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Dynamic Decision Making: Individual Attributes And Behavior in a Challenge Dice Game

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Abstract

Adopting both experimental and individual differences approaches we study dynamic decision making using the Challenge Dice Game. Experimentally, this computer task offered subjects immediate feedback and the opportunity to modify their strategic behavior over time. Subjects were found to behave more aggressively than equilibrium predictions and failed to approach optimal play with experience. From the individual difference perspective, characteristics thought to explain behavior and performance in uncertain and risky decision contexts were

compared to observed behavior and performance with mixed results. We conclude that existing psychological scales are imperfect and not necessarily strong predictors of behavior and performance in dynamic decision tasks.

Keywords: Dynamic decision making, Risk, Behavior, Performance, Individual differences, Experiment

1. Introduction

Much of the empirical research into judgment and decision making comes from the "heuristics and biases" tradition, which illustrates the dysfunctional consequences of adopting judgmental heuristics. While this body of research has made important contributions to the field, a central criticism is that while judgment is a continuous and interactive process that enables decision makers (DMs) to cope with their environment, much of the research has focused on discrete incidents, often lacking any form of meaningful feedback. Thus, DMs that appear biased in discrete tasks may be quite effective in continuous or natural environments where feedback and periodic adjustment in decision strategy are the norm.

One area of research, dynamic decision making (DDM), appears well-positioned to further our understanding of judgment and decision behavior in continuous and interactive environments. DDM can be characterized as a task system where the decision maker is faced with a sequence of decisions in which each decision can affect both the state of the system and subsequent decision making. A number of studies, which are reviewed below, have made important contributions to understanding behavior in dynamic decision environments. However, the research paradigms on which these studies are based are often criticized as being overly complex, with (often) ambiguous feedback, lacking clearly delineated subject goals, and not amenable to analytical solution.

1.1 Research Contributions

The current study addresses these shortcomings by embracing both the traditional experimental and the individual differences approaches to better understand behavior in a DDM context. Consistent with the experimental approach, we developed a simple, computer based binary decision task, the Challenge Dice Game (CDG), which provides subjects with immediate feedback on decision outcomes and clear progress towards their task-related goal. To accommodate the individual differences approach, we correlate subjects' behavior and performance in the CDG with individual characteristics reported to affect decision making processes. This focus is consistent with the view that DDM requires simultaneous use of multiple psychological functions and as a result, contributes to the psychology and DDM literatures interested in the nature and quality of thought and action in complex systems.

1.2 Inferences and Limitations of Static Decision Making

Experimental results from static decision making often show that DMs select less than optimal alternatives and that these selections are systematically biased. For example, DMs often ignore base rates and instead, make probability assessments based on representativeness or the availability of information (Tversky & Kahneman 1974). DMs also tend to possess

unwarranted confidence in their judgment (Fischoff & Slovic 1980); make insufficient adjustment from an initial starting point (Slovic & Lichtenstein 1971); are prone to hindsight biases (Fischhoff 1975); and hold misconceptions of chance (Kahneman&Tversky1972; 1973).

The inference drawn from this body of research is that humans are inept DMs with limited cognitive abilities (Dawes 1976). Yet for years this interpretation has not been well supported when observing DMs in more natural settings(Christensen-Szalanski & Beach 1984).Critics of this "heuristics and biases" research contend that judgment is best viewed as a continuous and interactive process that enables DMs to cope with their environment (Jungermann1983), and that decisions that appear biased or error-prone in the short-run maybe quite effective in dynamic decision making (DDM)contexts that allow for feedback and periodic adjustment as a series of non-independent decisions are made in real time (Atkins, Wood, & Rutgers 2002; Brehmer 1992; Kleinmuntz 1985).

1.3 Inferences and Limitations of Dynamic Decision Making

Despite its perceived utility, scholars cite a number of limitations to early DDM studies, including difficulty arriving at an optimal solution (Slovic, Fishhoff, & Lichtenstein 1977); insensitivity to deviations from obtained solutions (Rapoport 1975); delayed and inaccurate feedback processes (Sterman 1989); and complexity in the task environment that not only yielded little understanding of how decisions affect performance objectives, but also made it difficult to generalize results across experiments (MacKinnon & Wearing 1985). Slow progress in DDM research was also attributed to difficulties in extending methods used to study individual decisions to aggregate, dynamic settings (Sterman 1989). Fortunately, modern technology accompanied by the proliferation of computerized laboratories has lowered many obstacles (Neller& Presser 2004). Consequently, our ability to provide meaningful feedback to human subjects in DDM experiments has greatly improved. Advancements also enabled researchers to expand the set of tools available to better understand behavior in DDM situations (Busemeyer & Pleskac 2009); examine how DMs approach stochastic dynamic decision problems (Hey & Knoll 2011); determine the degree to which people plan in a DDM context (Bone, Hey & Suckling 2009); and investigate inconsistent DMs in dynamic decision settings (Hey & Panaccione 2011).

As DDM research grew, it became evident that studies fell into one of two categories; those concerned with individual differences as antecedents of behavior (Brehmer 2005) and those that followed the traditional, experimental approach (Brehmer 1992). Studies in the individual differences category often divided data into two groups – one where subjects exhibited relatively successful performance and one where performance was relatively poor. Attention then focused on examining behaviors, psychological traits, and other demographic characteristics theorized to explain performance differences between the groups such as that found with Americans and Germans DDM when compared to Brazilians, Indians, and Filipinos (Güss & Dörner 2011). Research falling under the experimental category traditionally examined the effects of task characteristics such as task complexity and feedback quality on cognitions, behavior, and performance within complex systems. The value of this

body of research is that it improved our understanding of how people interact with their environment. For example, experimental results have shown that the person-environment relationship is more likely circular rather than linear, and that individuals often rely on readily available information and tend to ignore the secondary effects of decisions (Brehmer 2005; Sterman 1989).

1.4 Organization of Present Study

To better understand how the present study connects with both experimental and individual approaches, section 2 provides an overview of relevant experimental studies of DDM. Section 3 examines five psychological factors (conscientiousness, locus of control, behavioral activation and inhibition, general decision making style, and choice under risk)often used in studies of decision making. Our methodology for the CDG and psychological measures are explained in section 4. Section 5 reports the results from the experiment and decision making survey. Findings, limitations and suggestions for further research are discussed in section 6.

2. Experimental Research in Dynamic Decision Making

A comprehensive review of DDM is beyond the scope of this paper. Instead, we focus on major themes and alternative approaches that connect with or inform the present paper. We begin with two of the earliest psychological studies on DDM. Toda (1962) examined how people plan or organize their behavior over time to accomplish defined goals. He developed a one-player "fungus-eater" game where the DM had to balance two, often competing objectives – survival and mining a precious ore. Edward's (1962) work extended the theory of subjective expected utility from a static to dynamic decision-making context. Under this methodology actual decisions were compared to theoretically optimal decisions. Changes in performance could then be systematically investigated as decision constraints, in the form of length of memory or information processing ability, were imposed on the DM.

Rapoport (1967, 1970) and Rapoport, Jones, and Kahan (1968) followed a similar approach in their study of multistage betting games (MBG). At each stage, the DM would allocate his entire capital across several mutually exclusive and collectively exhaustive alternatives. Each alternative obtains with a known probability and return on the amount invested. Rapoport and Stein (1972) proved mathematically that the optimal policy that minimized risk in the MBG is one of proportional betting. Results, however, showed only qualified support for this as a descriptive theory of play. For reviews of other experimental research up until the mid-seventies, see Rapoport and Wallsten (1972) and Rapoport (1975).

Over a decade later, Sterman's (1989) classic DDM study – the "Beer Distribution Game" – assigned subjects to one of four roles – producer, distributor, wholesaler, or retailer. Subjects in each role were required to manage stock in a simulated inventory distribution system. Although individuals received feedback at the end of each trial, time delays and general uncertainty in moving stock through the multi-actor system resulted in substantial inefficiencies. Subject behavior, which was far from optimal, showed several considerable regularities. Sterman concluded that much of the subjects' poor performance and limited ability to learn from experience was attributable to misperceptions of feedback. More recent research

on DDM has examined, among other things, the effect of feedback type on learning (Atkins et al. 2002) and, whether subjects plan ahead in DDM environments (Bone et al. 2009). Our study complements existing research within the experimental approach by (*i*) adopting a simple task environment with a computable optimal solution that allows us to benchmark individual performance, (*ii*) providing accurate and timely feedback following each decision, and (*iii*) allowing for fifty repeated trials to assess how subjects learn or adapt their play with experience.

3. Psychological Considerations

Research in psychology suggests that individual attributes affect how people process information, choose among alternatives, and ultimately, perform decision tasks. Relatively few empirical studies have however, directly examined how characteristics of the individual influence decision-making processes and outcomes outside of static decision-making contexts (Levin, Gaeth, Schreiber, & Lauriola 2002). Yet such an examination is necessary given the frequency with which individuals confront DDM situations. Accordingly, we explore the effect of five psychological factors in our CDG. Our general research question regarding to facets of DDM as well as specific hypotheses related to individual difference are summarized in Table 1.

3.1 Conscientiousness

The effect of personality on motivational processes and outcomes has a long history in the organizational psychology literature (Judge & Ilies 2002). As one of the "Big-5," conscientiousness is defined with characteristics including competent, self-disciplined, organized, responsible, deliberate, and achievement-oriented (Barrick & Mount 1991).Studies have found conscientiousness to be a predictor of performance across numerous settings where performance is dependent on the individuals' actions and decisions. For example, Barrick and Zimmerman (2009) found that conscientiousness was positively related to confidence in one's self, one's decisions, and job performance. Likewise, Colquitt and Simmering (1998) demonstrated that conscientious individuals are also motivated to learn from experience. Accordingly, we anticipate that conscientious DMs will be more competent at adjusting their play to feedback in a continuous, interactive decision-making task, and expect a positive relationship between conscientiousness and performance due to the conscientious individuals' discipline, achievement-orientation, and motivation to learn from experience. We also expect that conscientious DMs will outperform less conscientious DMs.

3.2 Locus of Control

Individuals differ in the extent to which they attribute outcomes to their own decisions and actions, versus that of the environment (Rotter 1966). For those with an internal locus of control, outcomes are seen as directly contingent on their own behavior or effort since internals consider themselves in control of and responsible for what happens in their life. In contrast, externals are relatively passive, attributing outcomes to which they are associated to "something else"; factors that are beyond their own control such as luck, chance, or powerful persons or institutions. Empirical research has shown that locus of control impacts performance through its role in how individuals make decisions (Anderson 1977). For example,

internals tend to focus on task-oriented coping schemes, whereas externals focus more on defensive coping schemes when deciding how to respond to accountability requirements (Mero, Guidice, & Anna 2006). Those with an internal locus of control are also more likely to achieve difficult goals than those with an external locus of control (Hollenbeck, Williams, & Klein 1989).

Consistent with Boone, De Brabander, and van Witteloostuijn's (1999) study of locus of control in a repeated prisoner's dilemma game, we suggest that this trait can be related to the choices individuals make when confronted with a DDM task. Specifically, we predict that internals, with their sense of control over the environment, may behave more aggressively(Ward, 1995)in the CDG whereas externals, lacking confidence in their own ability and thus, willingness to adjust their decision strategy over repeated trials (Boone et al. 1999),may behave more conservatively when confronted with a DDM problem. We also expect that performance in the CDG will be better for internals compared to externals. Stated differently, assuming externals lack confidence in complex environments, and as result, are less motivated to achieve desired outcomes than internals (Spector 1982), we expect that externals will not achieve the same level of performance as internals.

3.3 Behavioral Activation and Inhibition Systems

Two general motivational systems underlie the behavior of individuals – behavior activation and behavior inhibition (BAS-BIS; Carver & White 1994).Linked to BAS, positive reactivity is the extent to which individuals seek out rewards that are tied to a specific activity or outcome. BAS typically divided into three categories for study – fun seeking, drive, and reward responsiveness. Linked to BIS, negative reactivity is the extent to which individuals prefer to avoid punishments or aversive stimuli tied to an activity or outcome.

The impact of this multidimensional individual difference on performance has gained increasing support, although findings are not uniform across decision-making studies. Suhr and Tsanadis (2007) found that individuals high on fun seeking and reward responsiveness tended to perform poorly on the Iowa Gambling Task (IGT); findings consistent with the argument that both categories of BAS lead to impulsive decision-making behavior, and consequently, poor performance. In contrast, Franken and Muris (2005) found that higher levels of reward responsiveness predicted higher IGT performance, while fun seeking's effect on performance was non-significant. Finally, Pothos, Perry, Corr, Matthew, and Busemeyer (2011) found reward responsiveness to be positively associated with performance in a prisoner's dilemma game where defection was the optimal strategy.

Based on existing research and the characteristics of BAS, we expect that BAS-fun and BAS-reward will be positively related to aggressive decision making and negatively related to DDM performance. In contrast, we predict that DMs with BAS-drive will be more inclined to make optimal decisions and to display positive performance on a DDM task. Given their negative affect, we also hypothesize that high BIS DMs will approach the DDM environment more conservatively and that BIS will be negatively related to performance because the desire to avoid errors and punishment (losses) may limit DMs from developing coping strategies to prevent repeated defeat in in a DDM task.

3.4 General Decision-Making Style.

This individual difference is defined as a habit-based disposition to respond to specific decision contexts in a patterned way (Scott & Bruce 1995). General decision-making style (GDMS) also reflects differences in basic cognitive abilities, including self-evaluation, information processing, and self-regulation (Galotti et al. 2006). GDMS is composed of five styles (Loo 2000; Scott & Bruce 1995),*rational* – comprehensive search for and logical appraisal of alternatives prior to making decisions; *intuitive* – reliance on premonitions and feelings when making decisions; *spontaneous* – sense of immediacy and preference to get through the decision-making process as quickly as possible; *dependent* – seeking decision guidance and advice from other persons when making decisions; and *avoidant* – circumventing decision making whenever possible. While individuals can hold multiple preferences (Scott & Bruce 1995), they are unlikely to concurrently draw from opposing styles (Gambetti, Fabbri, Bensi & Tonetti 2008), such as intuitive and dependent.

In terms of GDMS's effect on performance, Scott and Bruce (1995)found negative relationships between the rational style and innovative behavior, and the dependent styles and innovative behavior. Brand Laier, Pawlikowski, and Markowitsch (2009) considered risk in their examination of the relationship between decision-related cognitive style and decision performance in a Game of Dice Task (GDT). This research found that intuition was inversely related to performance when given feedback in a risky decision context and positively related to performance in the absence of feedback.

Drawing from prior conceptual developments and empirical findings of GDMS, we hypothesize that the avoidant and dependent styles will be positively related to conservative behavior in the CDG and negatively related to performance, since individuals in this DDM context must compete alone and completion of the task demands that decisions be made in real time without consulting others. We also expect DMs with either rational or intuitive decision making styles to behave more consistently with the optimal policy, and as a corollary, expect positive relationships between these two decision-making styles and performance. With rational DMs, we assume that they will factor gambling reasoning into the decision process by incorporating information from prior turns. Hence, we expect rational DMs to perform better than DMs who do not consider the odds of various outcomes before making subsequent decisions, or factor in perceived "lessons learned" from prior decision outcomes. We expect similar performance for intuitive styles because the two styles often complement each other (Sadler-Smith & Shefy 2007) and thus, result in similar decision-making processes and outcomes.

In contrast to intuition, which draws on individuals' innate ability to synthesize information quickly and effectively (Dane & Pratt 2007), spontaneity is consistent with a shoot-from-the-hip decision strategy. We suggest that spontaneous DMs are apt to sacrifice careful and effective decision making in the quest to make speedy decisions (Scott & Bruce 1995). We similarly expect that individuals with a spontaneous decision-making style will be more aggressive and thus, perform less well in the CDG.

3.5 Choice under Risk

One of the most consistent findings of decision-making research is that DMs are often prone to risk aversion .Namely, people typically underweight an outcome that is probable and overweight an outcome thought to be certain. Labeled the certainty effect, Kahneman and Tversky (1979) demonstrated this bias by collecting responses to two choice problems. We believe three types of DMs can be identified in this problem set. The first, called the *utility maximizer*, is an individual who, when compelled to choose between two or more options, prefers to select the one with the highest expected payoff. The second, we call the *certainty effect seeker*, is the individual who, in the same decision context, fails to choose the option with the highest expected value; preferring instead the choice with a lower, but certain, expected value. Finally, the *inconsistent DM* is neither a strict utility maximizer, nor a certainty effect seeker. These individuals approach choice problems in an unpredictable or erratic manner.

We expect that DMs who are utility maximizers will behave differently than certainty seekers; the latter of which are likely to avoid having substantial points in jeopardy and thus, behave more conservatively than the former. Given their inconsistency, we do not make any behavioral predictions on our third group of DMs. In terms of performance in the CDG, we expect utility maximizers to perform better than those who either fall prey to the certainty effect or those who are inconsistent DMs.

4. Methodology

One hundred and seven undergraduate juniors and seniors, enrolled in an upper-division management course at a large southwestern university were invited to participate. We eliminated fourteen individuals who either declined to participate in the study or failed to complete all components of the study. The resulting sample consisted of 57 men and 36 women, with an average of 7.4 years of work experience. Subjects' mean age was 25.7. Within the sample, 47% were Caucasian, 7% African American, 24% Asian, 16% Hispanic, 2% Pacific Islander, and 4% "other". Finally, 77% of the subjects were U.S. citizens and all but five were pursuing a business degree.

Subjects were asked to complete a survey collecting data on demographics and individual attributes related to judgment and decision making. Those fulfilling this requirement were then invited via e-mail to participate in the CDG. This temporal separation between completion of the survey and participation in the experiment was used to minimize common method bias (Podsakoff, MacKenzie, & Podsakoff 2012). After registering for the experiment, subjects were emailed an informed consent form and instructions for accessing the software at campus computer labs.

4.1 Challenge Dice Game

We designed a computerized task that simulated an environment consistent with the definition of DDM – a context where multiple and interdependent decisions are made as a function of the decision maker's actions and/or in response to environmental events (Edwards 1962). In our CDG, subjects played 50 repeated trials (games)of a simple dice game against a computer. The object of each game was to accumulate more points, in a single turn, than the computer. Subjects began each game by rolling an electronic die on the computer screen. If a 2 through 6

was rolled, those points were added to the subject's *turn total*, and the subject could choose to *roll* again, or *hold*. Subjects could roll the electronic die as many times as desired, however, if the roll resulted in a 1, all of the points accumulated during their turn were lost and it became the computer's turn to play. If the subject chose to hold, accumulated points were save din the subject's *game total*, and play shifted to the computer. The computer's task was simple: playing by the same rules, accumulate more points than the subject's *game total*, thereby winning the trial.

Subjects earned $0.75 for each trial they won plus a complimentary$5.00 for attending the session, thereby making it possible for them to earn up to $42.50[i].Subjects were also instructed that (*i*) the outcome of each roll is determined randomly and each number has a 1/6 chance of appearing on any given roll, (*ii*) the computer does not 'cheat' by giving itself fewer rolls of 1s, and (*iii*) because subjects are required to roll first, the computer has an advantage and will likely win about twice as many trials as the subject. On average, subjects earned $18.43. All subjects completed all fifty trials in less than 30 minutes.

4.2 Survey

All non-demographics were measured using previously published scales that have been well-accepted as psychometrically sound and theoretical grounded. Unless otherwise specified, subjects responded to each question using 5-point Likert-type scales ranging from 1 (strongly disagree) to 5 (strongly agree).

4.2.1 Conscientiousness.

Conscientiousness was measured using a version of Costa and McCrae's (1992) NEO Personality Inventory known as the Conscientiousness-NEO Domain in the International Personality Item Pool (IPIP; Goldberg et al. 2006). This 10-item measure contains questions including, "I pay attention to details" and "I don't see things through".

4.2.2 Locus of Control.

Locus of control was measured using Levenson's (1981) scale as published in the IPIP (Goldberg et al. 2006). Questions in this 5-item scale included, "I believe some people are born lucky" and "I believe in the power of fate".

4.2.3 Behavioral Activation and Inhibition Systems.

To capture this personality trait, Carver and White (1994) developed the BAS/BIS scale. BAS-Drive was assessed with four items including, "I go out of my way to get things I want". BAS-Reward was assessed with four questions including, "When I get something I want, I feel excited and energized". Four questions assessed BAS-Fun, including "I crave excitement and new sensations". Lastly, the BIS scale included seven items with questions including, "I worry about making mistakes".

4.2.4 General Decision-Making Style.

Scott and Bruce's (1995) five-dimensional, 24-item measure of GDMS was used in the study. *Avoidance* was assessed with five questions including, "I generally make important decisions

at the last minute". *Dependent* was measured using five questions including, "If I have the support of others, it is easier for me to make important decisions". The five items capturing the *intuitive* dimension included, "When making decisions, I rely upon my instincts". Included among the four items measuring *rational* style was, "I make decisions in a logical and systematic way". Finally, *spontaneous* was assessed using five items including, "I generally make snap decisions".

3.2.5 Decision Making Under Risk.

The final section of the survey presented two problems to explore subjects' decision preferences in the face of risk. Decision theorists may recognize these problems as those used by Kahneman and Tversky (1979) to study the certainty effect. Their results showed that (*i*) 82% of the DMs chose Option B in Problem 1 and 83% chose Option C in Problem 2, and that (*ii*) this pattern of decision making violates axioms of expected utility theory[ii].

Problem 1

A) Winning \$2500 with 33% probability, or
Winning \$2400 with 66% probability, or
Winning \$0 with 1% probability

B) Winning \$2400 with 100% probability

Problem 2

C) Winning \$2500 with 33% probability, or
Winning \$0 with 67% probability

D) Winning \$2400 with 34% probability, or
Winning \$0 with 66% probability

We used our subjects' responses to these two questions to create a variable that captures a DM's approach to risk. Individuals who chose Options A and C were considered *expected utility maximizers* (coded 1); individuals who selected Options B and C fell prey to the *certainty effect*(coded 2); and individuals who chose either of the remaining paired selections (A and D, or B and D) were labeled *inconsistent* DMs (coded 3).While we are cautious in making a specific prediction given the paucity of research available to ground a hypothesis, we suspect and will explore whether unique differences in performance exist among these three groups in our dynamic CDG.

Table 1. Research Question and Hypotheses

RQ	What are the individual characteristics, behavior, and performance of DMs in a context where multiple and interdependent decisions are made as a function of the actions and/or in response to environmental events?
H1	Conscientiousness is positively related to performance in DDM such that conscientious DMs will outperform less conscientious DMS
H2a	Internal locus of control is positively related to aggressive behavior in DDM

H2b	External locus of control is positively related to conservative behavior in DDM
H3	Performance in DDM is higher for DMs with an internal locus of control compared to those with an external locus of control
H4a	BAS-fun is positively related to aggressive behavior in DDM
H4b	BAS-reward is positively related to aggressive behavior in DDM
H4c	BAS-drive is positively related to optimal behavior in DDM
H4d	BIS is positively related to conservative behavior in DDM
H5a	BAS-fun is negatively related to DDM performance
H5b	BAS-reward is negatively related to DDM performance
H5c	BAS-drive is positively related to DDM performance
H5d	BIS is negatively related to DDM performance
H6a	An avoidant decision style is positively related to conservative behavior in DDM
H6b	A dependent decision style will be positively related to conservative behavior in DDM
H6c	A rational decision style is positively related to optimal behavior in DDM
H6d	An intuitive decision style is positively related to optimal behavior in DDM
H6e	A spontaneous decision style is positively related to aggressive behavior in DDM
H7a	An avoidant decision style is negatively related to DDM performance
H7b	A dependent decision style is negatively related to DDM performance
H7c	A rational decision style is positively related to DDM performance
H7d	An intuitive decision style is positively related to DDM performance
H7e	A spontaneous decision making style is negatively related to DDM performance
H8	An individual's approach to risk (risk seeking, certainty effect, or inconsistent) differentially affects their DDM performance

5. Results

We begin by examining results from the CDG experiment. We then turn to results from the survey and look at relationships among individual differences, decision behavior, and performance observed in the CDG.

5.1 Experiment

A total of 17,891 decisions were made by the ninety three subjects. Most of these (12,351) were roll decisions as subjects began to accumulate points during a turn. Our interest is in the remaining 5,540 decisions. Decisions in this subset were placed into one of four decision categories: (*i*) *aggressive roll*, where subjects chose to roll when the optimal policy[iii] prescribed hold; (*ii*) *conservative hold*, where subjects chose to hold when the optimal policy prescribed roll; (*iii*) *equilibrium hold*, where subjects' hold decisions were consistent with the optimal policy; and (*iv*) *aggressive hold*, where subjects chose to hold after one or more aggressive roll decisions. The aggregate results, reported in Table 1, indicate that subjects were nearly twelve times more likely to roll when the optimal policy prescribed hold than they were to hold when the optimal policy prescribed roll (3,574 aggressive rolls compared to 301 conservative holds). Examining the hold decisions shows that 1,339 are classified as aggressive and only 326 hold decisions were consistent with the optimal policy. We tentatively conclude that our subjects were much more likely to play aggressively than conservatively.

Table 2. Decisions by Type

Decision Type	Count
Equilibrium Roll	12,351
Aggressive Roll	3,574

Conservative Hold	301
Equilibrium Hold	326
Aggressive Hold	1,339
Total	17,891

To further examine roll/hold decisions, we compared the frequency distributions of observed and predicted cutoff thresholds (see Figure 1). To estimate subjects' observed cutoff thresholds, we considered the set of 1,966 hold decisions. For each hold decision the estimated cutoff threshold (v) was computed as $v = (t_{d-1} + 1 + t_d)/2$, where t_{d-1} is the turn-total value of the immediately preceding roll decision, and t_d is the turn-total value when the subject decides to hold. For example, if a subject decided to roll on a *turn total* of 16 and the roll resulted in a 5, and the subject then decided to hold with a *turn total* of 21, the cutoff threshold was estimated to be $v = (16 + 1 + 21)/2 = 19$.

As seen in Figure 1, the variance of the observed distribution (50.6) is substantially larger than that of the predicted distribution (2.1). The mean of the observed threshold (20.2) is also significantly greater than predicted mean of 16.7 ($t = 21.793$, $p<.0001$), indicating that subjects tended to roll beyond predicted threshold values.

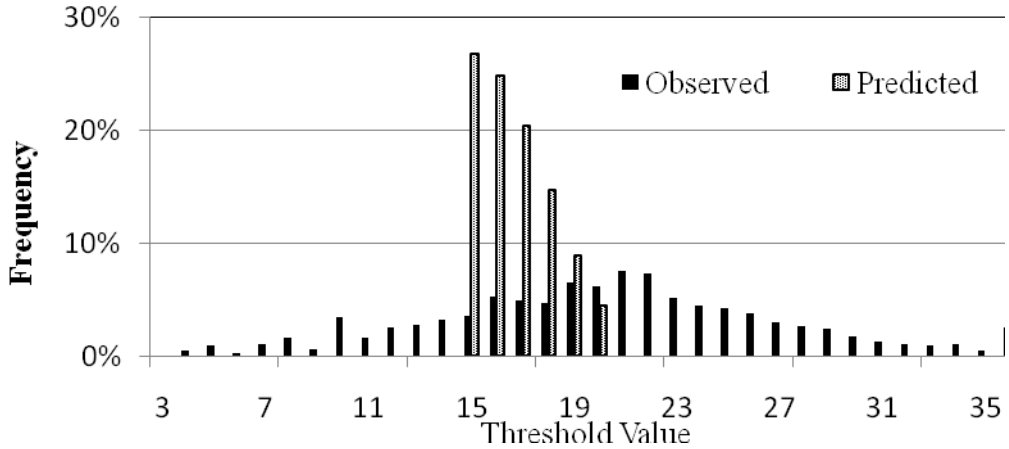

Figure 1. Observed and Predicted Cutoff Thresholds

To see if this behavior changed over time, we computed mean v for each of the fifty trials and compared observed to predicted cutoff thresholds by trial (see Figure 2). This analysis showed that observed cutoff thresholds were close to predicted levels during the first seven or so trials and then increased to more than 20 points throughout most of the remaining trials. If subjects learned from experience, we would expect to see their cutoff thresholds approaching optimal play as they gained experience with the decision task. However, there is no support for subject learning – at least in terms of learning the optimal strategy. In fact, a paired t-test comparing subjects' mean v from the first block of 25 trials to the last block of 25, indicates that players moved further away from optimal predictions ($t = 3.563$, $p<.001$).

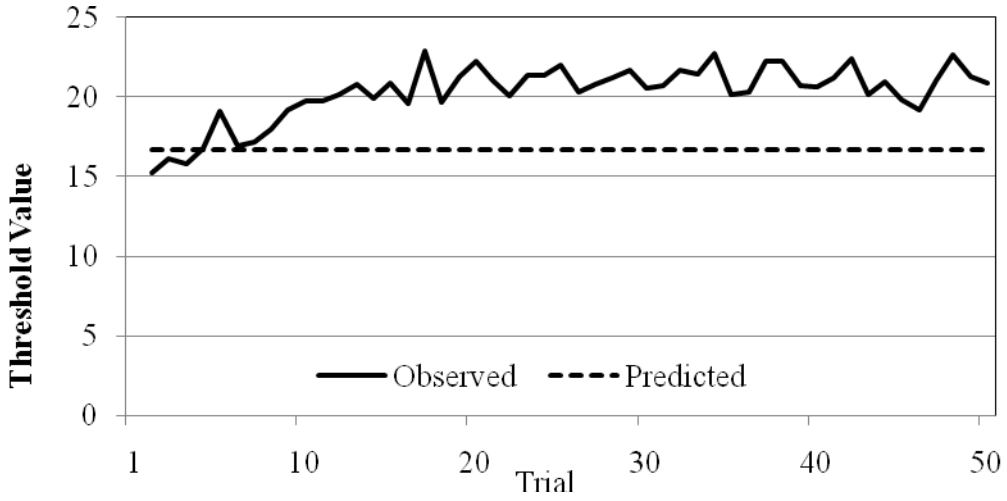

Figure 2. Cutoff Thresholds by Trial

5.2 Survey

Means, standard deviations, and correlations are reported in Table 2.Internal consistency coefficients, reported on the diagonal of the table, were at or above.70 (Nunnally 1978), with the exception of GDMS–Rational, which fell slightly short at .66. A number of observations were made by examining the significant correlation coefficients (p<.01 and p<.05) among subjects' personality traits and decision-making styles. As expected, conscientious subjects tended to be individuals with an internal locus of control(r = .31) as well as sensitive to positive stimuli (BAS) tied to drive (r = .26) and to rewards(r = .31). Also of note, subjects with an internal locus of control tended to be less sensitive to fun-seeking stimuli (r = -.33). Conscientiousness and locus control were each negatively associated with the avoidance (r = -.50 and r = -.48), dependent(r = -.22 and r = -.39), and spontaneous (r = -.29 and r = -.40) decision-making styles, while conscientiousness was positively associated with a rational decision-making style. (r = .36).Finally, sensitivity to negative stimuli (BIS) was positively associated with avoidant (r = .24) and dependent (r = .39) decision-making styles.

With respect to performance in the CDG, we examined correlations between mean deviation (which measures distance from optimal play), number of games won, and the four decision types (aggressive roll, conservative hold, equilibrium hold, and aggressive hold) with personality traits and decision-making styles. Table 2 shows that aggressive rollers often held an external rather than internal locus of control (r = -.20), preferred dependent (r = .21) and rational decision-making styles (r = .22), and were sensitive to BAS-drive stimuli (r = .21).

Analysis also uncovered a positive relationship between aggressive holders and a dependent decision-making style (r = .20). Additionally, mean deviation was positively related to both the rational decision-making style (r = .22) and drive-motivated BAS (r = .20). The number of games won was positively associated with equilibrium rolls (r = .63) and with aggressive holds(r = .44), indicating that subjects best chance of winning is by behaving consistent with the optimal play, or *successfully* rolling beyond the optimal policy. The strong correlation

Table 3. Correlations between Psychological Variables and Decision Outcomes

Item	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Conscientiousness	3.87	.59	(.72)																
Locus of Control	3.27	.87	.31**	(.74)															
DMS-Avoidance	2.12	.80	-.50**	-.48**	(.87)														
DMS-Dependent	3.39	.71	-.22*	-39**	.29**	(.74)													
DMS-Intuitive	3.36	.76	.16	-.05	.10	.13	(.84)												
DMS-Rational	4.12	.48	.36**	.16	-.07	.10	.12	(.66)											
DMS-Spontaneous	2.60	.81	-.29**	-.40**	.43**	.14	.14	-.40**	(.84)										
BAS-Fun	3.69	.67	.04	-.33**	.13	.13	.17	-.14	.43**	(.70)									
BAS-Reward	4.51	.45	.31**	-.01	-.12	.08	.18	.19	-.06	.17	(.76)								
BAS-Drive	3.68	.75	.26**	-.02	-.03	-.13	-.29**	.16	.13	.19	.21*	(.85)							
BIS	3.34	.76	-.14	-.18	.24*	.39**	-.02	.09	.04	-.03	.19	-.06	(.82)						
Mean Deviation	8.70	4.1	.11	-.19	.00	.18	.02	.22*	-.04	.11	-.09	20*	.07						
Aggressive Rolls	38.4	23.3	.05	-.20*	.03	.21*	.02	.22*	-.02	.09	-.06	-21*	.08	.91**					
Conservative Holds	3.24	4.4	.01	.07	-.04	-.15	.04	-.02	-.01	.02	.14	-.09	-.13	-.41**	-.45**				
Equilibrium Holds	17.9	4.4	-.08	.04	.01	.07	.01	-.06	.01	-.13	.03	-.16	.10	-.27**	-.05	-.38**			
Aggressive Holds	14.4	5.1	-.02	-.04	.07	.20*	-.00	.12	-.06	-.13	-.06	-.07	.07	.22*	.40**	-.58**	.75**		
Games Won	17.4	3.6	.04	.00	-.02	-.05	.11	.08	-.12	-.07	.22*	-.08	.15	-.21*	-.06	-.02	.63**	.44**	
Age	25.7	6.4	.03	.00	-.14	-.12	-.06	.06	-.07	-22*	-.09	.06	.03	.25*	.25*	.01	-.11	.05	-.08

Results for sample size n=93; *p<.05; **p<.01; Cronbach's alpha in parenthesis on the diagonal

among the four decision types are unsurprising since these measures are not independent; for example an aggressive hold depends on the subject first making an aggressive roll.

A number of relationships related to subjects' response to the risk scenarios are noteworthy. Consistent with the findings of Kahneman and Tversky (1979) noted earlier, the majority (71%) of our subjects selected Choice B over Choice A in problem scenario 1. Likewise, the majority (55%) of subjects selected Choice C over Choice D in problem scenario 2. Hence, it appears that our subjects, like those in previous tests of utility theory, found a change from sure gain to uncertainty (B→D) to be more disconcerting than changes between two uncertain conditions (A→C).Next, we partitioned subjects into their respective approach to risky decision making. This revealed that there were twice as many certainty seekers (34) as there were utility maximizers (17). A large portion of subjects (42), however, made decisions that were inconsistent from one problem to the next.

We then examined the relationship between the three approaches to risky decision making and CDG performance. An analyses of variance (ANOVA) revealed significant differences among decision approaches on mean deviation [$F(2,90) = 4.95$, $p<.01$] and aggressive rolls [$F(2,90) = 4.86$, $p<.01$]. Marginally significant differences among decision approaches were also found for conservative holds [$F(2,90) = 2.69$, $p<.10$] and aggressive holds [$F(2,90) = 2.40$, $p<.10$]. Differences among the decision approaches on games won were not statistically significant.

A subsequent Bonferroni multiple comparison test found that subjects in the utility maximization category had higher ($p<.01$) mean difference scores ($M = 11.11$, $SD = 4.72$) than those subjects in the certainty effect category ($M = 7.46$, $SD = 3.29$, $d = .89$), but not when compared to subjects with an inconsistent approach ($M = 8.72$, $SD = 4.20$, $d = .54$) although the effect size (Cohen's d) of this latter set, suggests a moderately strong difference (Cohen 1988).Subjects in the utility maximization category were also more ($p<.01$) aggressive rollers ($M = 50.88$, $SD = 21.34$) than those in the certainty effect category($M = 30.47$, $SD = 16.25$, $d = 1.07$), but not when compared to subjects with an inconsistent approach ($M = 39.83$, $SD = 26.64$, $d = .46$), although the effect size is moderate. Subjects in the utility maximization category had marginally fewer ($p<.07$) conservative holds ($M = 1.06$, $SD = 1.30$) than certainty seekers ($M = 3.91$, $SD = 4.25$, $d = .91$), but not when compared to subjects with an inconsistent approach ($M = 3.57$, $SD = 5.10$, $d = .67$). Both tests, however, had large effect sizes, suggesting strong differences between comparison groups. Finally, subjects in the utility maximization category had a marginally larger number ($p<.09$) of conservative holds ($M = 16.53$, $SD = 3.24$) than those with a certainty effect approach ($M = 13.29$, $SD = 4.86$, $d = .79$), but not when compared to subjects with an inconsistent approach ($M = 14.43$, $SD = 5.58$, $d = .46$), although the effect size is moderate.

6. Discussion and Conclusions

DDM research examines judgment and behavior in continuous and interactive environments characterized by periodic feedback and adjustment in decision strategy. While much of this research falls into one of two types – the traditional experimental approach or the individual differences approach – our study considers both. Experimentally, we examine behavior in a dice game that offers subjects immediate feedback and the opportunity to modify their strategy

over time. From an individual difference perspective, we examine characteristics thought to help explain behavior and performance in uncertain and risky decision contexts. We conclude that both perspectives offer insights on DDM. Experimentally, results indicate that our subjects tended to play aggressively, choosing to roll beyond the optimal threshold. While it is possible that employing 50 trials had some effect, as subjects were more aggressive in the last block of 25 trials, it also appears that asymmetry in player types mattered. Giving subjects a single turn to accrue points within each trial may have influenced decision behavior. This constraint, coupled with the strategic disadvantage of rolling first[iv] could have influenced subjects to play more aggressively.

Consistent with claims that it is challenging to find predictable relationships between "performance in dynamic micro-worlds and performance on psychometric tests" (Brehmer 2005, p. 90), our findings from the individual differences approach were mixed. We did not find support for the role of conscientiousness, suggesting that it is not a meaningful predictor of DDM behavior or performance. The lack of evidence that subjects approached equilibrium with repeated play may provide a secondary explanation for why we did not detect this hypothesized relationship.

Results were more conclusive with locus of control. However, rather than behaving conservatively, externals were more aggressive, choosing to roll when the optimal strategy recommended hold. This was the behavior we expected from internals given their sense of control over the environment. Upon reflection, this observed finding may be partially explained by the decision-making styles preferred by externals (spontaneous) versus those preferred by internals (rational). While marginally significant, there is support for our prediction that internals performed better than externals (had smaller mean difference scores), indicating that their decisions were more consistent with optimal play.

With respect to the relationship between DMs' BAS/BIS and their behavior in the CDG, we found that neither BAS-fun nor BAS-reward was significantly related to aggressive decision making. Instead, it appears that DMs lower on BAS-fun and BAS-reward make more optimal decisions and aggressive hold(not roll) decisions; albeit these relationships were marginally significant. Notably, it was DMs higher on BAS-reward who won more games; a finding that while contrary to our prediction and that of Su hr and Tsanadis (2007), is consistent with the positive performance found by Pothos et al, (2011). This finding as well as the non-significant relationship between BAS-fun and performance is consistent with findings of Franken and Muris (2005). Contrary to expectations, DMs high on BAS- drive were more inclined to make aggressive rather than optimal decisions and performed worse (higher mean deviation scores) than DMs not similarly motivated. It could be that subjects' steadfast pursuit of the valued, yet secondary goal of winning money led many to make roll decisions that limited their ability to achieve the primary goal of accumulating more points than the computer. Finally and as predicted, DMs higher on BIS did approach DDM more conservatively, just not to a statistically significant level. Likewise, the hypothesis predicting a negative relationship between BIS and game performance was supported. DMs who took steps to avoid aversive stimuli performed poorly relative to optimal play.

The links between the rational decision-making style and CDG performance ran contrary to expectations. It may be that limited avenues to search for information and alternatives (a feature of rational decision making) led these DMs to make incorrect roll/hold decisions. This conclusion seems reasonable considering that individuals driven by a steadfast pursuit of goals were more likely to have large mean deviation scores. Perhaps the desire to win as much money as possible in the context of limited information and/or the failure to learn the optimal strategy from prior rounds reduced the likelihood that rational DMs made the most strategically favorable decisions. If this speculation were true, it would be consistent with prior research claims (noted earlier) that DMs often select less than optimal alternatives.

Approaching significance and consistent with our prediction, DMs with a dependent decision-making style had lower CDG performance. The cause, however, is not due to conservative behavior, but rather, the tendency of DMs with a dependent style to engage in aggressive rolls and aggressive holds.

The intuitive, avoidant, and spontaneous decision-making styles were not related to either behavior or performance. We are particularly puzzled by the lack of significance with intuition and suggest that additional research is needed in this area. It would seem that intuition is a valuable attribute in this context. With the other two styles, we are not so concerned. Research indicates that DMs are not required to use all five styles and may prefer certain styles to others. Moreover, given the voluntary nature of our study, it is possible that few of our subjects were individuals with a strong avoidance style.

While we would have hoped for stronger relationships between our individual difference variables and CDG performance, our findings are in many respects and as noted, consistent with research suggesting that psychological scales seldom correlate with actual decision performance (Brehmer 1992). Recently, Brehmer (2005, p. 90) opined, "to understand how people cope with complex dynamic systems, one needs to abandon the focus on optimality that was inherited from traditional decision-theory and focus on the reasonable ways in which people cope with their world." He then suggested that boundedly rational DMs (like subjects in our study) might be content with satisficing.

While not the focus of our research, the relationships found among the study's psychological attributes were theoretically consistent and thus, worth mention. For example, conscientious subjects in our study typically possessed an internal locus of control, were responsive to drive and reward stimuli, and preferred a rational decision-making style. Subjects with an external locus of control were more responsive to fun seeking stimuli and tended to prefer dependent and spontaneous decision making styles. Finally, subjects' sensitive to negative stimuli (BIS) preferred avoidant and dependent decision-making styles. The relationships found between decision-making style and personality was consistent with prior research suggesting that while DMs may draw from multiple styles, they rarely rely heavily on opposing styles (Gambetti et al. 2008). Individuals whom we expected to be motivated by rewards and personal drive – those higher on conscientiousness and internal locus of control– were so disposed. Individuals with an internal locus were also less willing to try new, unplanned activities. Individuals with the opposite traits (low conscientious externals) had a greater disposition towards spontaneous,

dependent, and avoidant decision styles. It appears that these individuals also avoid aversive stimuli.

The correlations between behaviors and performance in the CDG were theoretically consistent, although they did not always relate to individual differences as expected. For example, conservative and aggressive holds were inversely related, whereas aggressive rolls were positively related to aggressive holds. Equilibrium rolls were positively related to the number of games won, aggressive rolls were positively related to mean deviation (poorer performance), and mean deviation was positively associated with aggressive rolls while negatively related to equilibrium rolls.

Some relationships related to subjects' response to our uncertainty under risk scenarios were also noteworthy. Utility maximizers behaved more aggressively, whereas certainty seekers behaved more conservatively. In kind, utility maximizers performed worse than certainty seekers in the CDG. Thus, in the context of this dynamic decision task, it was not in individuals' best interest to engage in aggressive behavior for rarely did it assist in either winning a game or approaching optimal play.

Our study is not without its limitations. For one, it is difficult to establish causality in the relationships examined. Although we selected psychological scales used in previous decision-making research, it is also possible that other scales may offer better predictive value. In addition, while subjects completed the survey prior to the CDG, we sampled their individual characteristics at a single point in time, with subjects completing the survey anywhere from 1 to 14 days in advance of the experiment. Although the measures are intended to reflect relatively stable traits, it is possible that subjects had different influential experiences between taking the survey and participating in the CDG. We also note that our subjects came exclusively from a student population. Generalizing results to other groups of DMs, and perhaps to situations where consequences are more significant, should therefore be done with caution.

Future research might also benefit from a more systematic approach to the study of DDM. For example, although the results from Sterman's (1989) experimental simulation have been replicated by others, the more common practice (including this study) is for researchers to adopt their own DDM paradigms. This makes comparisons across studies more difficult and tenuous. Adopting more similar task environments would be an important step toward a more systematic approach to DDM research. Research might also consider whether individual differences measures commonly used when studying decision making are appropriate predictors of behavior in dynamic decision tasks. Ours is not the first study that has reported weak or non-significant relationships between observed decision behavior and measures designed to predict said behavior. While we stop short of calling for the development of a different set of measures, researchers might consider the applicable scope of existing measures.

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[i] No incentives were tied to students' course grade.

[ii] Options C and D were constructed by eliminating a 66% chance of winning $2400 from Options A and B.

[iii] Optimal policy requires subjects to roll with *turn total* values less than fifteen, and hold with values greater than or equal to fifteen. This solution is available upon request.

[iv] Following optimal play, subjects could expect to win approximately 36% of the trials played.