Contextual Differences in Reinforcement Affect Self-Control in SHR and WKY Subjects

Jonathan C. Rich
Utah State University

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Contextual Differences in Reinforcement Affect Self-Control in SHR and WKY Subjects

by

Jonathan C. Rich

Thesis submitted in partial fulfillment of the requirements for the degree of

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Approved:

Amy L. Odum Scott Bates

Nicholas Morrison

UTAH STATE UNIVERSITY
Logan, UT

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Abstract

Contextual Differences in Reinforcement Affect Self Control in SHR and WKY Subjects

The spontaneously hypertensive rat (SHR) is the outcome of selectively breeding its progenitor the Wistar Kyoto (WKY) for hypertension. In the present experiment, the context of reinforcement was manipulated to determine its effect on impulsivity across the SHR and WKY strains of rat. An additional block of delays was added onto the end of a standard delay discounting procedure to vary the context of reinforcement from one condition (0 sec.) to the next (60 sec.). Results indicate that both SHR and WKY subjects made fewer impulsive decisions when a shorter delay followed the longest delay in the task—although this effect was more pronounced in the SHR strain. This suggests that differences in contextual factors of reinforcement may affect impulsivity, but that the magnitude of this effect may depend on fundamental differences in genetics or other biological substrates.
Appreciation/Contributors

I would like to express my gratitude to the various programs and individuals who supported this project. I would like to thank Utah State University, the URCO program, the department of psychology, the honors department, and Dr. Amy Odum for their help in funding this project. I appreciate the help from my honors advisor Dr. Scott Bates, and from the members of the honors department who played a role in getting the ball rolling. I would also like to extend my gratitude to all the members of Dr. Odum’s research team—as well as to certain members of Dr. Timothy Shahan’s team—for their insight and advice.

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# Table of Contents

Abstract................................................................. 2
Appreciation/contributors............................................... 3
Table of Contents......................................................... 4
Table of Equations/Figures............................................. 5
Forward........................................................................ 6
Introduction............................................................... 7
Methods....................................................................... 16
Results....................................................................... 19
Discussion............................................................... 22
References..................................................................... 24
Author's Biography.................................................. 32
Table of Equations/Figures

Figure 1 - Average AUC for SHR and WKY strains under initial conditions: 60s block of delay trial followed by a 0s delay block of trials. *Page 20*

Figure 2 - Average AUC for SHR and WKY strains under final conditions: 60s block of delay trials followed by another 60s block of delay trials. *Page 20*

Figure 3 - AUC for SHR and WKY strains under both conditions. Condition 1: 60s block of delays followed by a 0s block of delays; Condition 2: 60s block of delays followed by another 60s block of delays. *Page 21*
Foreword

In its broadest colloquial usage the word ‘impulsivity’ is an eclectic and ill-defined construct that is identified with a collection of behaviors conveying lack of forethought, risk, inappropriateness, or any spontaneous and unpremeditated action. Such behaviors are often maladaptive, and usually result in unfavorable or even disastrous outcomes: Shopping sprees that leave behind mountains of debt; temper-tantrums that are immediately gratifying in their expression of frustration, but which ultimately lead to more intense repercussions such as spankings, groundings, or time outs; late night chatting, midnight movies, or a few excess drinks that in the morning reduce the likelihood of being on time or alert for work; an extra burger for dinner, egg for breakfast, or coke for lunch, along with the forgoing of exercise in exchange for a mid-day nap that aggregates like compounding interest into an obesity epidemic and costly health service. Impulsivity as a phenomenon is ubiquitous, as are its repercussions. It is the job of science to break this construct down, tease apart its every nuance, and then attempt to define and understand each of its component parts while, concomitantly, explaining their place in relation to the swirling collage that makes up the whole.

The ensuing information is a limited review on an enormous topic, which is then followed by the outcome of a single experiment and an explanation of that experiment’s results. It is focused on a single facet of the multifaceted construct impulsivity: delay discounting, or the subjective decline in the value of outcomes as they become more remote in time. It is concerned with how contextual factors of reinforcement, state variables, and trait variables influence
measures of impulsivity across two strains of rat. One strain an animal model of Attention-Deficit/Hyperactivity Disorder, and the other strain its progenitor.

As a whole, the experiment investigates both distinct and interacting patterns of behavior that have biological and environmental roots. Further, it looks at various state and trait elements of behavior while manipulating the context in which reinforcement is delivered to determine its effect on impulsivity within a delay discounting paradigm.

Introduction

The term impulsivity encompasses a large array of behaviors that share common motifs: compulsive, lacking forethought, irrational, strongly driven or uncontrollable, inappropriate (see e.g., de Wit, 2008). Expounding on a review by Evenden (1999) impulsivity seems to be the composite function of multiple individual functions of behavior varying in form and degree. Furthermore, although each of these individual behavioral functions are, in part, related to the plethora of everyday behaviors we regard as exhibiting impulsive choice or action, one function may cancel out or overpower another, and any individual function need not be related to or have any effect on another.

Adding another layer of complexity to an already involved expression, the term impulsivity is not only used to define multiple interrelated behaviors, but the behaviors we define to be impulsive are also influenced by a variety of interacting environmental, biological, and contextual factors (Odum & Buamann, 2010). A number of different experiments have investigated how such factors influence impulsive behavior. These experiments include studies
examining contextual or environmental effects on impulsivity, and used techniques such as environmental enrichment paradigms (Dalley, Theobald, Pereira, & Robbins, 2002; Perry, Stairs, & Bardo, 2008), manipulation of order of reinforcement (Fox, Hand, & Reilly, 2008), fading procedures (Mazur, & Logue, 1978), reward magnitude and type (Logue, Pena-Correal, Rodriguez, & Kabela 1986; Odum, Baumann, & Rimington, 2006), and manipulation of contexts in which subjects had previous associations with impulsive gambling behaviors (Dixon, Jacobs, & Sanders, 2006).

These experiments also included studies examining biological effects, or organic influences on impulsivity and thus include genetic influences (Eisenberg et al., 2007; Eisenberg, Campbell, Mackillop, Lum, & Wilson, 2007; Pavlov, Chistiakov, & Chekhonin, 2011), strain differences (Anderson, & Woolverton 2005; Fox et al., 2007; Isles, Humbly, Waters, & Wilkinson 2004; Madden et al., 2008), and physiological induced effects using brain lesions (Cardinal, Robbins, & Everitt, 2000; Winstanley, Baunez, Theobald, & Robbins 2005; Winstanley, Dalley, Theobald, & Robbins 2004), or a variety of different compounds (De Wit, & Mitchell, 2010). Finally, besides being a behavioral tendency that is influenced in aggregate by the various above mentioned contingencies, certain forms of impulsivity have been suggested to be traits of personality (Odum, 2011), and therefore impulsive behaviors carried out by some individuals may reflect relatively enduring tendencies to act impulsively on a global level, and in many situations.

In an attempt to operationalize general forms of impulsivity scientists have constructed an assortment of laboratory paradigms thought to be putative forms of impulsive behavior. Three such forms are failure of attention, inability to inhibit pre-potent responses, and the inability of delayed outcomes to control current choices (Madden, & Johnson, 2010). The last of these forms
can be more narrowly defined as delay discounting, or the tendency of future outcomes to decrease in subjective value as a function of the time until their receipt (Mazur, 1987). This specific form of impulsivity is a single facet of the more involved area of general impulsivity (de Wit, 2008); and, with the multidimensional nature of impulsive behavior in mind, the remainder of this paper is more specifically oriented toward this more particular facet of impulsivity.

**Delay Discounting**

Delay discounting refers to the tendency of outcomes that are deferred in time to decrease in value as the interval widens until their receipt (Mazur, 1987). Delay discounting is studied in the laboratory using both human and animal subjects, and through the use of multiple discounting tasks and procedures (Odum, & Baumann, 2010; Madden, & Johnson, 2010). In general, such procedures involve choices between larger-later rewards that can be obtained after a delay or smaller-sooner rewards that are available immediately. Following a choice (or a set of choices) one of these variables is systematically increased or decreased while keeping all other variables static. This is done to determine the manipulated variable’s effect on the held-constant variables. By titrating one outcome with another via the manipulation of some variable such as time or reward amount, it is possible to hone in on a subject’s personal indifference point—the present value of the delayed outcome (Odum, & Baumann, 2010; Madden, & Johnson, 2010). In this way it is possible to quantify a given subject’s individual rate of discounting.

As with all psychological phenomena, the rate at which future rewards are discounted is influenced by both environmental and biological factors. Variation in discounting that is a product of the environment is regarded to be the result of state variables. Conversely, variation in discounting that is the product of a subject’s internal-biology is regarded to be the result of trait
variables (Odum, 2011; Odum, & Baumann, 2010). In essence, state variables are transient changes in behavior caused by the environment, and trait variables are relatively enduring tendencies that are caused by a subject's preexisting behavioral tendencies (Odum, & Baumann, 2010).

Empirical investigation on the effects of state and trait variables has brought to light multiple trends in discounting behaviors. State variables currently thought to affect discounting include reward type and amount, context of choice, working memory, drug administration, and deprivation (Odum, & Baumann, 2010). Similarly, trait variables currently thought to affect the discounting of delayed rewards include personality measures, age, gender, IQ, race, culture, income, education, psychiatric disorders, drug and gambling addictions, and genetics (Odum, & Buamann, 2010). On the whole, the interactive influence of both state and trait variables on discounting is what drives the behaviors we observe. It is the mixture of these cognitive forces, within a defined context, that eventuates in behaviors symptomatic of impulsivity or self-control.

Generally speaking, the tendency to devalue future outcomes at a high rate tends to result in detrimental outcomes. In the context of delay-discounting, steep discounting is a term that refers to an inclination toward choosing smaller-immediate rewards over larger-later rewards, and is indicative of impulsive choice (Logue, 1988). Steep discounting is associated with many everyday maladies such as drug addiction (Bickel, Odum, & Madden, 1999; Madden, Petry, Badger, & Bickel, 1997; Odum, Madden, Badger, & Bickel, 2000; Petry, 2001; Yi, Mitchell, & Bickel, 2010), obesity (Davis, Patte, Curtis, & Reid, 2010), and pathological gambling (Alessi, & Petry, 2003) to name a few. Furthermore the tendency to steeply discount outcomes that are deferred in time is also associated with multiple psychiatric illnesses including antisocial personality disorder, and attention-deficit/hyperactivity disorder (Petry, 2002; Scheres, Tontsch,
Theony, & Kaczkurkin, 2010; Williams, 2010). Saying this, the robust association between Attention-deficit/hyperactivity (ADHD) disorder and various types of impulsive behaviors is of a singular importance to the experiment that will be reviewed in this article.

**Attention-Deficit/Hyperactivity Disorder**

Like most psychiatric disorders, ADHD involves a complex interaction of psychological, environmental, and physiological variables, and thus cannot be understood at any one level of explanation (Sagvolden, & Sergeant, 1998). As a syndrome, ADHD has been suggested to be the result of multiple lower level processes that work in aggregate and are manifest as high level behavioral summaries (Williams, 2010). Between 1.3 and 5% of grade-school children are affected by ADHD, and the onset of the disorder is usually manifest before the age of 7 (Sagvolden, & Sergeant, 1998). In childhood, the disorder is more common among boys, but this trend seems to reverse itself in adulthood when the disorder becomes more prevalent among females (Biederman et al., 1994). Finally, although multiple subtypes of ADHD do exist, and vary in their specific behavioral patterns, the three most pervasive and fundamental symptoms of this disorder are impulsiveness, inattentiveness, and over-activity (Taylor, 1998; Todd et al., 2001).

Of the three fundamental behavioral characteristics of ADHD, impulsiveness appears to be the most robust (Sagvolden, & Sergeant, 1998). Individuals with ADHD have been shown to score higher on various measures of impulsivity across multiple domains (Antrop, Stock, Verte, Wiersema, Baeyens, & Roeyers, 2006; Scheres et al., 2010; Scheres et al., 2005; Winstanley et al., 2006). In response to this observation, it has been theorized that individuals with ADHD have a steeper than normal delay-of-reinforcement gradient (Sagvolden, 1996). In essence, a
delay-of-reinforcement gradient is simply the relationship between the overall effect of a given reinforcer on an individual’s behavior, and the amount of time that passes between the response emitted to obtain that reinforcer and the actual receipt of reinforcement (Sagvolden, & Sergeant, 1998). This means that an individual with a steep gradient of this sort would experience less robust conditioning effects on behavior following consequences than would another individual with a shallower gradient. It is the possibly steeper than normal delay-of-reinforcement-gradient among individuals with ADHD that is thought to explain many of the impulsive behaviors so characteristic of this disorder (Sonuga-Barke, 2002).

As previously mentioned, impulsiveness is currently seen as a core symptom of ADHD (Sagvolden, & Sergeant, 1998). Given the integral relationship between impulsiveness and ADHD, mechanisms engineered to mitigate an individual’s sensitivity to delay are of the utmost importance to the treatment of this disorder. A few such contrivances have been shown to have ameliorating effects on impulsiveness among individuals with ADHD and include medication (predominantly stimulants; Jensen et al., 2001), and environmental manipulations (Antrop et al., 2006; Carvalho et al., 2010). Whether these interventions operate on impulsivity directly or on impulsivity indirectly through their effects on some other factor that in turn affects impulsivity, is yet to be determined.

*The Spontaneously Hypertensive Rat*

As previously mentioned, ADHD is the aggregate of a number of biological and environmental influences interacting with each other in a convoluted manner. A corollary of this is difficulty pinning down cause and effect relationships in experimentation (Sagvolden, Rusell, Aase, Johansen, & Farshbaf, 2005). For this reason it can, at times, benefit the experimenter to
use animal models in approaching the study of this disorder. Although there is a definite
distinction between animal models and the actual disorders for which they speak, these basic
models are advantageous to our ultimate understanding of human disorders, because they are less
complex than the higher ordered constructs they speak for. Moreover, animal proxies may be
preferred over their more complex counterparts, because confounds located within the
environment or the genetic make-up of these non-human organisms are much more manageable.
In the end, it is for reasons of simplicity, as well as control, that these models are beneficial to
the scientific community as a whole.

Within the last decade, the Spontaneously-Hypertensive Rat (SHR) has been established
as a credible animal model of ADHD (Adriani, Antonio, Granstrem, Carli, & Laviola, 2003;
Johansen, Sagvolden, & Kvande, 2005; Sagvolden, 2000; Sagvolden, et al., 2005; Sagvolden, et
al., 2009). Sagvolden et al. 2000 proposed that an animal model of ADHD must meet three
fundamental criteria to be accepted as a representative of the human disorder: face validity,
construct validity, and predictive validity. The first of these three validation criteria, face
validity, is concerned with how reasonable or logical a measure of a construct appears to be.
Sufficient support for the face validity of the SHR as an animal model of ADHD can be seen
through the similarities in behavior existing between SHRs and human individuals with ADHD
(Sagvolden et al., 2000; Sagvolden et al., 2005). Both individuals with ADHD as well as SHRs
display hyperactivity, impulsivity, and sustained attention deficits when compared to controls.
On the whole, the recognition of similarities in behavior between these two constructs provides
sufficient support for the face validity of the SHR as an animal model of ADHD.

A second validation requirement, construct validity, refers to how well inferences can be
made from the model about the construct it represents. This validation requirement differs from
that of face validity in that face validity is more a measure of intuition than an empirical association between the actual and modeled constructs. Similar to humans with ADHD, SHRs show motor impulsiveness as well as robust declines in the subjective value of rewards that are attached to a delay (Adriani et al., 2003; Fox, Hand, & Reilly 2008). Furthermore, research on the neurological mechanisms of SHRs conducted by Bendel and Eilam (1992), and also by Schultz (1998), has shown SHRs to share a neuro-structural resemblance to individuals with ADHD. Such structural resemblances include impaired cross-talk between specific brain regions (Oades 1998), a hypo-functional nucleus accumbens (Russell, de Villiers, Sagvolden, Lamm, & Talijaard 1998), and the reduced release of the neurotransmitter dopamine in the prefrontal cortex (Russell, de Villiers, Sagvolden, Lamm, & Talijaard 1995), and other brain areas (Boix, Qiao, Kolpus, & Sagvolden 1998; Russell et al., 1998). In essence, because similarities in behavior and observed parallels in neuro-structure make generalizations between these two organisms more plausible, the SHR can be said to display construct validity (Sagvolden et al., 2000; Sagvolden et al., 2005).

A final validation requirement proposed by Sagvoden et al. (2000) is predictive validity. Ultimately, an animal model is said to possess predictive validity if the data acquired from the study of the model has a correlation with the actual form of the modeled behavior, and from this correlation previously unknown aspects of the modeled behavior can be predicted. Predictions of novel of behaviors resulting from experiments using SHR subjects as models of ADHD include: more precise definitions of delay-gradients, hyperactivity, and impulsivity (Sagvolden et al., 2000; Sagvolden et al., 2005). In addition, current studies using SHR subjects may help elucidate the effects of certain pharmaceutical drugs on the behavior of individuals with ADHD (Bizot et al., 2007; Sagvolden, 2006). All things considered, while substantial testing continues to be done
to determine the credibility of the SHR as an animal model of ADHD, evidence strongly supports the SHR as meeting the necessary validation requirements to be considered a legitimate representation of the human construct it speaks for (Adriani et al., 2003; Johansen et al., 2005; Sagvolden, 2000; Sagvolden et al., 2005; Sagvolden, 2009).

As regards SHR subjects and delay discounting, Fox et al., (2007) showed SHRs to be more impulsive than controls when performing delay discounting tasks. A temporal discounting procedure was used in which both SHR’s and WKY controls were presented with choices between the receipt of either smaller rewards delivered immediately, or the receipt of large rewards delivered after a various set of delays. The results indicated SHRs were significantly more impulsive than WKY controls, as assessed by the higher number of choices that SHR subjects made for the smaller-immediate reward. All in all, the findings are in agreement, not only with what previous research using SHRs has shown, but also with what previous research has shown using human subjects of the ADHD population (Scheres et al., 2010).

Present Experiment

As previously mentioned, two types of variables are thought to affect behavior: state variables and trait variables (Odum, & Baumann, 2010). State variables are short-term influences on behavior caused by the environment. Trait variables are relatively stable and implicit characteristics of an organism that influence behavior. In the present experiment, the state variable of context was altered to determine its effect on impulsivity across two strains of rat, the SHR strain and its progenitor the Wistar Kyoto. Furthermore, besides investigating the effect of contextual factors on impulsivity, this study also investigated the effect of the trait variable, strain, on impulsivity, and thus will replicate the procedure of Fox et al., (2007) in which the
SHR strain was found to be more impulsive than its progenitor. Lastly, a final aspect of this experiment considered the interactive effect of both state and trait variables, namely the interactive effect of both strain and context on impulsivity: Does the state effect, as a result of context manipulation, depend on trait influences such as strain of rat (strain being tied to genetic propensities and biological inclinations to behave a certain way)?

**Methods**

**Subjects**

Experimentally naïve rats of the Wistar-Kyoto (WKY) and spontaneously hypertensive (SRH) strains were used as subjects for this project. WKY rats were selected as a control strain because they are the genetic progenitor of the SHR. Subjects were purchased from Charles River, Portage, Michigan, USA, and were 60 days old upon arrival. Throughout the course of this experiment, subjects were housed on the campus of Utah State University in the Laboratory Animal Research Center (LARC). Subjects were housed in a temperature controlled room operating on a 12/12h light/dark/cycle, and given free access to water. Over a fourteen-day period, the free feeding weights of the subjects were established. All subjects were kept at 80% free feeding weight throughout the project to maintain motivation and a healthy weight. Testing was carried out at approximately the same time each day in the behavioral laboratory located in the LARC. All activities were in compliance with the USDA Animal Welfare Act, PHS “Policy for the Humane Care and Use of Animals,” U.S. Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training; and the Animal Welfare Policies of Utah State University.
Apparatus

Standard Med-Associates Inc. operant chambers were used to carry out each session’s testing in a sound controlled environment. Each of these chambers was 30.5 cm long, 24.1 cm wide, and 21.0 cm high. Stainless steel rods spaced 1.3 cm apart and measuring 0.5 cm in diameter made-up the floor of the chambers; the walls/ceiling were composed of Plexiglas siding. Two retractable levers, both on the same wall, were 11.4 cm apart from one another; a 28V DC, 100 mA stimulus light was located above each separate lever. 45 mg dustless precision pellets were used in all chambers. A pellet receptacle was connected to a 45 mg pedestal mount pellet dispenser, and was situated between the two levers. One 28 V DC house light was situated in the center of the opposite wall from the levers, lights, and pellet dispenser.

Med-Associates interfacing and programming was used on a computer in an adjacent room to control the events of the experiment and record data.

Procedure

Prior to testing and baseline sessions, subjects underwent magazine training in which free food was presented on a fixed time (FT) 1 min schedule of reinforcement. After, subjects learned to lever press on a fixed ratio (FR) 1 schedule of reinforcement. Following magazine training and the shaping of lever pressing behavior, baseline sessions began. Baseline data were collected until stability in responding was established. During this time, subjects’ presses on lever A resulted in a small reward (1 pellet), and subject’s presses on lever B resulted in a larger reward (4 pellets). The lever associated with the larger reward was counterbalanced across subjects. At the beginning of each session, the house-light was illuminated, and a nose poke response was required to initiate the presentation of the two choice levers.
Each session consisted of 6 blocks of 8 choice trials, and began with 2 forced-choice trials in which each lever was presented individually without the other to expose the subjects to the consequences associated with each lever. A single lever press was required for subjects to select between the larger or smaller reward. Lever presses in all trials resulted in the reward associated with each lever. Throughout the session, the delay until the presentation of the large reward in each block was increased from 0 to 10, 20, 30, and 60 s. After a choice response, the house-light was extinguished, the levers were retracted, and the onset of the tray-light signaled the delivery of food. Intervals between the receipt of food and the initiation of the next trial lasted 60 s.

Following the presentation of either reward, a nose poke initiated an inter-trial interval (ITI) in which the house-light was extinguished until the start of the next trial and responses to either lever did not result in reinforcement (this was to inhibit rapid responding on the lever associated with the smaller reward). Each trial lasted 60 s, regardless of the subject's choice response. If a response was not made within 10 s of the start of a trial, the session would automatically progress to the next trial. Each session lasted approximately 2 hours.

To vary the context of reinforcement, a final block of choice trials was added, either 0 or 60 s depending on what contingencies of the experiment were in place. During baseline the delay in the final block of choices was 0 s. After responding became stable experimental sessions were put into effect and the delay in the final block was changed to 60 s. Experimental sessions were conducted under these contingencies for 40 days at which point responding had stabilized.
Data assessment

Area under the curve was calculated for both SHR and WKY groups of subjects using the following equation:

\[ x_2 - x_1 \left[ \frac{y_1 - y_2}{2} \right] \]

Where \( x_1 \) and \( x_2 \) are successive delays and \( y_1 \) and \( y_2 \) are the present values associated with those delays (Myerson, Green, & Warusawitharana, 2001). Essentially, the more a given subject discounts, the smaller its area under the curve will be. Area under the curve can vary from 0.0 (steepest possible discounting) to 1.0 (no discounting).

Note on programming error

Due to programming errors, subjects were not exposed to the consequences of pressing each lever in the forced choice trials. Each subject was exposed to four forced choice trials in which responses made on either lever resulted in the presentation of the small or large rewards immediately, and were thus independent of the contingencies that were actually in effect. This error most likely introduced confounding variation in the effects observed, and all results need to be replicated under the proper contingencies to validate any findings presently observed.

Results

In general, SHR’s showed higher measures of impulsivity with respect to WKY’s in all conditions. Tests of between-subject effects show a significant difference in average area under the curve (AUC) between strains \( F(1,6) = 32.385, p = 0.001 \); calculated using the last 15 days of
both conditions. Figures 1 and 2 show the average AUC for both SHR and WKY strains under the initial and final conditions respectively. More specifically, Figure 1 displays the mean AUC for both SHR (left) and WKY (right) subjects under the initial conditions in which the final block of choice trials had a 60s delay attached to the larger reward. Similarly, Figure 2 displays the mean AUC for SHR (left) and WKY (right) subjects under the final conditions in which the final block of choice trials had a 0s delay attached to the larger reward.

Figure 1
Average AUC for SHR and WKY strains under initial conditions: 60s block of delay trials followed by a 0s delay block of trials. AUC for SHR subjects is on the left.

Figure 2
Average AUC for SHR and WKY strains under final conditions: 60s block of delay trials followed by another 60s block of delay trials. AUC for SHR subjects is on the left.
Interestingly, measures of impulsivity were lower in both strains following changes to the initial conditions. Tests of within subjects contrasts show a significant difference in AUC between conditions for both strains $F(1,6) = 15.737, p = 0.007$. In other words, following experimental manipulation, both SHR and WKY subjects significantly made fewer impulsive responses.

Figure 3 shows AUC with respect to strain and condition. Although the effect was more pronounced in the SHR strain, a significant interactive effect was not found between strain and context $F(1,6) = 4.505, p = 0.078$. The insignificant interaction here is most likely due to insufficient statistical power. Moreover, the observed data suggests a significant interaction would have been obtained given a larger sample size.

![Figure 3](image)

AUC for SHR and WKY strains under both conditions. Condition 1: 60s block of delays followed by a 0s block of delays; Condition 2: 60s block of delays followed by another 60s block of delays.
Finally, the proportion of choices made for the larger reward in the initial block of experimental sessions was compared to the proportion of choices made for the larger reward in the final block of experimental sessions. The delay attached to the larger reward was 0 sec. for both the initial block and the final block of choice trials in the experimental sessions, and an insignificant difference between the proportions of choices made for the larger reward amongst these two blocks of choice trials would suggest consistency in choice throughout experimental sessions.

The comparison described in the previous paragraph was made for all subjects in aggregate as well for all subjects of each strain independent of the other using paired samples t-tests. An analysis of all subjects in aggregate gave rise to an insignificant difference between choice proportion for the large reward between initial and final blocks, $t(7) = 1.532, p = 0.169$. Analysis of each strain independent of the other resulted in similar insignificant findings: $t(3) = 1.351, p = 0.27$ for WKY subjects and $t(3) = 1.408, p = 0.254$ for SHR subjects.

**Discussion**

The results of this experiment suggest that differences in the context of reinforcement have an effect on impulsivity within a delay discounting paradigm. Specifically, the data imply that when subjects experience a set of choices with a long delay attached to the larger reward followed by a set of choices with a short delay attached to the larger reward, then those subjects display general increases in self-control. The exact reason for this finding is yet to be determined, but a near significant interactive effect between strain and condition suggests that
the overall influence of contextual reinforcement on discounting may have biological or genetic implications.

Furthermore, the results of this experiment also corroborate the findings of Fox et al., (2007) in that SHR subjects showed significantly steeper levels of discounting compared to subjects of their progenitor, the Wistar Kyoto. This conclusion is in agreement with the general validity of the SHR as an animal model of Attention-Deficit/Hyperactivity disorder, and extends the general impulsive trends symptomatic of this strain to the area of delay discounting. Still, other experiments will be needed to determine how closely the discounting behaviors of SHR’s resemble those of human individuals with ADHD under this paradigm.

Finally, the non-significant difference between proportion of choices for the large reward in the initial 0 delay block and the proportion of choices made in the final 0 delay block of the first condition indicates two things. First, because the proportion of choices for the large reward in the final 0 delay block was not significantly different from that of the first 0 delay block, satiation does not seem to significantly contribute to the overall decline in self-control across a session in an Evenden and Ryan procedure. Second, for the same reasons the results of this experiment preclude the possibility that within session carry-over effects largely account for the general increase in discounting that is observed in the later blocks of a session in an Evenden and Ryan procedure. This said, although factors of satiation and carry-over effects may nuance quantitative measures of impulsivity in a general sense, the findings of this experiment suggest that, comprehensively, measures of delay discounting obtained from Evenden and Ryan procedures are in fact valid indicators of impulsivity as far as they are not profoundly affected by either satiation or carry-over effects within a session.
References


Author’s Biography

Born January 17, 1988, Jonathan Rich grew up on a farm in a small rural community. The last born of his three siblings, Jonathan was prone to mischief. He possessed a keen eye for adventure, and during his ascent from elementary school up to his graduation from Bear Lake High in Montpelier, Idaho, Jonathan became exceedingly familiar with some of his teachers while serving detention. One of the hardest things for him to master during his teenage years was obedience to, and compliance with, authoritative rules. Perhaps, it’s this independent spirit and refusal to accept anything at face value that fueled his passion to learn and ultimately propelled him through his academic career.

Following the receipt of his High School Diploma, Jonathan ventured to Logan, Utah where he continues to attend school at Utah State University. At this moment, Jonathan is finishing a dual major at USU in the fields of Psychology and Biology. Following graduation he plans to attend medical school and specialize in the field of Psychiatry.