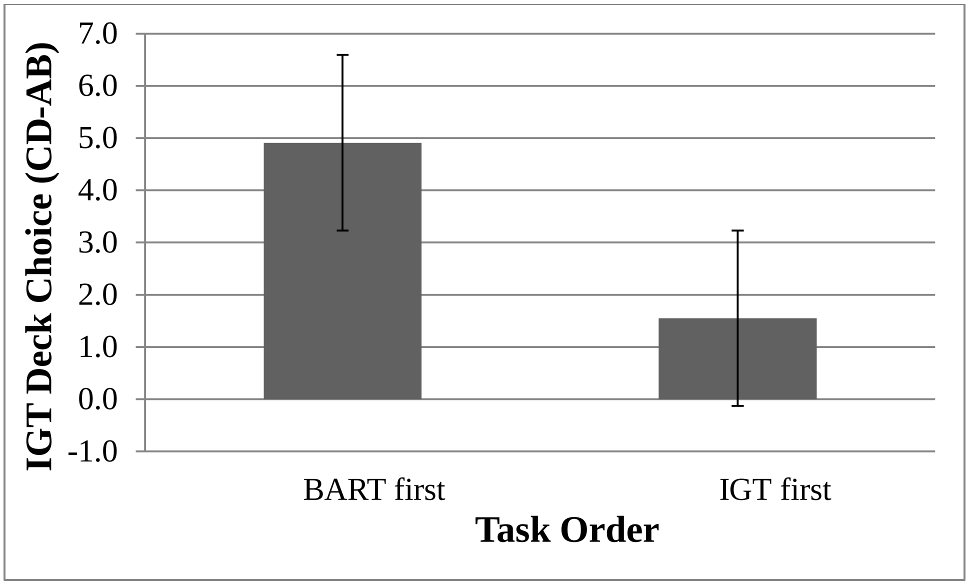

Figure 4. Mean differences in IGT deck choice by task order (error bars indicate ±SEM; p=0.002).

On the IGT, deck choice is often analyzed by trial block, given that the task involves learning about the gains and losses that result from each deck choice. Therefore we conducted a mixed model ANOVA with trial block as the within-subjects factor and caffeine (two levels: caffeine, placebo) and order (two levels: IGT first or BART first) as between-subject factors. The caffeine x order x trial block interaction was statistically significant (F(5,412)=2.88, p=0.014; see Figure 5), indicating that the pattern of learning was affected by both caffeine and task order.

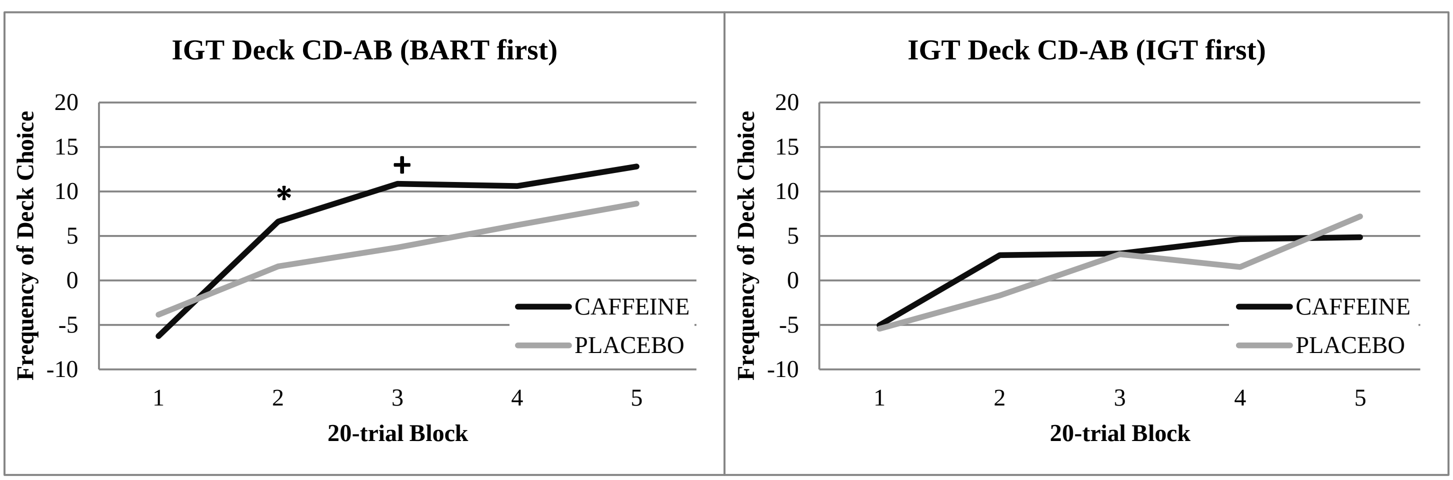

Figure 5. Advantageous deck choice on the IGT by caffeine and task order. *p<0.05 for caffeine vs. placebo; +p<0.05 for caffeine x order interaction.

In order to investigate individual differences in the effects of caffeine on decision making, best-fit linear regression models were constructed to identify the variables that explained a significant amount of variance. Separate regression analyses were completed for each dependent variable (IGT winnings, IGT deck choice, BART pumps, adjusted BART pumps, BART explosions, and BART winnings) with caffeine (two levels: caffeine, placebo), gender (two levels: male, female), and order (two levels: IGT first or BART first) as fixed factors and continuous individual difference variables as covariates (GDMS, ABIS, DOSPERT, sleep on previous night, average sleep, habitual caffeine consumption, and age). We included two way interactions among fixed factors given the previously observed order x condition interaction. See Table 2 for variables included in the models, significance, and effect size. Figures 6-10 depict the regression coefficients (β values) for each of the factors and covariates within each of the significant models.

Table 1

Linear Regression Best Fit Models for Dependent Variables

Dependent Variable	Variables in Best Fit Model	R^2
IGT winnings	GDMS Avoidant, ABIS Non-Planning, Condition x Task Order, Task Order x Gender *	0.16
IGT deck choice	DOSPERT Ethical, GDMS Avoidant, Condition x Task Order, Task Order x Gender **	0.19
BART winnings	GDMS Rational, GDMS Intuitive, Condition x Task Order, Task Order x Gender *	0.21

BART pumps	GDMS Intuitive, ABIS Motor, Condition x Task Order, Task Order x Gender **	0.21
Adjusted BART pumps	GDMS Intuitive, ABIS Motor, Condition x Task Order, Task Order x Gender *	0.157
BART explosions	GDMS Dependent, Hours sleep last night, Task Order x Gender	0.078

* $p < 0.05$ ** $p < 0.01$

It is important to acknowledge that the measurement of daily caffeine intake included in this study was extrapolated indirectly from questions about serving number and size (see Appendix B for questions).

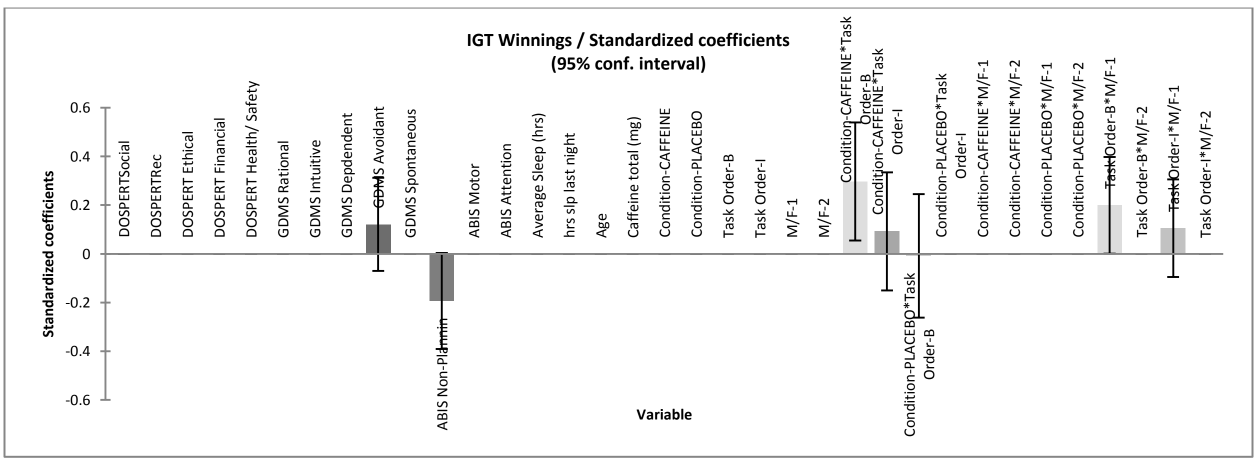

Figure 6. Standardized coefficients (β values) for IGT winnings best fit model. Where confidence intervals do not include 0, the coefficient for that variable was significant as a predictor within the model.

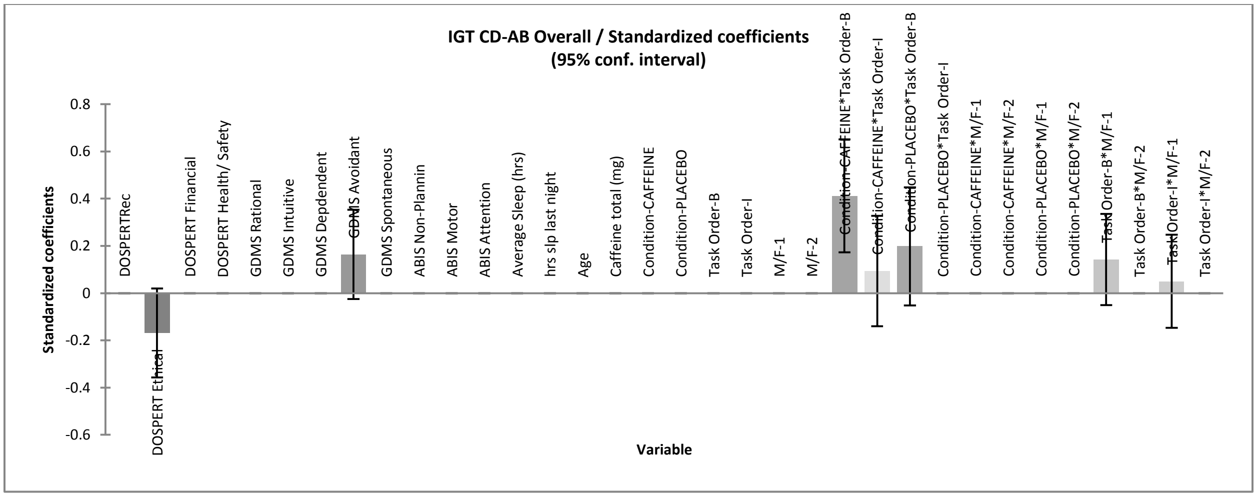

Figure 7. Standardized coefficients (β values) for IGT deck choice best fit model. Where confidence intervals do not include 0, the coefficient for that variable was significant as a predictor within the model.

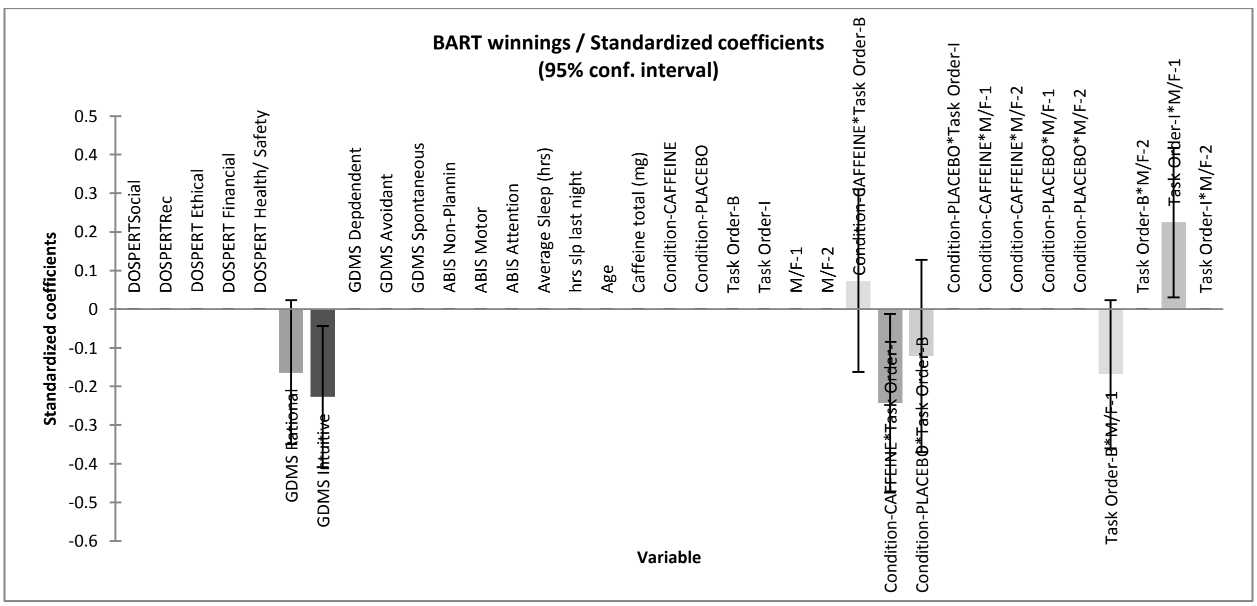

Figure 8. Standardized coefficients (β values) for the BART winnings model. Where confidence intervals do not include 0, the coefficient for that variable was significant as a predictor within the model.

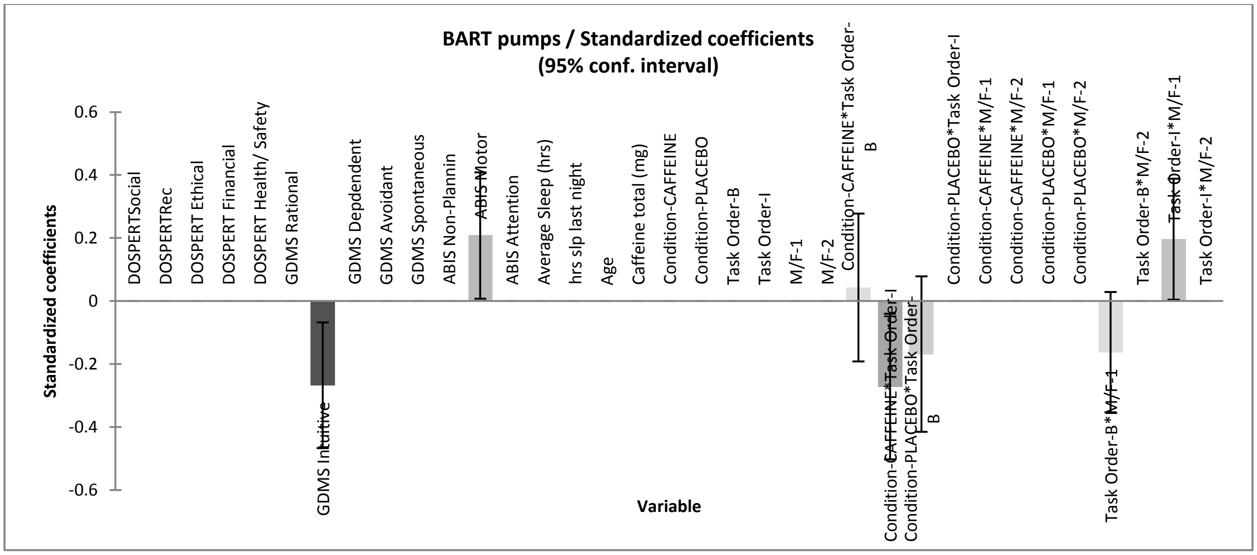

Figure 9. Standardized coefficients (β values) for the adjusted BART pumps model. Where confidence intervals do not include 0, the coefficient for that variable was significant as a predictor within the model.

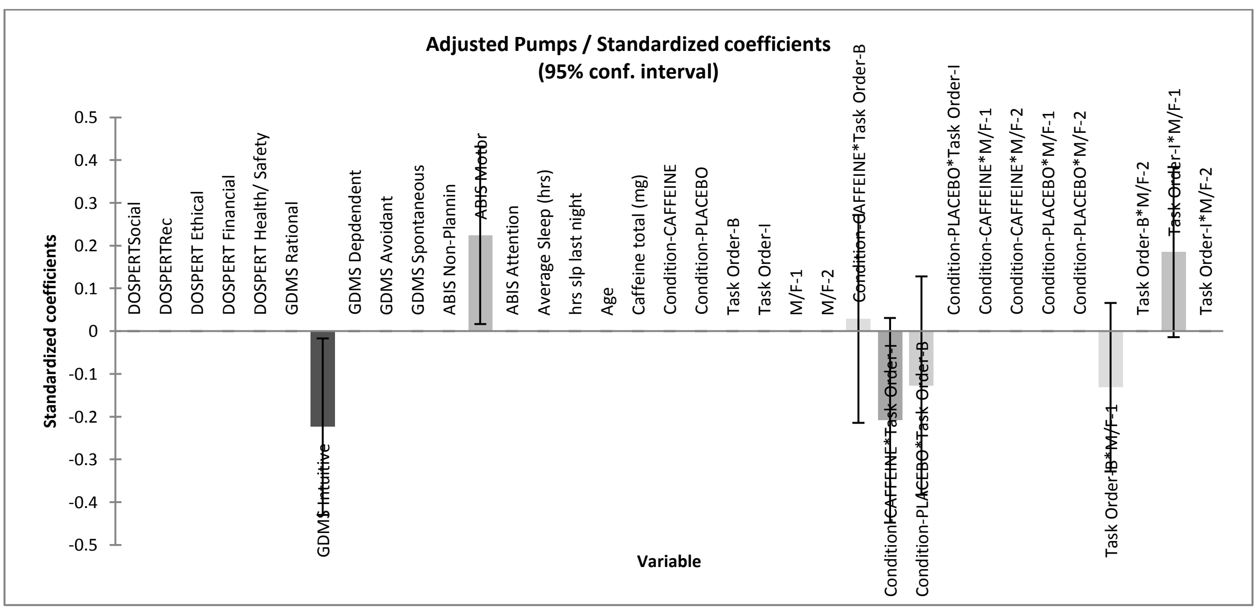

Figure 10 Standardized coefficients (β values) for the adjusted BART pumps model. Where confidence intervals do not include 0, the coefficient for that variable was significant as a predictor within the model.

Pairwise correlations were calculated for all dependent variables and individual difference variables. Multiple significant correlations were found, as summarized in Table 2.

Table 2.

Pearson's r Correlation Matrix

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1. IGT RT	**1**																									
2. BART RT	**0.343**	**1**																								
3. IGT Winnings	**-0.191**	-0.094	**1**																							
4. IGT CD-AB	**-0.201**	**-0.171**	**0.771**	**1**																						
5. IGT BD-AC	-0.083	0.034	0.006	-0.062	**1**																					
6. BART winnings	-0.071	**-0.418**	**0.163**	0.145	0.031	**1**																				
7. BART expl	-0.053	-0.137	0.026	**0.218**	-0.004	-0.013	**1**																			
8. BART pumps	0.020	**-0.427**	0.082	0.057	0.005	**0.938**	-0.046	**1**																		
9. BART adj pumps	0.124	**-0.370**	-0.011	-0.057	-0.029	**0.727**	-0.100	**0.911**	**1**																	
10. DOSPERT S	-0.130	-0.014	0.079	0.072	**-0.242**	0.022	0.008	0.023	0.004	**1**																
11. DOSPERT R	**-0.266**	**-0.258**	-0.055	-0.024	0.035	0.075	-0.014	0.084	0.057	**0.222**	**1**															
12. DOSPERT E	-0.063	-0.060	0.011	-0.061	-0.039	0.058	-0.006	0.077	0.074	**0.279**	**0.166**	**1**														
13. DOSPERT F	-0.134	-0.041	0.127	0.088	-0.046	0.126	-0.073	0.146	0.140	**0.206**	**0.323**	**0.307**	**1**													
14. DOSPERT H/S	-0.108	-0.017	0.094	0.037	-0.070	0.025	-0.096	0.045	0.021	**0.421**	**0.440**	**0.507**	**0.214**	**1**												
15. GDMS R	-0.073	0.017	0.097	0.024	**-0.258**	-0.110	0.086	-0.090	-0.031	**0.175**	0.049	-0.134	0.028	-0.030	**1**											
16. GDMS I	-0.030	0.030	-0.136	-0.075	0.137	**-0.169**	0.029	-0.146	-0.100	0.104	0.114	0.128	-0.043	**0.225**	**-0.194**	**1**										
17. GDMS D	0.120	0.109	-0.041	-0.046	0.101	0.023	0.106	0.041	0.091	-0.026	-0.046	0.064	-0.040	0.078	0.129	0.085	**1**									
18. GDMS A	0.079	-0.058	0.066	0.136	-0.091	0.129	0.058	0.124	0.094	-0.044	0.123	**0.278**	0.147	**0.239**	**-0.161**	**0.169**	0.118	**1**								
19. GDMS S	-0.049	-0.068	-0.075	-0.042	0.022	-0.015	0.004	0.023	0.038	0.068	**0.241**	**0.458**	**0.427**	**0.355**	**-0.235**	**0.459**	-0.027	**0.345**	**1**							
20. ABIS NP	0.004	0.082	**-0.164**	-0.078	0.085	-0.040	-0.038	-0.026	-0.025	-0.082	0.082	**0.201**	0.082	**0.190**	**-0.564**	0.114	0.045	**0.237**	**0.214**	**1**						
21. ABIS M	-0.109	-0.113	-0.053	-0.081	0.094	0.035	0.007	0.098	0.136	0.082	0.089	**0.355**	**0.268**	**0.359**	**-0.238**	**0.447**	-0.052	**0.307**	**0.628**	**0.217**	**1**					
22. ABIS A	-0.012	-0.042	-0.002	0.044	-0.078	-0.001	-0.089	0.007	0.030	-0.141	0.008	0.116	0.134	0.148	**-0.318**	**0.206**	0.135	**0.249**	**0.413**	**0.358**	**0.392**	**1**				
23. Ave Sleep (hrs)	-0.108	-0.028	0.054	-0.005	0.029	-0.048	-0.131	-0.075	-0.089	0.001	-0.074	-0.028	-0.057	-0.054	-0.036	**-0.207**	-0.139	-0.150	**-0.174**	0.004	-0.157	-0.053	**1**			
24. Sleep last night (hr:	0.043	**-0.199**	-0.001	-0.064	0.056	0.026	-0.147	0.006	-0.012	0.146	0.033	0.076	-0.091	**0.164**	-0.041	-0.040	**0.191**	-0.078	**-0.163**	0.123	-0.122	-0.037	**0.397**	**1**		
25. Age	**0.226**	0.096	0.026	-0.018	0.022	-0.038	0.125	-0.055	-0.070	**0.175**	-0.064	-0.037	-0.008	-0.053	0.154	-0.029	-0.060	-0.111	**-0.195**	-0.136	**-0.219**	**-0.218**	-0.028	-0.013	**1**	
26. Caffeine (mg)	**0.245**	-0.073	-0.082	0.035	**-0.172**	0.123	0.050	**0.203**	**0.199**	**0.205**	0.075	0.124	0.087	**0.299**	0.008	0.043	-0.082	0.126	0.094	-0.092	0.066	-0.085	**-0.164**	0.017	**0.213**	**1**

Bolded values are different from 0 with a significance level alpha=0.05 for a one-tailed correlation, and bolded and underlined values are different from 0 with a significance level alpha=0.05 for a two-tailed correlation.

Discussion

Caffeine Effects

Our hypothesis was supported in that those participants receiving caffeine won significantly more money on the IGT and made significantly more advantageous deck choices on the IGT when compared to placebo. These results indicate that caffeine consumption can improve outcomes in the context of risky or impulsive decision making tasks.

Those who completed the BART first chose significantly more advantageous decks on the IGT compared to participants who completed the IGT first. This may be because it took caffeine longer to reach its full effect: although recent research indicates that the perceived effects of caffeine are felt as little as 10 minutes after ingestion (Adan et al., 2008), our findings may indicate that maximal effects are not felt until later. This may explain why a condition by task order interaction was present in all significant regression models. Further research might leave a longer time for caffeine to reach maximal effect. However, this effect was unpredicted, and is unreported in other studies using both tasks: order effects were not explicitly mentioned (Xu et al., 2013), not analyzed (M. Buelow, personal communication, July 24, 2015), or authors did not mention counterbalancing or order effects (Brown et al., 2015; Upton, Bishara, Ahn, & Stout, 2011; Bishara et al., 2009), leaving the possibility of similar results hidden in the data.

Participants who received caffeine reported no greater levels of subjective behavioural arousal based on the SSS. This is likely because caffeine took longer than the allotted delay period to reach efficacy: those participants who completed the IGT second showed a much more substantial caffeine effect as measured by IGT winnings and pattern of deck choice over time. Contrary to our hypothesis, caffeine did not improve performance on the BART relative to placebo. The differential impact of caffeine on IGT and BART outcomes merits further discussion.

Our study is not the only to have found caffeine impacting the IGT and the BART differently. Previous research indicates that extremely sleep deprived participants have improved performance on the BART after caffeine ingestion relative to placebo (Killgore et al., 2011), but no such effect has been noted in sleep deprived individuals on the IGT (Killgore et al., 2007; Killgore et al., 2012). Our results are the inverse of these findings, in that under normative conditions, individuals perform better on the IGT after caffeine application, while BART performance remains unaffected by caffeine. As both tasks are thought to measure real-life risk-taking (Bechara et al., 1994, Lejuez et al., 2002), it is unexpected that caffeine impacts them differently, even inversely, in different contexts.

Caffeine improves many aspects of cognitive and executive functioning (such as working memory or attention; see Nehlig, 2010 for review), so it is possible that one task uses executive function and the other does not. However, research has demonstrated both tasks use the dorsal lateral prefrontal cortex, an area involved in executive functioning (Gansler, Jerram, Vannorsdall, & Schretlen, 2011; Rao, Korczykowski, Pluta, Hoang, & Detre, 2008; Li, Lu, D'Argembeau, Ng, & Bechara, 2010). Furthermore, both IGT winnings and CD-AB deck choice were significantly negatively correlated with IGT reaction time, indicating that an improvement in reaction time (common after caffeine consumption; see Nehlig, 2010) is not responsible for increased winnings or beneficial deck selections on the IGT.

Another possible explanation is that caffeine improves learning, and only the IGT requires learning. According to previous studies, caffeine improves only incidental learning (Nehlig, 2010). Research indicates that the IGT is an incidental learning task – when questioned part-way through the task, participants are unable to explicitly explain their deck choices (Bechara et al., 1997). Many subsequent studies substantiate the view that the IGT is a learning task (Aklin et al., 2005; Carter, & Pasqualini, 2004; Buelow & Suhr, 2009; Turnbull et al., 2005). The same is not true for the BART. In fact, some authors specifically argue that the IGT requires learning, whereas the BART does not (Aklin et al., 2005).

An alternative explanation is that caffeine assists with decision making in the context of risk. In particular, the IGT has been studied as a decision making task (e.g. Li et al., 2009). Other studies refer to both the IGT and the BART as real-life risky decision making measures (e.g. Buelow & Blaine, 2015), and indeed, poor performance on either task is correlated with a series of risky behaviours. For example, poor performance on the IGT is correlated with real-life instances of impulsivity and risk propensity, such as the incurring of unsecured debt (Ottaviani, & Vandone, 2011), social dysfunction in drug dependent individuals (Cunha, Bechara, de Andrade, & Nicastri, 2011), and psychopathy in incarcerated individuals (Beszterczey, Nestor, Shirai, & Harding, 2013). Similarly, poor performance on the BART is associated with psychopathy (Hunt, Hopko, Bare, Lejuez, & Robinson, 2005), smoking, drug use, gambling, unsafe sex, stealing, carrying weapons, fighting, and infrequent seatbelt use (Lejuez, Aklin, Zvolensky, & Pedulla, 2003; Lejuez et al., 2002). Thus, it would appear that both tasks measure decision making tendencies that can result in risky behaviours. This furthers the question of why caffeine improved decision making on one task but not the other. Recent research has indicated that the BART and IGT measure two different types of decision making, with authors concluding that more research is necessary (Buelow & Blaine, 2015). Our data are consistent with this viewpoint: both tasks require complex decision making, and as caffeine impacts them differently, these tasks must be measuring different aspects of decision making. The distinct constructs measured by the IGT and BART require further discussion.

IGT and BART Constructs

The BART was originally created to measure risk taking (Lejuez et al., 2002), and has since be utilized as a measurement of psychopathy and substance abuse (Hunt, Hopko, Bare, Lejuez, & Robinson, 2005; Hopko et al., 2006). The IGT was originally created to detect specific impairments in individuals with ventromedial prefrontal cortex damage (VMPFC; Bechara et al., 1994), and has since been used in typical populations to measure impulsivity and risk, in that certain individuals make risky decisions on the IGT (i.e., continuing to select from the bad decks even though they know the risks; Buelow, & Suhrb, 2013). The differential impact of caffeine suggests that these tasks do not measure the same construct. However, we did find some correlations between outcomes on both variables, indicating some similarity (see table 2). Overall, it seems likely that some elements of the constructs the IGT and BART measure are shared, but that differences still exist.

Many studies have investigated the validity of the IGT and the BART (see Buelow & Suhr, 2009 and Lejuez, Aklin, Zvolensky, & Pedulla, 2003, respectively, for example), however, the current analysis maintains a narrowed focus, using Kahneman's and Damasio's theories to ground performance on both tasks.

Studies have indicated a connection between emotional intelligence and IGT performance (Turnbull et al., 2005; Webb, DelDonno, & Killgore, 2014), and indeed, initial research by Damasio indicates the importance of emotional intelligence (Bechara et al., 1994). Authors argue that people who are adept at identifying subjective emotional changes may use these gut-feelings to inform decision making and therefore have good performance on the IGT (Webb et al., 2014).

Emotional intelligence is a construct that is closely associated with the “intuitive” GDMS profile or System 1 thinking (Demaree, Burns, & DeDonno, 2010). Other research has identified IGT performance as correlated with IQ (Webb et al., 2014), something associated more with the “rational” GDMS profile or System 2 thinking, whereas some research has found no correlation (Toplak, Sorge, Benoit, West, & Stanovich, 2010). However, GDMS intuitive and rational were not included in the best fit linear regression models for IGT outcomes, and not correlated with IGT performance; thus, our findings do not support the claim that emotional intelligence or IQ help with IGT performance, to the extent that the GDMS measures these constructs. Indeed, many studies have questioned whether the IGT really tests emotional decision making (for example, Guillaume et al., 2009).

Similar to the IGT literature, research on the BART is mixed regarding the relative importance of cognitive and emotional intelligence, or rational and intuitive thought, or System 2 and System 1 thinking. Some researchers found that number of inflations per trial on the BART was significantly positively correlated with IQ (Bogg, Fukunaga, Finn, & Brown, 2012). Other research found that IQ was not independently related to BART outcomes, but was a factor in a hierarchical regression model to explain risky behaviour in delinquents (Lejuez et al., 2002). However, some researchers found no correlation at all between BART outcomes and measures of executive function and intelligence (Hanson, Thayer, & Tapert, 2014). Little research has investigated emotional intelligence, System 1, or intuitive thought and BART outcomes; however, Hunt et al. (2005) found that emotional detachment did not on its own significantly impact BART performance, but was included in a significant regression model for BART performance, indicating that a lack of emotions somehow influences BART outcomes. Both the BART and IGT appear to measure similar constructs that are influenced to varying extents by emotional intelligence and cognitive intelligence, intuition and rationality, or System 1 and System 2 thinking.

Individual Differences

As one of the aims of this study was to investigate individual differences in reaction to caffeine on IGT and BART performance, best fit linear regressions were performed on all of the dependent variables.

Gender. In the current study males won significantly more than females on the IGT, regardless of caffeine condition. Furthermore, of the significant regression models, all included task order by gender interactions (see Table 1). This is consistent with research finding gender as an important factor in performance on the IGT (van den Bos, Homberg, & de Visser, 2013), and might be partially explained by research indicating that caffeine's effects are felt faster in males than females (Adan et al., 2008). Other studies have established that males typically choose more from advantageous decks on the IGT than females (see van den Bos et al., 2013 for overview), though this was not reflected in our findings. However, some research indicates no gender differences on the IGT (Bechara et al., 1994). While success on the IGT has been understood as becoming risk averse as the task progresses (Schmitt, Brinkley & Newman, 1999), previous research indicates that being overly risk averse is not helpful for outcomes on the IGT (Wang et al., 2012). Thus, the higher risk aversion in our females may account for the gender difference in performance on the IGT. Previous research indicated sex differences in BART performance (Lejuez, et al., 2002; Cazzell, Li, Lin, Patel, & Liu, 2012), but these findings were not replicated in our study. Overall, our sample did not include enough males to support strong conclusions about gender differences either directly or as a mediator of caffeine effects.

Habitual caffeine use. Habitual caffeine consumption is significantly positively correlated with both BART pumps and adjusted pumps, and both BART pumps and adjusted pumps are significantly positively correlated with BART winnings (indicating that higher pumps are associated with greater winnings). Together, these findings suggest that habitual caffeine consumption is related to optimized performance on the BART. Furthermore, high habitual caffeine consumption was associated with low loss aversion scores (BD-AC deck choice). The reasons behind this relationship are unclear. This finding may indicate that habitual caffeine consumption decreases loss aversion and allows individuals to perform in a more optimal manner in situations where the best choice is an option that confers low probability of substantial loss (i.e., deck D). On the other hand, it is also possible that those who consume lots of caffeine do so in order to compensate for risky tendencies. While our study was not designed to directly examine habitual caffeine use, our findings suggest that certain individuals may use caffeine in part to optimize their decision making in the realm of risk and/or impulsivity.

The expected significant positive correlation between DOSPERT health and safety and habitual caffeine consumption is explained by previous research indicating that health conscious individuals are less likely to consume caffeine due to a belief that it is unhealthy (Shlonsky, Klatsky, & Armstrong, 2003). The significant positive correlation between DOSPERT social and habitual caffeine consumption, indicating that individuals who are more risky socially are more likely to consume caffeine, may have occurred because the vast majority of our participants scored high on the social riskiness scale of the DOSPERT.

Age. The correlation between habitual caffeine consumption and age was expected, as it mirrors previous population wide research (Statistics Canada, 2008), in that women increase their coffee consumption between the ages of 19 and 30 – as women were the majority of our sample this correlation is unsurprising.

Some research indicates that as individuals age they rely less on rational thinking (Sladek, Bond, & Phillips, 2010); however, we found significant negative correlations between age and scores on GDMS spontaneous, ABIS motor, and ABIS attention scales, indicating that older individuals are less spontaneous and impulsive. This anticipated finding is contrary to the aforementioned research, but consistent with findings that younger individuals tend to be impulsive (Krawczyk, 2002; Johnston, O'Malley, Bachman, & Schulenberg, 2005). Some authors speculate that young adults and adolescents often make suboptimal decisions due to underdeveloped prefrontal cortices (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999; Johnston et al., 2005), which is also congruent with our finding that age is significantly negatively correlated with spontaneity and impulsivity.

GDMS. BART performance was not significantly impacted by caffeine application alone, but can be explained by individual difference measures. Of the significant regressions, all contained GDMS Intuitive as an explanatory factor. GDMS Intuitive is significantly negatively correlated with BART winnings, indicating that lower intuitive decision making style is associated with higher gains. Furthermore, number of balloon explosions is positively correlated with GDMS intuitive, suggesting that high intuitive decision making styles are associated with more pops, and thus poorer outcomes. Both BART pumps and adjusted pumps are negatively correlated to the GDMS Intuitive profile, and BART pumps and adjusted pumps are significantly positively correlated to BART winnings; in tandem, these results suggest that GDMS Intuitive is related to poorer outcomes on the BART. Lastly, GDMS Rational is included in the model to explain BART winnings, and is also negatively correlated with BART winnings, indicating that a more rational decision making style is associated with lower winnings. Thus, it would appear that neither rational nor intuitive decision making styles are helpful for optimal BART performance.

Interestingly, BD-AC deck choice was significantly negatively correlated with GDMS Rational scores, indicating that those who scored high in the rational domain of the GDMS were less risk averse. This is interesting in light of previous research showing that risk aversion does not necessarily result in optimal decision-making outcomes (Wang, Krajbich, Adolphs, & Tsuchiya, 2012). Nevertheless, GDMS rational scores were not associated with successful performance on the IGT or BART in the present study.

ABIS. IGT winnings were significantly negatively correlated with ABIS non-planning, indicating that individuals who are low on this scale won more on the IGT. High non-planning ABIS scores indicate a lack of self control (ability to plan and think carefully before acting) and dislike of cognitive complexity (e.g. challenging mental tasks; Patton, Standford, & Barratt, 1995). This is consistent with other research, as impulsive individuals often score low on the IGT (Buelow, & Suhrb, 2013; Burdick et al., 2013). Furthermore, ABIS Motor is included in the regression model for both BART pumps and adjusted BART pumps. For both of these dependent variables, ABIS motor is positively correlated, suggesting that physical tendency toward impulsivity is related to higher number of responses on this measure. This makes sense, as motor impulsivity is described as acting without thinking (Coutlee et al., 2014).

Of interest, all three ABIS subscales were significantly negatively correlated to the GDMS rational scale and positively correlated with other GDMS profiles. The ABIS and GDMS have not been correlated previously, to our knowledge, and this finding sheds some light on how the construct of impulsivity maps onto decision making styles.

Finally, previous literature has suggested correlating the DOSPERT and the BART to see the relationship between the two (Blais & Weber, 2006): we found no significant relationship between DOSPERT scores and BART outcomes.

Implications, Limitations, and Future Research

These findings have implications for college students, as they report daily caffeine consumption, often at very high levels (Shohet & Landrum, 2001). Our results suggest that caffeine consumption may in fact be beneficial when attempting to resist particular types of risky or impulsive decision making. Given that trait impulsivity is correlated with a series of risky behaviours (such as unprotected sex, Dir, Coskunpinar, & Cyders, 2014; risky driving behaviours, Bachoo, Bhagwanjee, & Govender, 2013; problem drinking behaviours and risky behaviours while intoxicated, Jones, Chryssanthakis, & Groom, 2014; and drug abuse, Winters, Botzet, Fahnhorst, Baumel, & Lee, 2008), caffeine's ability to decrease impulsive and risky tendencies may help prevent certain problem behaviours. However, caffeine did not reduce risky/impulsive behaviour on the BART task, suggesting it may not be universally helpful. In addition, caffeine does not decrease risk tendencies in all contexts: for example, caffeine in combination with alcohol is associated with a series of harmful and risky behaviours, such as dangerous driving (see Striley & Khan, 2014 for review). Moreover, experimental studies have demonstrated that caffeine combined with extreme sleep deprivation (75 hours wakefulness) does not improve performance on the IGT relative to baseline performance and placebo, and may actually impair performance relative to baseline (see Figure 1 of Killgore et al., 2007). Our findings add to the literature on caffeine and risk; in the right context, caffeine can help to mitigate risky and impulsive behaviours, perhaps by improving associative learning regarding probability of gains and losses.

One of the limitations of this study was the low number of male participants. Of the 106 participants, 21 were male. Of those 21 male participants, only 4 were randomly assigned to the caffeine condition. Given that there was a main effect for gender on IGT winnings, and gender did account for some variability in IGT winnings, the relative samples of each gender may have been problematic. Most of the participants in the current study were in their early 20s, thus limiting the validity of the significant correlations between age and individual difference measures. Another potential limitation of this study was the low dose of caffeine administered, especially because our participants had a relatively high baseline of caffeine consumption (Median=205mg SD=265.55mg, Range=0-1350mg). 200 mg of caffeine may have been too small a dose to have induced detectable effects on all the measures of risky decision making. Furthermore, the delay between caffeine administration and the first decision making task appeared insufficient to allow caffeine to reach its full efficacy, as revealed by task order effects and the lack of differential score on the SSS.

Further research should focus on identifying what construct measured by the IGT is affected by caffeine. Our results indicate that IGT outcomes are not associated with impulsivity, as measured with the ABIS. Research could focus on the impact of caffeine on emotional intelligence to test the possibility that improvement on the IGT was influenced by emotional intelligence and moderated by caffeine consumption. Furthermore, limited research (see Corley et al., 2010) has investigated the relationship between IQ and caffeine consumption, which may be interesting in light of Kahneman's and Damasio's theories. Additionally, researchers should investigate whether regular caffeine consumers report less risky or impulsive behaviours, or if caffeine can help prevent real-world risk-taking tendencies. Given that both of the decision-making tasks here (and in particular the IGT) involve a dynamic learning process by trial-and-error, an examination of individual differences in ability to learn via gain/loss feedback (i.e. reward/punishment) is warranted to further understand the role of caffeine in performance improvement and the mechanisms by which this is accomplished.

The dosage of caffeine used in this study may not have been large enough to create a significant means difference on IGT winnings according to a t-test, especially because the base-rate of caffeine consumption was quite high for the majority of our sample. Further research should examine dose-dependent effects of caffeine and should include adequate delay following caffeine administration (20 minutes minimum). Additionally, future studies should ensure equal male to female ratios and more age diverse samples to better account for age and gender differences.

In conclusion, we found that caffeine, in tandem with individual difference variables, significantly impacted performance on one of two risky decision making tasks. These results indicate that caffeine could moderate risky decision making, at least in some contexts, for people with particular decision-making styles. However, the inconsistencies in the two tasks used to measure risky decision making indicate that further research involving caffeine should focus on developing more specific methods to operationalize particular aspects of risky decision making with better construct validity.

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Appendix A: Screenshot of the Stroop

Appendix B: Demographic Survey

1. Gender (please circle)

    a. Male

    b. Female

    c. Other

2. What is your age? ____________________

3. How many hours of sleep did you get last night? __________________________

4. How many hours do you usually sleep per night? __________________________

5. How many coffees do you usually drink per day? (ex. 1, 2 etc) ___________________

6. What size of coffee do you usually drink? (ex. Large, Venti, 4 cups, 12 oz etc) ____________________

7. How many caffeinated teas do you usually drink per day? (ex. 1, 2 etc) __________________________

8. What size of caffeinated tea do you usually drink? (ex. Large, Venti, 4 cups, 12 oz etc) ______________

9. Do you ever use caffeine tablets? (please circle)

    a. Yes

    b. No

10. If so, how many caffeine tablets do you take per week? _________________

11. How many caffeinated soft drinks do you usually drink per day? (ex. Diet/regular Coke/Pepsi, Barq's rootbeer, Redbull, or other energy drinks) __________________________

12. What is the size of the caffeinated soft drink you usually drink? (ex. can, liter) ___________________

Appendix C: General Decision Making Style survey

Instructions: Listed below are statements describing how individuals go about making *important decisions.* Please indicate whether you agree or disagree with each statement

1. I double-check my information sources to be sure I have the right facts before making decisions

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

2. I make decisions in a logical and systematic way.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

3. My decision making requires careful thought.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

4. When making a decision, I consider various options in terms of a specific goal.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

5. When making decisions, I rely upon my instincts.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

6. When I make decisions, I tend to rely on my intuition.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

7. I generally make decisions that feel right to me.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

8. When I make a decision, it is more important for me to feel the decision is right than to have a rational reason for it.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

9. I explore all of my options before making a decision

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

10. When I make a decisions, I trust my inner feelings and reactions.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

11. I often need the assistance of other people when making important decisions

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

12. I rarely make important decisions without consulting other people

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

13. If I have the support of others, it is easier for me to make important decisions

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

14. I use the advice of other people in making my important decisions

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

15. I like to have someone to steer me in the right direction when I am faced with important decisions.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

16. I avoid making important decisions until the pressure is on.

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

17. I postpone decision making whenever possible

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

18. I often procrastinate when it comes to making important decisions

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

19. I generally make important decisions at the last minute

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

20. I put off making many decisions because thinking about them makes me uneasy

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

21. I generally make snap decisions

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

22. I often make decisions on the spur of the moment

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

23. I make quick decisions

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

24. I often make impulsive decisions

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

25. When making decisions, I do what seems natural at the moment

1	2	3	4	5
Strongly disagree		Neutral		Strongly agree

Appendix D: Abbreviated Barrat Impulsiveness Scale

DIRECTIONS: People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and circle appropriate number on the right side of this page. Do not spend too much time on any statement. Answer quickly and honestly.

1	2	3	4
Rarely/Never	Occasionally	Often	Almost
Always/Always			

1. I plan tasks carefully.	1	2	3	4
2. I do things without thinking.	1	2	3	4
3. I don’t “pay attention.”	1	2	3	4
4. I plan trips well ahead of time.	1	2	3	4
5. I am self controlled.	1	2	3	4
6. I concentrate easily.	1	2	3	4
7. I am a careful thinker.	1	2	3	4
8. I plan for job security.	1	2	3	4
9. I say things without thinking.	1	2	3	4
10. I act “on impulse.”	1	2	3	4
11. I act on the spur of the moment.	1	2	3	4
12. I am a steady thinker.	1	2	3	4
13. I am future oriented.	1	2	3	4

Appendix E: Domain Specific Risk Taking Scale

For each of the following statements, please indicate the **likelihood** that you would engage in the described activity or behavior if you were to find yourself in that situation. Provide a rating from *Extremely Unlikely* to *Extremely Likely*, using the following scale:

1	2	3	4	5	6	7
Extremely Unlikely	Moderately Unlikely	Somewhat Unlikely	Not Sure	Somewhat Likely	Moderately Likely	Extremely Likely

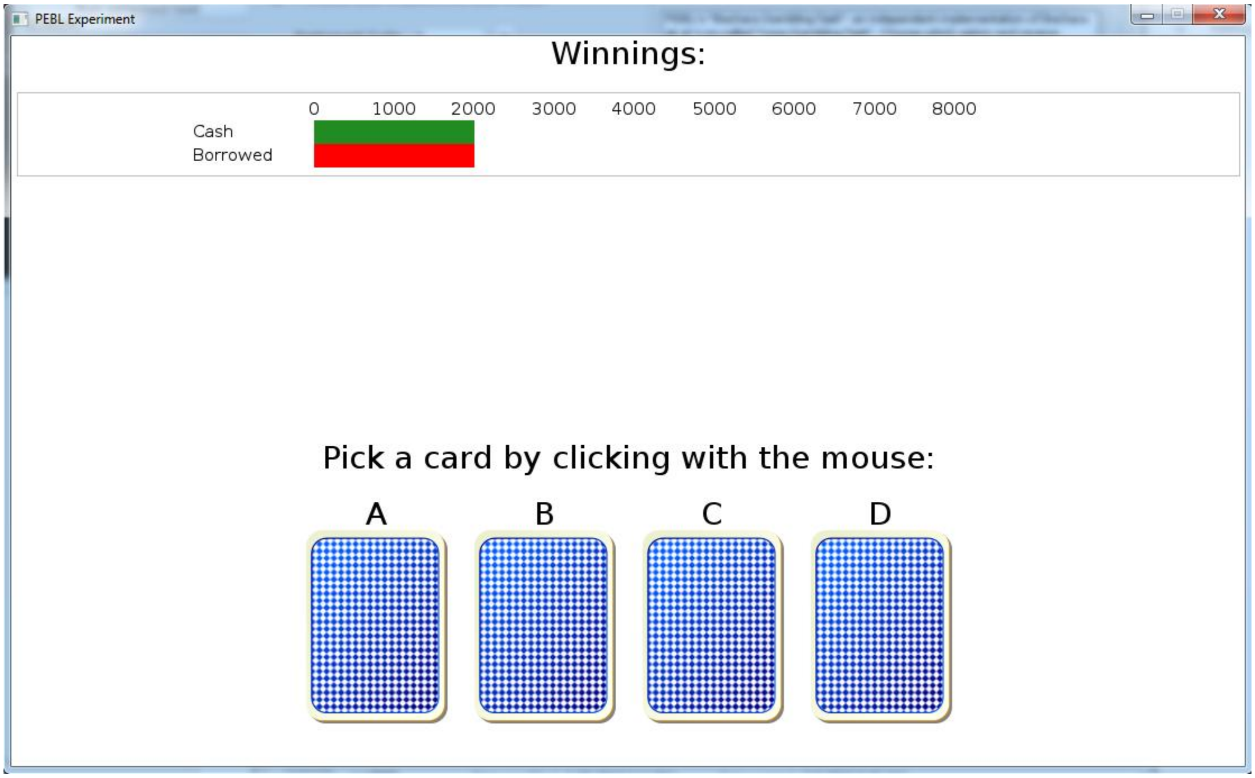
1. Admitting that your tastes are different from those of a friend.	1	2	3	4	5	6	7
2. Going camping in the wilderness.	1	2	3	4	5	6	7
3. Betting a day's income at the horse races.	1	2	3	4	5	6	7
4. Investing 10% of your annual income in a moderate growth mutual fund.	1	2	3	4	5	6	7
5. Drinking heavily at a social function.	1	2	3	4	5	6	7
6. Taking some questionable deductions on your income tax return.	1	2	3	4	5	6	7
7. Disagreeing with an authority figure on a major issue.	1	2	3	4	5	6	7
8. Betting a day's income at a high-stake poker game.	1	2	3	4	5	6	7
9. Having an affair with a married man/woman.	1	2	3	4	5	6	7
10. Passing off somebody else's work as your own.	1	2	3	4	5	6	7
11. Going down a ski run that is beyond your ability.	1	2	3	4	5	6	7
12. Investing 5% of your annual income in a very speculative stock.	1	2	3	4	5	6	7
13. Going whitewater rafting at high water in the spring.	1	2	3	4	5	6	7
14. Betting a day's income on the outcome of a sporting event.	1	2	3	4	5	6	7
15. Engaging in unprotected sex.	1	2	3	4	5	6	7
16. Revealing a friend's secret to someone else.	1	2	3	4	5	6	7
17. Driving a car without wearing a seat belt.	1	2	3	4	5	6	7
18. Investing 10% of your annual income in a new business venture.	1	2	3	4	5	6	7
19. Taking a skydiving class.	1	2	3	4	5	6	7
20. Riding a motorcycle without a helmet.	1	2	3	4	5	6	7
21. Choosing a career that you truly enjoy over a more prestigious one.	1	2	3	4	5	6	7
22. Speaking your mind about an unpopular issue in a meeting at work.	1	2	3	4	5	6	7
23. Sunbathing without sunscreen.	1	2	3	4	5	6	7
24. Bungee jumping off a tall bridge.	1	2	3	4	5	6	7
25. Piloting a small plane.	1	2	3	4	5	6	7
26. Walking home alone at night in an unsafe area of town.	1	2	3	4	5	6	7
27. Moving to a city far away from your extended family.	1	2	3	4	5	6	7
28. Starting a new career in your mid-thirties.	1	2	3	4	5	6	7
29. Leaving your young children alone at home while running an errand.	1	2	3	4	5	6	7
30. Not returning a wallet you found that contains $200.	1	2	3	4	5	6	7

Appendix F: Stanford Sleepiness Scale

This is a quick way to assess how alert you are feeling. Please circle the number of the statement that most applies to you at this moment.

Degree of Sleepiness	**Scale Rating**
Feeling active vital, alert, or wide awake	1
Functioning at high levels, but not at peak; able to concentrate	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream like thoughts	7

Appendix G: Screenshot of Iowa Gambling Task



Appendix H: Screenshot of Balloon Analogue Risk Task