GROUP MATCHING AND GROUP CONTINGENCIES

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ABSTRACT

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Matching relations identified by Herrnstein (1961) demonstrate behavior rates as a function of the ratio of reinforcement rates for alternative behaviors. The mathematical relationship identified by Herrnstein and modified by Baum (1974) was later applied to foraging animals, given the option of two patches (Kennedy & Gray, 1993). This application lead to the demonstration that animals (Baum & Kraft, 1998) and humans (Kraft & Baum, 2001) will engage in emergent group behavior that is distinct from individual matching relations. To more completely understand group matching in humans, group relations beyond foraging must be investigated. This study expands on the findings of Kraft and Baum (2001) and subsequent studies by introducing a group contingency for point earnings. Using an ABAB/BABA experimental design, interdependent group contingency was compared to individual contingency in two experimental sessions with different sets of participants. To better understand individual performance in matching rations, a temporal discounting measure was administered to participants (Beck & Triplett, 2009). Scores were transformed into area-under-the-curve values and correlated with total points earned. Participants were divided into teams based on their scores on a measure of temporal discounting with which they earned points during the group contingency conditions. An effect for group contingency was found for Experiment 2 but not Experiment 1. Order effects apparent in the data from both experiments are attributed to the BABA design used in Experiment 2. Results across the two experiments show a relationship between temporal discounting scores and total points earned for participants with valid temporal discounting scores (n = 13). Future research should expand upon these findings in applied contexts.

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To Pop-pop.
I’m sorry I missed you.

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CHAPTER 1

INTRODUCTION

Problem Statement

All behaviors have alternatives and the choice to perform one behavior over another is the subject of the matching law. Probabilities for each choice are relative, calculated as a ratio of reinforcement delivered and response frequencies per choice. History of reinforcement with each alternative predicts how responses will be allocated across choices.

Matching relations were developed studying pigeons using basic research designs (Herrnstein, 1961). Beyond basic research, applied demonstrations and applications of the matching law are only limited by the degree to which choice-making is controlled and reinforcement values are reliably measured. Matching equations have accounted for a statistically significant amount of variance in studies of sports plays (i.e., Reed, Critchfield, & Martens, 2006), preference during social interactions (i.e., Conger & Killeen, 1974), academic responding (i.e., Mace & Neef, 1996), aggressive and self-injurious behavior (i.e., Borrero & Vollmer, 2002), and consumer behavior (i.e, Hantula, Brockman, & Smith, 2008). It is a robust theory that has been demonstrated repeatedly, across numerous applications, with experimental designs and using actual behavioral responses as the dependent variable.

The matching law has been demonstrated with individual and group behavior alike. When applied to the performance of groups, unique findings are observed. Until recent research demonstrated otherwise (i.e., Critchfield & Atteburry, 2003; Kraft, Baum

& Burge, 2002; Kraft & Baum, 2001), the behavior of individuals was regarded as the most basic unit of the behavior of humans. Analysis of group behavior, however, suggests that groups perform differently than individuals, identifying group behavior as its own basic unit of human performance. Rather than analyzing the outcomes of group performance as the aggregate of individual choice-making, group behavior is characterized by outcomes that cannot be predicted by the performance of its members. Group performance often produces a higher degree of matching than the choices of its individual members (i.e., Critchfield & Atteberry, 2003; Kraft & Baum, 2001), suggesting the group itself is its own behavioral operator.

Group choice has been studied using a single contingency with all individuals competing for the most points (i.e., Critchfield & Atteberry, 2003; Kraft & Baum, 2001). Individuals' behavior was reinforced with points based on their choices. Sensitivity to reinforcement was differentially reinforced with greater point rewards. Total points led to cash prizes for the highest earners. This study introduced an interdependent group contingency to explore its effects on individual and group performance. Conditions alternated between individuals accruing points toward their own outcomes to a team approach for which individuals earned points toward their team's total. Degree of matching across conditions was compared.

Individual difference in matching relations has been explained using measures of temporal discounting (Critchfield & Atteberry, 2003). Temporal discounting refers to the weakening of consequences due to delay (Critchfield & Kollins, 2001) and is used to describe the degree to which an individual prefers to wait for larger rewards when smaller rewards delivered sooner are also available. This individual preference accounts for difference in reinforcement histories that affect choice-making on a concurrent schedule. The present study incorporated a temporal discounting measure to describe variance in individual sensitivity to matching relations, analyzed as total point accruals.

From school to work, optimizing behavioral performance is a curious problem. How does group membership affect individual motivation? Is a group as strong as its individual members or is it a unique entity that changes individual performance? How does group competition differ from individual competition? Does collaboration enhance or weaken individual performance? These questions pertain to all measures of human performance, from a student learning how to read to economic trends. The answers to these questions inform how to best direct ourselves and others so that motivation is maximized and maintained, supporting other constructs described as interest, concentration, and arousal. Matching relations provide a measurement tool that describes, very precisely, baseline and change in individual performance. In addition to being precise, matching relations account for a high degree of variance across studies and independent variables. The present study, using a highly internally-valid reversal design and matching relations as the dependent variable, provides new insights on the effect team membership has on both individual and group behavior.

For ease of reading, a glossary of terms is provided as Appendix A.

Statement of Purpose

The purpose of the present study was to expand upon the findings that group choice is distinct from the behavior of individuals. To date, group choice has been compared to individual choice with only the distribution of points across choice options manipulated. This study introduces a new contingency type as the independent variable. An interdependent group contingency was in effect following baseline conditions. The study examined degree of individual and group matching in both conditions. The outcome of the study contributes to the question of whether the behavior of individuals and groups is more or less sensitive to matching relations when reinforcement is sought using a team approach or individual competition.

CHAPTER 2

REVIEW OF THE LITERATURE

Matching Law Theory

Herrnstein (1961) described the matching law, a linear relationship between relative response rates and relative reinforcement rates represented with a simple mathematical proportion. Using pigeons and variable interval (VI) concurrent schedules of reinforcement, Herrnstein (1961) demonstrated a difference in response allocation as a function of reinforcement delivery rate of any single response. Further, response rate to a single schedule is relative to the reinforcement rate of the response alternative of the concurrent schedule. Since Herrnstein's identification of the matching law, research has provided replication and support for his findings with pigeons (e.g., Hunter & Davison, 1982), other animals (i.e., Matthews & Temple, 1979), and humans in both experimentally contrived (i.e., Neef, Mace, Shea, & Shade, 1992) and naturally-occurring contexts (i.e., Reed, Critchfield, & Martens, 2006). In sum, the matching law asserts that the magnitude of reinforcement delivery (rate, quality, and immediacy) of both responses reinforced in a concurrent schedule will predict the magnitude of response on either schedule.

Herrnstein's (1970) matching equation was originally identified a proportional relationship between reinforcement rates and behavior rates:

$$\frac{B_1}{B_1 + B_2} = \frac{r_1}{r_1 + r_2}$$

In the above equation, B_1 and B_2 are the number of responses an individual allocates toward each of the responses and r_1 and r_2 are the number of reinforcers obtained at each of the choice resource sites. The generalized matching equation (GME) was identified by Baum (1974) by changing proportions to ratios and adding two parameters to the equation identified by Herrnstein (1970).

$$\log \left[\frac{B_1}{B_2}\right] = a \log\left[\frac{R_1}{R_2}\right] + \log k$$

The slope is represented by *a* and *k* is the intercept (or bias). Slope values less than one indicate undermatching, values greater than one are overmatching, and a value equal to one is perfect matching (response choices optimize obtained reinforcement). Bias is the preference for one option over the other not accounted for by what the reinforcement ratio predicts. Any preference in response topography or difference in response effort between the two choices is reflected in the bias value.

External Validity and the Matching Law

Non-Educational Applications

The matching law was developed with basic research practices that use controlled settings and naïve animals. Much of the applied research with humans is in the special education setting. Before this research is explored, applications to non-educational contexts will be discussed. Leading off the review are research studies that applied the matching law to professional athletics. Reed, Critchfield, and Martens (2006) analyzed professional football plays as a concurrent choice condition of rushing and passing plays, identifying yardage gained as reinforcement. The ratio of yards gained in passing versus rushing plays was used as a predictor of actual passing and rushing plays called by coaches and offensive coordinators. When each team's season statistics were analyzed, the generalized matching law accounted for 76% of the variance in play calls. When calls were analyzed game-by-game for each team, the matching law equation accounted for at least 40%-85% of the variance in play calling for 28 of the 32 teams analyzed (median variance across the 28 teams was 62% of the variance account for by the matching law). Interested in how bias might account for game play situations, Stillings and Critchfield (2010) examined systematic changes in the situations describing each play and changes in play choices that cannot be accounted for by the generalized matching equation. These values are the bias. Upon examination of 192 games, findings show that the GME accounted for 40-70% of the variance in play choices (passing versus rushing) and the bias trends explained deviations from matching across several variables. The data showed that play calls were biased toward passing when 10 or more yards were needed to obtain a new set of downs and when two minutes or less remained to play in a half. Play calls were biased toward rushing when less than four yards were needed and when a team had possession within eights yards of the opponent's goal line.

Vollmer and Bourret (2000) also provided support for naturally-occurring matching law predictions in athletics when they examined the basketball-shooting behavior of basketball players. The ratio of three-point shots attempted to all shots attempted was compared to the ratio of reinforcement for three-point shots to all other shots in a study of basketball plays. Vollmer and Bourret (2000) found, for some players, an almost perfect correspondence between the proportion of shots attempted to the proportion of shots scored, when adjusting for reinforcement magnitude (total amount of points attained from the shot).

Social behavior may also be manipulated using relative difference in available reinforcement contingencies. Conger and Kileen (1974) demonstrated matching with college students using social reinforcement in the context of discussion. Two confederates reinforced the student participant with indications of agreement on two VI schedules and analyzed the direction of participant eye gaze as the dependent variable. The study found duration of eye gaze to match delivered reinforcement. These findings were corroborated by Borrero et al. (2007).

Consumer behavior may also be described and predicted with matching relations. In the case of online shopping, variables such as delay during purchasing and whether or not an item is in stock will predict participant response allocations across available vendors. Hantula, Brockman, and Smith (2008) provided participants with multiple stores from which to shop, each with a different ratio of items in-stock, or reinforcement ratio. Researchers found in-stock feedback to predict both time allocated to each store (r^2 = .96) and purchases made at the store (r^2 = .85). These findings support similar results of previous studies (e.g., Rajala & Hantula, 2000).

Educational Applications

Basic research demonstrated the effectiveness of the matching law and applied research of naturally-occurring behavior demonstrated the validity of the matching law with humans in non-laboratory settings. Now the parameters and utility of matching law application will be explored with regard to educational settings.

Reinforcement rate was demonstrated to adhere to matching law predictions in an educational setting. Martens, Lochner, and Kelly (1992) increased academic engagement of two fourth-grade boys by delivering social reinforcement for responding to various VI reinforcement schedules. Reinforcement was delivered on a VI 5, VI 4, VI 3, and VI 2 schedule for academic engagement. Increases in the density of the reinforcement schedule predicted increases in rates of academic engagement. Across the two participants, the matching law equation accounted for 99.1% and 87.6% of variance in academic engagement across sessions.

In addition to reinforcer rate, Neef, Mace, Shea and Shade (1992) demonstrated that reinforcer quality can be manipulated to produce differential response rates. Reinforcement quality was examined using a low quality reinforcer for one response (program money) and a high quality reinforcer for the other (nickels). The researchers demonstrated a preference for the high quality reinforcer schedule through reversal of reinforcer assignment per response. When nickels were used across both responses, the VI 30 second schedule was preferred over the VI 120 schedule. When the VI 120 for nickels and the VI 30 for program money were concurrently competing, more participant responses were allocated to the VI 120 nickels response choice.

Student choice may also be predicted by the matching law using variable ratio schedules. Mace, McCurdy, and Quigley (1990) examined whether choice of two work tasks could be manipulated by matching theory with an individual who was studying for the graduate equivalence degree (GED) test. Math problems were placed in two piles, one multiplication and the other division. The concurrent schedules were manipulated, delivering edibles with a continuous reinforcement schedule for one pile and a VR 2 schedule for the other. Though the student still responded to the leaner schedule, he had a strong preference for the richer schedule. Replicated using a more profoundly affected student and assembly tasks, the student exclusively preferred the richer schedule as the sessions progressed. The findings demonstrated the effectiveness of matching relations using a concurrent VR schedule. In addition, the researchers showed that increases in choice of one schedule means a decrease in choice of the other schedule. The suppressive effect the stronger schedule has on the alternative response is an important consideration for concurrent schedules used in school settings. That is, whenever a richer schedule of reinforcement is applied exclusively to one response, other responses will be suppressed, despite their academic value to the student.

The suppressive effect richer schedules have on relatively leaner schedules may be useful in understanding problem behaviors. Borrero and Vollmer (2002) conducted a functional analysis on the problem behaviors of four individuals with developmental disabilities. Once the reinforcing variable was identified for each student, descriptive data were analyzed retrospectively. The researchers found that proportion of problem behavior to the desired response approximately matched the proportion of reinforcement for problem behavior. That is, the differential reinforcement for problem behavior predicted problem behavior rates. Borrero and Vollmer (2002) provide evidence that the problem behavior was maintained with reinforcement of greater magnitude than the reinforcement provided for alternative responses on a concurrent schedule (when both responses are available). This finding suggests that differential reinforcement in favor of appropriate behavior would decrease problem behavior response rates, as predicted by the matching law.

Additionally, concurrent choice and the matching law have been demonstrated to effectively remediate avoidance behavior. Through the use of reversals, Hoch et al. (2002) demonstrated that original preference of participants with autism for alone play areas was changed to play areas containing a playmate when quality of toys or longer play time was paired with the playmate play area. Used this way, careful application of matching relations may change preferences or attenuate avoidance behavior.

Finally, though not in the educational setting, Baker and Rachlin (2002) used differential reinforcement of choice options to teach participants to cooperate. Using a scenario called the prisoner's dilemma, participants had the choice to cooperate or defect and received different amounts of reinforcement based on how their choice matched their opponent's choice. Using a computer program as the opponent, responses were reinforced based on the point allocations in Table 1.

Table 1.
Baker & Rachlin (2002) Prison's Dilemma Point Earnings

	Defect	Cooperate
Defect	2,2	6 (defect), 1(cooperate)
Cooperate	1 (cooperate), 6 (defect)	5, 5

Using the above point earnings, players benefit when the opponent cooperates. In the short-term, players benefit the most when they do not cooperate but their opponent does cooperate, by earning six points compared to five points when both cooperate. When several rounds are played, individual players benefit by reinforcing their opponent's cooperation. This means making the choice to cooperate, though one point less than a possible outcome for selecting defect, will garner the most points over time. These methods provide a unique analysis of matching, whereby the behavior of another and the interaction of players over time influence reinforcement and, subsequently, choices between the two response options. Baker and Rachlin (2002) conducted the experiment twice. For the first experiment, researchers informed participants that they were playing against a computer (n = 24). When the mean percentage of cooperation choices for the first 20 trials was compared to the final 20 trials, a significant increase in participant cooperation was observed ($p < 0.05$). Participants were optimizing reinforcement received over the long-term by selecting the option that maintained reinforcement gains, rather than that which returned the greatest amount of points on any single trial. The experiment was then repeated with a new set of participants (n = 18). The methodology remained the same except the researchers led the participants to believe they were playing another person (though they were actually playing against the computer). Responses were still submitted on a computer, but the display was changed to support the notion that another human was the opponent. During these trials, no significant increase in mean cooperation choices among participants was observed when the first 20 trials were compared to the last 20 trials (data were analyzed in two groups, n = 8, $p = 0.85$, n =

10, $p = 0.12$). These findings support the role of context in learning and cooperation. Rather than appealing to the popular notions of altruism (choices to cooperate) and selfishness (choices to defect), the authors explain the findings as a difference in behavioral strategies as a function of social context. Related to this study, exploration of the difference in individual and team play not only introduced a new contingency, but a new social context.

Group Matching as Emergent Behavior

Group matching was first described by Baum and Kraft (1998) when emergent flock behavior was observed in pigeons given the choice of two feeding areas. Group matching came out of ecological theory applied to foraging behavior. Fretwell and Lucas (1970) described the Ideal Free Distribution (IFD), the tendency for groups of animals to maximize foraging efforts by dispersing across areas relative to reinforcement available. Kennedy and Gray (1993) provided an equation adapted from the generalized matching equation to calculate ideal free distribution:

$$\log \left[\frac{N_1}{N_2}\right] = a \log\left[\frac{R_1}{R_2}\right] + \log b$$

The equation is mathematically equivalent to the generalized matching equation. For this equation, the N terms are the number of animals searching patches 1 and 2 and the R terms represent resources obtained at the respective patches. The slope, *a*, describes the linear function relating the two ratios. Slope is often used to describe group sensitivity to the difference in available resources (i.e., Kraft & Baum, 2001). Two deviations from matching are undermatching and overmatching (Baum, 1974). Undermatching is too few choices for the richer option and overmatching is too many. Systematic bias, log *b,* describes the degree of under or over matching.

Kennedy and Gray (1993) used the matching law to measure difference in the distribution of animals per resources available. The article concludes that ideal free distribution does not accurately predict the distribution of foraging animals, as distribution consistently undermatches available resources. The article also suggests future studies on ideal free distribution consider the relative and absolute resource availability, number of animals, perceptual abilities of animals (rejected by Baum, 1998), competitive interactions, competitive abilities of animals, and the effect of travel between sites (rejected by Baum, 1998). Similar to Kennedy and Gray's (1993) perceptual ability of animals explanation for undermatching, Abrahams (1986) suggests that imperfect information regarding available resources on any food patch will lead to underuse of patches with many resources and overuse of patches with relatively low resources.

To investigate the possible reasons for Kennedy and Gray's (1993) undermatching further, Baum and Kraft (1998) tested three of the reasons for undermatching raised by Kennedy and Gray (1993): competition with other forargers, travel between sites, and perceptual information regarding the resources at each site. Using pigeons and feed, Baum and Kraft (1998) implemented five phases as follows: separated areas (low competition with travel), troughs (moderate competition with travel), bowls (high competition with travel), adjacent areas (low competition with no travel), and adjacent areas (low competition with a visual barrier). Findings show that competition varied inversely with the size of the patches, or bias for the leaner option. They also found that competition lowered the flock's sensitivity to resource distribution, as the birds were less sensitive to resource distribution with the bowls (high-competition) than with the troughs (low competition). It was also found that sensitivity increased when travel was required (a statistically significant finding). The pigeons switched less when travel was involved. The authors concluded that switching interference, as opposed to interference within the patches, produced undermatching and travel itself had only a small effect on flock distribution. This finding is consistent with experiments on operant choice. Also, a visual barrier blocking other choices had no effect on sensitivity. This suggests that comparison between patches occurs sequentially rather than simultaneously.

Upon analyzing the individual behavior of the pigeons and comparing degree of matching to the behavior of the flock (IFD), Baum and Kraft (1998) conclude that individual behavior does not mirror the behavior of the flock. The authors refer to the flock behavior as emergent, explaining that the flock's behavior cannot be accounted for by the aggregate of the behavior of its individuals. Rather it emerged from dynamic interactions between the individual members.

> "Whatever the rules that govern behavior of the individuals, they differ from the regularities at the level of the group, but they work in aggregate so as to produce the performance of the group." (Baum & Kraft, 1998, p. 243)

Describing flock behavior as emergent is supported by the lack of consistency across birds and differences from session to session within birds regarding preference or probability of switching. This disorder within subject behavior suggests that orderliness of the flock as a whole is an emergent behavior, which they will later describe as "group choice" in Kraft and Baum (2001).

Group Matching and Humans

To explore group choice with human participants, Sokolowaki, Tonneau, and Baque (1999) designed a new methodology that approximates the foraging environment to replicate ideal free distribution in humans. Participants were provided red and green cards for choice-making. During each trial of a game (20 trials in a game), the participants chose either the red or green card and placed it on their card holder for all to see. Tokens were collected from each participant. Tokens from participants that chose the red card were placed in a red box and tokens from participants that chose green were placed in a green box. The experimenter then drew a total of ten tokens from the boxes, with distribution across colors changing with each game. The participant corresponding to each token drawn received one point. The ratios of green to red for the drawings of the five games were as follows: 6:4, 1:9, 8:2, 3:7, and 5:5. At the end of each game, the participants with the most points won 52 francs. The experiment found similar rates of matching consistent with findings in other species. These findings support the application of behavioral ecology models to human choice-making.

To test whether group behavior is distinguished in humans as it is for pigeons, Kraft and Baum (2001) tested group choice using methodology adapted from Sokolowski et al (1999). Participants were given the choice of two colors, red or blue. At each choice trial, participants chose a color, had the opportunity to see the choices of others and to change their own and then submitted their final choice (referred to as after-switch data in the analysis). Rather than having a certain probability for winning points, all participants choosing a color shared the points allocated to that color (per predetermined ratios). For each block of trials, ratio of points allocated to each color choice changed, then remained consistent for each trial within the block.

Upon visual analysis of the group-level data, Kraft and Baum (2001) made three observations of the trial-to-trial data: card choices approximated ideal free distribution predictions, the before-switch data ($a = 0.84$, $r^2 = 0.99$) were more variable than the after-switch data ($a = 0.91$, $r^2 = 0.99$), and group patterns stabilized after five or six trials. Analysis showed that when perfect matching was not possible with the given number of participants with the given points ratio, undermatching was preferred by the group. What could seem like cooperation are actually highly varied individual patterns of responding that worked out to optimize point earnings for all. Individual responses were highly variable, supporting previous findings that group matching is distinct from individual earnings. For example, when the earnings ratio was 2:1, few individuals distributed their responses 2:1. The authors conclude that the variance in individual choice contrasted with the high point earnings of individuals, ideal free distribution, and deny the possibility that group choice is simply the sum of individual choices and is rather its own behavior. The study was repeated with two new groups of participants using a single session rather than two sessions to complete the blocks. This consideration was intended to further refine the methodology. To accomplish this, the total number of trials per block was reduced. The same trend of group matching with highly variable individual responses continued, though undermatching was higher in this second experiment, presumably due to the lower number of trials per block. A high degree of group matching was found for both experiments, both before-switch (r^2=0.96, 0.97) and after-switch (r^2=0.99, 0.99).

Methodology of Group Choice

After Kraft and Baum (2001) demonstrated group choice as a separate behavior from individual choice in humans, Kraft, Baum, and Burge (2002) tested methodologies by which to study group choice. The authors compared points shared evenly to probabilistic choices across various choice-making responses. In Experiment 1, points shared evenly was explored using choice of subgroup location (individual physically moved to another chair to make choice), choice of subgroup by displaying cards (raising one of two colored cards in the air), and making a choice on a computer of one of two cybergroups. For the first block of experiments, undermatching was greater for the initial choices and reduced for the final choices. This was evidence that the participants were sensitive to resource ratios. Also, variability in number of participants choosing each group was higher for the first few trials of each block. Variability decreased as the session continued for the chair and colored card responses but the cybergroup remained highly variable throughout. Use of the colored cards produced the best matching, though results were close to the chair methodology.

The card and cybergroup choice-making responses were repeated in two additional experiments using probabilistic choice making. Rather than sharing the points evenly among participants for each choice option, the total points available to each group were awarded to one group member chosen randomly every trial. Point ratios were replaced with rate of reinforcement delivery, preset by the experiments for all the trials in each block. Two groups of participants were tested. For one group, the points were delivered to a random participant on every trial and for the other group points were delivered to a random participant intermittently. The point distribution ratio was determined by how often the leaner group received points (if every fifth time, the ratio was 5:1). The results showed that probabilistically distributing points interfered with the ideal free distribution of group choice and most individuals in a group choice situation were not sensitive to their obtained points in the same manner as the group. Results from the probabilistic choice-making were more variable than the shared evenly experiments.

Comparing the two sets of experiments, undermatching was greater in the second set of experiments (probabilistic choice making). The groups in the second set of experiments made choices that were more steady and reliable but with lower than expected sensitivity to resource ratios. The authors speculate that lack of reinforcement could lead to indifference (perhaps more precisely described as extinction). Regarding response topography, the chair and card methods resulted in lower variability of responses across trials.

To better understand the methodology for IFD studies, they are compared in Table. 2.

Table 2.
IFD Studies with Humans: Methodology Used and Results Attained

Study	Participant Response	# of participants per session	# of sessions & duration	Ratios used	# of trials / condition	# of conditions / session	Results
Sokolowski, Tonneau & Baque (1999)	Choice of two colors, randomly selected winners per color receive one point (10 winners total, distribution across colors based on ratio)	15	1 x 3-hr	6:4, 1:9, 8:2, 3:7, 5:5	20	5	s = 0.67 r^2 = 0.99
Kraft & Baum (2001) Exp 1	Choice of two colors, points for each color (per ratio) divided among participants who chose that color	13	2 blocks/ day x 4 days	1:5, 2:1, 5:1, 1:2, 1:2, 5:1, 2:1, 1:5	40	8	s = 0.91 r^2 = 0.99
Kraft & Baum (2001) Exp 2	Choice of two colors, points for each color (per ratio) divided among participants who chose that color	2 groups: 10 & 16	1 x 2-hr / group	1:2, 1:5, 2:1, 5:1, 1:2	20	5	Group A s = 0.77, r^2 = 0.99 Group B s = 0.80, r^2 = 0.99
Kraft, Baum & Burge (2002) Exp 1a	Choice of two rows of chairs on which to sit points for each row (per ratio) divided among participants who chose that color, points shared evenly between participants per each color	17	2 x 2-hr	1:2, 5:1, 2:1, 1:5, 1:2, 5:1, 1:5, 2:1, 1:2, 5:1	26	10	s = 0.79 r^2 = 0.97
Kraft, Baum & Burge (2002) Exp 1b	Choice of two colors, points for each color (per ratio) divided among participants who chose that color, points shared evenly between participants per each color	18	2 x 2-hr	1:2, 1:5, 2:1, 5:1, 1:2, 5:1, 1:5, 2:1, 1:2, 5:1, 2:1	10	11	s = 0.95 r^2 = 0.99
Kraft, Baum & Burge (2002) Exp 1c	Choice of two colors, selected on monitor with other participants' choices displayed, points shared evenly between participants per each color	23	1 x 2-hr	5:1, 1:2, 1:5, 1:1, 3:1, 1:2, 1:5, 3:1, 5:1	16	9	s = 0.88 r^2 = 0.99
Kraft, Baum & Burge (2002) Exp 2a	Choice of two colors, points for each color divided among participants who chose it, points awarded to randomly selected participant per each color (one subgroup received points every trial, the other intermittent trials)	17	1 x 2-hr	5:1, 7:15, 1:5, 15:7, 5:1, 8:15, 15:8, 5:1, 1:5, 7:15, 5:1, 7:15, 1:5, 5:1	15	14	s = 0.60 r^2 = 0.88

Table 2 continued.

IFD Studies with Humans: Methodology Used and Results Attained

Study	Participant Response	# of participants per session	# of sessions & duration	Ratios used	# of trials / condition	# of conditions / session	Results
Kraft, Baum & Burge (2002) Exp 2b	Choice of two colors, selected on monitor with other participants' choices displayed, points awarded to randomly selected participant per each color (one subgroup received points every trial, the other received points at intermittent trials)	23	1 x 2-hr	2:1,1:5, 1:2, 5:1, 2:1	30	5	s = 0.53 r^2 = 0.81
Critchfield & Atteberry (2003) Study 1 Cohort 1	Same as Madden et al (2002, Experiment 2) Choice of two colors, points for each color (per ratio) divided among participants who chose that color, no talking or switching	46 (into small groups *n* = 9-12)	2 x 0.5-hr	1:2, 9:1, 1:5, 4:1	16	2	15 small groups across the two cohorts: median s = 0.72 range s = 0.36-1.3 r^2 = 0.94 – 0.99
Critchfield & Atteberry (2003) Study 1 Cohort 2	Same as Madden et al (2002, Experiment 2) Choice of two colors, points for each color (per ratio) divided among participants who chose that color, no talking or switching	64 (into small groups *n* = 9-12)	1 x 1-hr	5:1, 2:1, 1:2, 1:5	20	4	
Critchfield & Atteberry (2003) Study 2	Same as Madden et al (2002, Experiment 2) Choice of two colors, points for each color (per ratio) divided among participants who chose that color, no talking or switching	41 (4 groups, *n* = 9-12)	1 x 1-hr	5:1, 2:1, 1:2, 1:5	20	4	Equation 1 – range s =0.77–0.86 range *r* =0.93-0.99 Equation 2 – range s =1.06–0.84 range *r* =0.96-0.99

*There were at least 20 trials, but trials continued if the mean number of participants choosing the preferred color on the last three trials deviated by more than 5% from the mean number of participants making this choice on the preceding three trials or if there were visually apparent trends across the final 10 trials.

** The trials lasted at least 20 minutes, but continued until the behavior of the group was judged to be stable. Stability was assessed by comparing the mean number of participants in the red zone in the last five minutes with the mean number from this zone from the preceding 5 minutes. If these means deviated by less than one and no trends were visually apparent, the group's behavior was determined to be stable and the condition was terminated.

Some common themes may be observed across studies. With regard to number of participants, many studies selected a prime number for total participants. This consideration protects the integrity of participant choice selections as intuitive and not mathematically calculated, as prime numbers make perfect matching more difficult for participants to calculate mathematically and prevent participants counting other participant choices to influence their decisions. For the same purpose, a measure taken by some researchers was to use ratios that are unusual (i.e. Kraft, Baum, & Burge, 2002, Exp 2a; Critchfield & Atteberry, Study 1 Cohort 1). Finally, many of the studies consisted of two experiments that utilized two different participant sets. This allowed researchers to slightly change methodology to gain a clearer understanding of their findings.

An alternative to the discrete trial choice selections made in the studies reviewed in Table 1 is ongoing choice selections using a variable interval schedule. Madden, Peden, and Yamaguchi (2002) replicated the methodology of Kraft and Baum (2001) and then compared the results to an experiment with a methodology that more closely resembles actual animal habitat matching. Participants were provided the choice of two areas in which to stand, separated by a neutral area in between. Two different VI schedules were operating in the areas, one more frequent offering fewer points as the reinforcer and the other less frequent with a greater number of points delivered as reinforcement. This methodology allowed investigators to examine continuous behavior (occupying a certain space), which is more similar to the foraging behavior of animals for which the ideal free distribution was originally observed. Madden, Peden, and Yamaguchi (2002) hypothesized that group sensitivity to reinforcement would be greater (closest to 1) than that found using the Kraft and Baum (2001) methodology. Findings show the lowest degree of matching (greatest amount of undermatching) for the experiment using VI schedules and space occupied methodology. The slope for the Kraft and Baum (2001) methodology was 0.86 and the new methodology using VI schedules and space occupied produced a slope of 0.71. Though both show undermatching, Madden, Peden, and Yamaguchi (2002) were unable to support their hypothesis that methodology more similar to actual foraging would minimize undermatching. Authors attribute the difference to participants having less knowledge of the relative resources available in the two resource sites.

Temporal Discounting

Temporal discounting (TD) refers to the weakening of consequence effects due to delay (Critchfield & Kollins, 2001). A derivative of the matching law, discounting is used to describe individual differences in matching relations, explaining deviations from matching on the individual-level. Temporal discounting may be used interchangeably with a definition of impulsivity that describes a tendency to act on a whim and disregard more rational long-term strategies for success (Madden & Johnson, 2010). This impulsive tendency characterizes clinical problems such as gambling, drug use, and hyperactivity. For all these clinical problems, the pattern of behaving favors reinforcers delivered immediately, such as a drink, over the more desired but less immediately available alternative, the close relationships and satisfaction of sober living.

In the context of foraging, Stevens and Stephens (2010) describe the adaptive nature of the high-discounting rates that characterizes impulsivity. Foraging animals need to make decisions regarding time allocation so that as much food is attained as possible. A woodpecker, they describe, can clean all the worms out of a single tree or grab the easy worms and quickly move on to another stocked tree. The decision that pays off for the woodpecker depends on the available resources. When there are only a couple trees in the forest with worms, a more thorough approach is best. However, when several trees with worms are available, the woodpecker might find more worms by moving quickly from tree to tree, grabbing what's easily accessed and moving on. This analogy might be applied to a child looking for adult attention. When attention comes in spurts and is delivered at short intervals, the child learns to emit a variety of behaviors at short intervals, so as to maximize available reinforcement. When adult attention is maintained, the child may opt, like the woodpecker with a single worm tree, to maintain a single behavior over a longer period of time. These scenarios support the adaptive nature of acting immediately, despite the preference for reinforcers and achievements that require the investment of time.

For this experiment, temporal discounting was measured and analyzed to help explain variance at the individual level. To some degree, differences in degree of undermatching are expected across participants. A discounting measure may account for the variance in choice-making and difference in reinforcement attained between individuals.

Temporal discounting is described using an equation derived from the matching law (Mazur, 1987):

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

For the equation above, *V* is the time-discounted value of the reward, *A* is the subjective present value (amount of reinforcement), *D* is the total delay to hypothetical delivery, *k* is a discounting coefficient (slope of the delay curve), and 1 is a constant. A larger *k* denotes more discounting and a smaller *k* less. Per the equation, a steeper slope denotes a greater preference for immediate, smaller rewards over a delayed larger reward. Though solving for *k* is cited more often in studies (see Critchfield & Kollins, 2001), temporal discounting may be alternatively calculated using area under the curve method (AUC) method described by Myerson, Green, and Warusawitharana (2001). Though Smith and Hantula (2008) describe inferior test-retest reliability and convergent validity compared to *k*, AUC analysis is considered easier as it can be done in a simple spreadsheet with no curve-fitting.

To measure temporal discounting, participants are asked to choose between a larger later reward (LL) and a smaller sooner reward (SS). There are two types of hypothetical monetary choice tasks used in temporal discouting measures, repeated binary choice and fill-in-the-blank (FITB). Repeated binary choice method presents participants with two hypothetical monetary values, one which is available immediately and the other available following an indicated delay. Delay values remain constant as SS reward values systematically increase (or decrease) with each presentation. Equivalence points are recorded as the values at which participants change their response from LL to SS reward (or SS to LL, depending on whether the values are presented in ascending or descending order). FITB method of temporal discounting assessment presents participants with a hypothetical LL values for which participants identify a SS reward equivalent. Rather than choosing between two options, participants are creating a value and writing it in as their response. Though FITB method is a quicker method of assessment, it is considered more demanding cognitively because participants create their own SS values. Smith and Hantula (2008) evaluated temporal discounting tasks. Modes of administration, computer or pencil and paper, were also compared. Findings show a participant preference for binary choices and no significant difference in modes of administration. Regarding task type, steeper discounting was found for binary choice than FITB tasks. Within subject differences were found with regard to task type (binary choice or FITB; $r = 0.45$, p<.001) and reward magnitude (LL values; $r = 0.45$, p<.01) using the AUC method of analysis. Using k estimates, significant main effects were for reward magnitude only ($r = 0.71$, p<.000). These findings support the use of binary choice tasks over FITB.

To combine the short administration time of the fill-in-the-blank format with the less cognitive-demanding binary choice format, Beck and Triplett (2009) propose a group administered format derived from the original binary choice format described by Rachlin, Raineri, and Cross (1991). Rather than repeated presentation of two-options, participants are presented with all choices at once and select their preference for each indicated time interval (Appendix B). This not only shortens administration time, it also allows the researcher to collect data from many participants at once in a short amount of time.

In the context of a group-matching study, temporal discounting is proposed as a useful measure to explain individual differences in matching. Critchfield and Atteberry (2003) examined individual differences on a temporal discounting measure and tendency to undermatch. The authors speculated that the temporal discounting measure (using binary choices constructed as a pencil and paper flow chart) would predict degree of matching over time. Individuals who make selections for the smaller sooner reward on the of temporal discounting measure were considered to be more impulsive. Authors predicted that participants characterized as “self-controlled” by the of temporal discounting index would be most successful in earning points over their competitors, as they would more strongly prefer the rich resource patch. Using the group matching methodology described by Kraft and Baum (2001) and modified by Madden, Peden andYamaguchi (2002, Exp 2), Critchfield and Atteberry (2003) conducted group matching trials with 172 participants divided among 17 groups. Results showed that of temporal discounting was significantly related to sensitivity to matching relations ($p < .01$) for participants with the highest third and lowest third scores on the of temporal discounting measure. Individuals described as impulsive by their of temporal discounting score (using area-under-the-curve analysis) tended to choose the richer patch less often, switch between patches more often, obtain the better of two point possibilities less often, and earn fewer points overall than their less-impulsive competitors. These findings support the use of of temporal discounting to explain undermatching as an individual difference between participants.

For the purpose of this study, temporal discounting will be collected as a supplemental measure to help explain matching relations using the Beck and Triplett (2009) group-administered pencil and paper of temporal discounting assessment. This measure was chosen because it was found to be more appealing to participants (Smith & Hantula, 2008) and requires less administration time (compared to traditional binary choice methodology). Based on previous findings, it is expected that temporal discounting scores will predict the matching of individuals.

Group Contingencies

Group behavior methodology employs individual contingencies in the context of group behavior. Alternatively, a group contingency may be used to compare response rates and understand group and individual matching better. Group contingencies are behavior-consequence relationships in which the receipt of reinforcing or aversive stimuli for one or more of the group members depends, at least in part, on the behavior of some other group members (Neumann, 1977). Axelrod (1998) identifies two main types of group contingencies: consequence sharing and interdependent group contingency. Consequence sharing group contingencies are characterized by a consequence delivered to the group based on the performances of an individual group member or small subset of the group. An interdependent group contingency makes group outcomes contingent on group performance. The behavior of all group members determines the consequences for the entire group. This contingency is most like a team approach, where the performance of individual members is not measured, rather the performance is measured as a collective effort and the outcome is shared by all. Sports teams, music band competitions, and community conservation efforts are all governed by interdependent group contingencies.

The group matching methodology reviewed above uses individual contingencies exclusively. To understand how individuals perform when placed on a team for which they collectively accrue points for individual prizes, an interdependent group contingency may be implemented. When individual performance is part of the group aggregate and individual gains may be attained with varying degrees of performance, what happens to individual matching? Likewise, how does the dynamic of a team approach change group behavior? That is, will ideal free distribution be affected when the contingency is manipulated?

Research Questions

1. What are the results of a replication of Critchfield and Atteberry (2003)?
2. Compared to individual contingency, how does interdependent group contingency affect individual degree of matching?
3. Compared to individual contingency, how does interdependent group contingency, using three competing teams, affect group matching (ideal free distribution)?
4. Which of the three teams comprised the best arrangement for team play (garnered the most points across conditions)?

CHAPTER 3

METHODOLOGY

Pilot

The purpose of the pilot was to implement the methods with the opportunity to refine procedures prior to conducting Experiments 1 and 2.

Participants

Six Temple student volunteers were recruited from Temple's Sona database for psychology research to participate in a single 2-hour experimental session in a classroom on Temple's main campus. Student participants were awarded research credits as their primary incentive for participation.   Participants were asked their age, sex, major in college, and year of study on the informed consent form. Pilot matching data are not referenced in the Results chapter so Pilot participant demographic data will not be disclosed.

Setting

Participants met in a classroom on Temple's main campus. Participants were seated in desks arranged in an oval, with the experimenter seated at the head. The data collector was seated opposite the experimenter and worked silently recording responses.

Materials

Following the design of Kraft and Baum (2001), participants received a blue and red card, a pen, and a score sheet. The score sheet consisted of a table, with a row for each trial and a column for color chosen and points received. Participants used the blue and red cards as choice indicators for the baseline conditions and received different cards for the intervention conditions. The intervention choice indicators were blue and red with an outline in a different color, indicating each participant's team membership. Color assignments for the three teams were white, black, and white and black stripes. Choice indicators for both the baseline and intervention sessions indicated the participant number in bold black numbers in the center of the card. Participant numbers were also displayed on each desk. With six participants and three teams, there were two participants on each team.

Design

Using an ABAB design, the dependent variable was degree of matching based on the generalized matching equation (for analysis of individuals) and the Ideal Free Distribution (IFD) equation (for group matching). In addition, a temporal discounting measure was administered to determine team assignments and help explain individual variance in matching relations. The independent variable was the interdependent group contingency.

Procedure

All six participant registration slots were filled and all six participants came to the study. The 2-hour session consisted of a temporal discounting measure followed by the four experimental conditions. The temporal discounting measure was the pencil-and-paper, group-administered measure developed by Beck and Triplett (2009, Appendix B) with modified directions (Appendix C). Each condition was presented twice (ABAB) and consisted of two blocks of 20 trials per each presentation. There was also one practice block of 10 trials, prior to Condition 1, to allow participants to become familiar with the procedure. The contingencies of the blocks were counterbalanced across baseline and treatment conditions, as shown in Table 3. The design of ratio assignments per block is such that the block assignments for each experimental condition are different.

Table 3
Pilot Block Distribution Ratios (red:blue) by Experimental Condition

	Block 1	Block 2
PRACTICE	30:90	----
Condition 1: Baseline	20:100	40:80
Condition 2: Introduce	100:20	80:40
Condition 1: Baseline	40:80	100:20
Condition 2: Introduce	80:40	20:100

For each trial, participants were asked to choose one of two color options on the experimenter's verbal cue, "Choose now". Color choices were recorded by the data collector and points earned for each color were announced. The next trial began with the experiment's cue. Total points available for each color option were distributed between the two options with ratios that changed every 20 trials, or at the start of every block. All participants selecting the same color split evenly the points allocated to that color, per the ratios. For example, if the ratio was 100:20, then there are 100 points available for red and 20 points available for blue. If 10 participants select red and four select blue, the participants selecting red would receive 10 points each, and the participants selecting blue would receive five points each. Perfect ideal free distribution for this example would mean that participants split their choices as a group 5:1 across the two colors. Participants made one selection per trial and there was no opportunity for changing a response after receiving information on what other participants have chosen. For the baseline conditions the participants earned points toward their own individual totals. At the end of each baseline block, the same number of winners was selected as there are members of each team (two for the pilot). For the intervention blocks, all members of team with the most points received a ticket. The two participants with the most points at the end of a block earned a ticket for the prize drawing at the end of the session. Seven tickets were drawn for gift cards for itunes and local business, ranging from $5 to $40.

Condition 1: Baseline

For the baseline blocks, participants were ranked according to points accrued and the two participants with the most points at the end of the block received a ticket.

Condition 2: Interdependent Group Contingency

During the independent variable conditions, the contingency changed from individual contingencies to interdependent group contingency. Participants were assigned to teams to which they contributed their point earnings. There were three teams of two participants. Teams were assigned using the scores on the temporal discounting measure: high-scorers, low-scorers, and a combination of high and low. To determine team assignments, all scores were arranged in order from highest to lowest. Beginning with the second highest score, every third participant in the arrangement (from highest to lowest scores) was assigned to the combination team (black). Of the remaining four participants, the highest two were assigned the high-scoring team (white) and the lowest two scores were assigned to the low-scoring team (white and black stripes). Based on team assignment, all participants received a new set of cards, red and blue with a border of their team color. This allowed participants to know which other participant was on their team. Seating assignments did not change and individuals were instructed not to communicate, verbally or otherwise, with any other participant. The team with the most points at the end of the trial received a ticket for each team member.

A data collector recorded participant choices. As a back-up, and so participants could be aware of their trends and points accrued, participants were also asked to record their choices on score cards. The data collector used an Excel spreadsheet to enter the data. Points per trial and total points were computed automatically using Excel syntax.

Prior to the temporal discounting measure, participants signed an informed consent agreement and received an introduction to the procedure. Prior to the first trial, the experimenter read the instructions aloud as the participants read along. They read as follows (adapted from Madden, Pedden, & Yamaguchi, 2002):

> "Your task is to earn as many points as possible. The two players who earn the most points at the end of each round will receive a ticket for a prize drawing occurring at the end of the session. You can earn points by picking either the red or blue card. A certain number of points are assigned to each color, and you share the points with the other players who choose the same color. So, for example, if 100 points are assigned to red and 10 players choose red, then they each receive 10 points. If there are 20 points assigned to red and 4 players choose red, then they each receive 5 points. The number of points that I assign to each color will not change until the end of the round. When the point assignments change, I will let you know. When I say "choose now" you must hold up your card right away. If you do not, you could earn no points for that choice. After each choice, you must write down the color you chose and the number of points you earned.

> Dishonest reporting of earned points will disqualify you from receiving a ticket. There is no talking during the game."

Following baseline, additional scripted instructions were distributed to participants and read aloud by the experimenter.

> "Now we will continue the game using teams. There are three teams: white, black, and black and white stripes. You know which team you are on based on the border on your color cards. You will be earning points for your team. All the members of the team with the most points at the end of each round will receive a ticket for the prize drawing. If there is a tie at the end of the round, the game will continue for three more turns. Just like with the previous game, point assignments will change at the end of each round. Please remember there is no talking during the game."

Pilot Results

The purpose of the pilot was to test the methods for problems. The participant data collected during the pilot were of little use due to the fact that the total number of participants was so low (two participants were on each of the three teams) and group matching was achieved so consistently (see below).

There were three procedure problems detected from the pilot: participant understanding of the of temporal discounting measure, participants learning the ratios too quickly, and participant fatigue. Regarding the of temporal discounting measure, participants had a difficult time understanding the instructions and many did not complete the measure correctly. For the measure to be considered completed correctly, selected values decrease across the time frames presented. If the selected values remain constant, the lack of variance makes the calculated score meaningless. Likewise, if values selected increase and decrease as the time increases, then the specified time is not controlling the responses and the calculated score will not be useful. Finally, reverse discounting, when participants select values that increase as the time increases does not follow the same logic with which the hypothetical scenarios were designed. That is not to say that the participant responses are random or careless, but that there is likely a misunderstanding with the directions or the scenario presented. For these reasons, only of temporal discounting measures with selections that trend down were considered valid and scored. Of the six pilot participants, two completed the measure correctly. Solutions to this problem were explored and the method of administration of the of temporal discounting measure changed for Experiments 1 and 2 (see *Procedures* below).

Regarding the blocks of trials, participants quickly learned the ratios and made consistent choices for optimal outcomes. Per the Critchfield and Atteburry (2003) methods, the reinforcement ratios for each block were announced at the beginning of the block. With this information, participants knew before the trials began which color was the rich choice. Combined with the small group size, both the group and individuals began matching optimally at the beginning of the session, with little variability in the data as the trials progressed.

Finally, participants showed signs of fatigue during the second half of the session. This observation may be related to the ease of optimal choice selection described above.

All the trials were completed comfortably within the two-hour session and participants understood the directions as evidenced by a high degree of group matching.

Experiments 1 and 2

Participants

Participants were two groups of 12 student volunteers. Desired participation was 18 (20 students registered for each session); however, it was convenient that the total number of students who participated was a multiple of three (for three teams) and constant across the two sessions. Each group participated in one 2-hour session. Student participants were awarded research credits as their primary incentive for participation.   Participants were asked their age, sex, major in college, and year of study on the informed consent form. Demographic data will be reported in aggregate to remain consistent with prior research.

Procedure

Based on the findings of the pilot, some changes were made to the methods for Experiments 1 and 2. To address confusion over the of temporal discounting measure, a narrative was created and read by the experimenter prior to distribution of the of temporal discounting measure. The narrative was as follows:

> "Before we begin the game we have six questions to ask you. These questions are all very similar so it is important you understand what we are asking. You will be presented with a hypothetical situation pertaining to money. The questions will be distributed after I read this narrative. The narrative I am about to read is a

hypothetical situation that relates to the questions you will be asked. Please listen carefully."

"Brittany won $8 million dollars in the lottery. With the way the lottery operates, they don't have $8 million to give her all at once. The lottery tells Brittany that she can choose whether she would like to wait 10 years to receive the $8 million or accept a lesser amount, $5 million, right away. Brittany needs to decide if she wants to take less money now or wait 10 years for the full amount. What would you do if you were in Brittany's situation? Think about whether you would accept the $5 million today or wait ten years for the full $8 million. Do not say your answer out loud, just reflect on what your answer would be."

"Here is another, similar situation. William won a first-place prize in a raffle he entered at the shoe store. The prize he won was $1,000 in cash. When William went to claim his prize, the store manager told him that the contest fine print says that the store doesn't need to pay William right away. The manager told him that the store will not have the prize money for another month. The manager then told William that, if he prefers, he can take $400 today instead of waiting a month for the $1,000. William had to decide whether he wanted to wait one month for the $1,000 or take the $400 today. If you were in William's situation what would you chose? Would you take the $400 today or wait one month for the $1,000?

Let's say that William told the store manager that he would prefer to wait a month for the $1,000 than accept $400 today. Hearing this, the store manager told William he was willing to negotiate with him. Imagine you are in William's situation negotiating with the store manager. How low an offer are you willing to make to receive the money today? Would you accept no less than $600? or maybe you would accept no less than $800? What is the least amount of money you would accept today rather than waiting one month for the full $1,000? Listen carefully while I ask the question again: What is the least amount of money you would accept today rather than waiting one month for the full $1,000? Please think of your answer now while we pause."

"Think about this, what if William had to wait 2 years for the $1,000? If William had to wait two years for the full amount, do you think he would be willing to accept a lesser amount to receive the money today? What would be the least amount of money you would accept right now rather than waiting 2 years for $1,000? Is the amount of money you are willing to accept right now more or less than what you were willing to accept when you only had to wait one month?"

"You will now answer the 6 questions at your desk. We will do the first one together."

In addition to the narrative, the measure was reformatted so that the directions were presented for each new time frame (Appendix D).

Another problem detected from the pilot was that the participants learned the point distribution ratios and, once ideal free distribution was achieved, all participants maintained their selections for the duration of the block. As the study progressed, there was very little variability in participant responses. To address this, an additional two contingencies were added to the study (Table 4). With this modification, each contingency was only presented twice, with its second presentation in reverse form. Notice the first baseline condition, block 2, that the ratios are reversed for Experiment 2. This modification was made following Experiment 1, when it was noticed that the first four blocks were loaded blue. To made the procedures less predictable and avoid color preference contaminating the second four blocks, the second block of Experiment 2 was switched.

Table 4
Experiments 1 and 2 Block Distribution Ratios (red:blue) by Experimental Condition

	Block 1	Block 2
PRACTICE	70:50	----
Condition 1: Baseline	30:90	20:100 (Exp 1) 100:20 (Exp 2)
Condition 2: Introduce Interdependent Group Contingency	40:80	15:105
Condition 1: Baseline	80:40	105:15
Condition 2: Introduce Interdependent Group Contingency	20:100	90:30

To address participant fatigue and possible lags in motivation, an additional prize drawing was inserted into the middle of the session, following the second condition. Finally, to accommodate more people in the same space, participants were seated in a large "U" around the classroom as opposed to the oval, with the data collector and experimenter at the front of the room. All participants had visual access to other participants' choice indicators.

With the exception of the items listed above, the experimental procedures for Experiments 1 and 2 were identical to the pilot session. Regarding design, Experiment followed an ABAB design and Experiment 2 followed a BABA design.

CHAPTER 4

RESULTS

Results are organized by analysis type. Findings from Experiments 1 and 2 are reported consecutively to allow for comparison. Data regarding total points accumulated across conditions include point earnings for trials 2 – 20 for each of the eight blocks (19 trials per block, 152 trials per participant). Point earnings for the first trial of each block are excluded due to the fact that participants did not have information on the reinforcement ratio in effect prior to the first point distribution of each block. The pilot was used for modification of procedures and no participant data were analyzed so pilot participant demographics and choice-making will not be reported.

Demographics of Participants and Team Assignments

Regarding Experiments 1 and 2, demographic data was collected and compared (Table 5). Between the two experiments, there was no statistical difference in the age ($t(21) = -0.945$, $p = 0.36$, $d = -0.38$) however a difference was found for years in college, Experiment 2 participants were in college longer mean years in college ($t(21) = -2.19$, $p = 0.04$, $d = -0.43$).

Table 5
Participant Demographic Information Across Experiments

	Experiment 1 11-06-10	Experiment 2 11-13-10
Total Participants	12	12
Mean Age	20	22
% Male	33%	42%
% Psychology Majors	50%	67%
Mean Years in College	2	3

As with the pilot, not all participants completed the of temporal discounting measure without error. of temporal discounting measures are considered valid when the responses vary at least once across the six items and responses consistently follow a descending trend (as wait time increases, response values decrease). There were eight valid scores and four errors for Experiment 1 and six valid scores and six errors for Experiment 2. For the entire study, there are 14 valid of temporal discounting scores. There appears to be no difference in the demographic data collected between participants with valid of temporal discounting scores and those who did not complete the of temporal discounting measure correctly (Table 6).

Table 6
Participant Demographic Information by Correct or Incorrect of Temporal Discounting *Measure Completion*

	Correctly Completed TD	TD Measure Errors
Total Participants	14	10
Mean Age	21	22
% Male	43%	30%
% Psychology Majors	57%	60%
Mean Years in College	2	2

Valid of temporal discounting measures were scored using the area-under-the-curve (AUC) technique (Myerson, Green, & Warusawitharana, 2001). AUC analysis was chosen as the analytic tool for the of temporal discounting data because it provides an output that is conducive to making comparisons (scores range from 0 – 1), is not sensitive to the number of terms used in the measurement tool, and does not make assumptions about the shape of the discounting function (Smith & Hantula, 2008). AUC values indicate the steepness of the discounting curve, with an AUC of 1.0 indicating no discounting. Teams were assigned during the experimental sessions using raw AUC calculations (before of temporal discounting measures were assessed for validity). Therefore, invalid of temporal discounting scores were used in team assignments. Table 7 shows the mean AUC for all valid of temporal discounting measures. Despite the high proportion of error scores used in team assignments, all teams across the two experiments follow the desired AUC characterization. To determine which team comprised the best arrangement for team play, total points earned by each team are compared. However, due to the high proportion of errors, the interpretation of these numbers is limited. Due to the errors, team assignments will not be analyzed beyond their mean AUC and total points earned.

Table 7
Mean AUC and Total Points Earned by Team and Experiment

	Mean AUC (*n* valid scores)		Total Points Earned	
	Experiment 1	Experiment 2	Experiment 1	Experiment 2
White (high AUC)	0.94 (2)	0.87 (1)	6319	5966
Black (mix)	0.65 (2)	0.82 (1)	5929	6243
Stripes (low AUC)	0.61 (4)	0.62 (4)	5897	5981

Choice Allocations

Total points earned by each participant during each trial are shown below by block of trials, labeled as point ratios (Figures 1 & 2). Ideal free distribution (IFD) is denoted with a solid horizontal line for each ratio value. Group matching is shown by the degree to which choices for each color are gathered near the ideal free distribution. For ratios 15:105 and 105:15, ideal free distribution was not possible because the number of participants did not divide evenly into the number of points available for either choice. For all other ratios, ideal distribution was possible with the given number of participants.

For many of the blocks, a change in group distribution toward ideal free distribution can be seen as soon as the second trial. The distribution closest to ideal free distribution was the last block of Experiment 2. For this block, participant choice allocations fall on the ideal free distribution lines for 4 of the 20 trials.

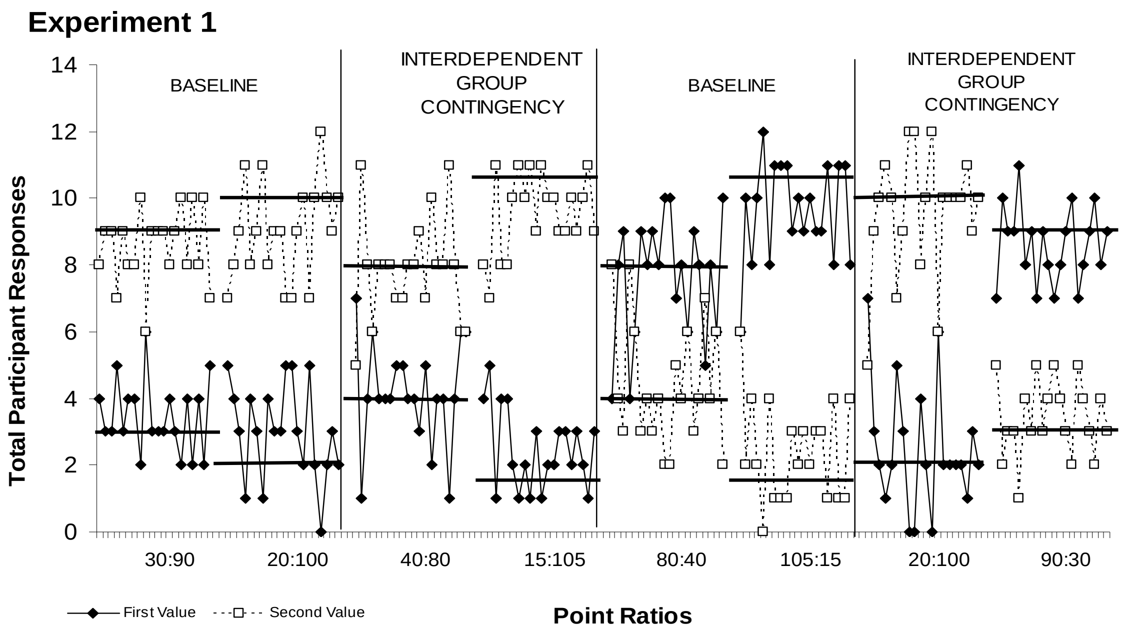

Figure 1. Total choice allocations for Experiment 1.

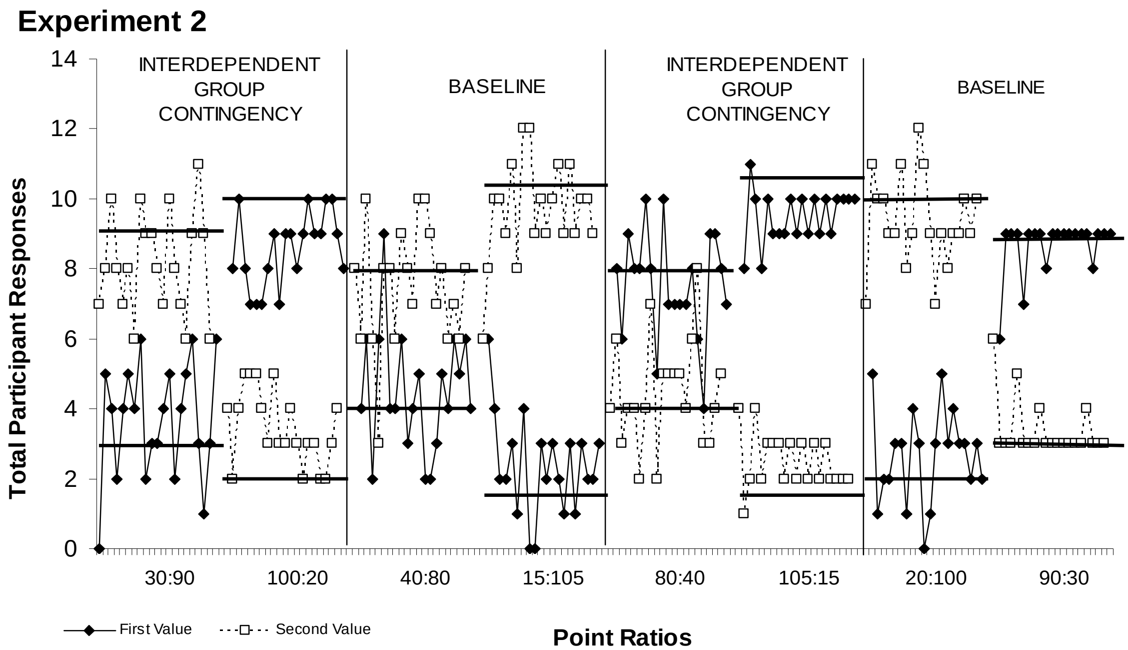

Figure 2. Total choice allocations for Experiment 2.

Group Matching

For a closer look at the actual and ideal distributions, Table 8 summarizes the number of participants in each block of trials, the points allocated to red and blue subgroups, the predicted ideal free distribution of the groups' choices based on the number of participants and shared points, the observed ideal free distribution of groups' choices across the block of trials with the first six trials excluded, and the percentage of trials in which the groups matched the point ratio, undermatched ($a < 1$) by 1 individual, and overmatched ($a > 1$) by 1 individual. Table 8 also includes the points individuals earned for choosing red and blue cards when the groups undermatched and overmatched the point ratio.

For the six blocks in which the Experiment 1 group could match perfectly (all members earning ten points), they did so 29 – 43% of the time. For the six blocks in which the Experiment 2 group could match perfectly, they did so 14 - 86% of the time. In the remaining two blocks (15:105 and 105:15), perfect ideal free distribution was impossible and the groups either undermatched by one or overmatched by one for the majority of trials. As shown by the percentages, undermatching by one was more common than overmatching by one, especially for the Experiment 2 group. Regarding participant choice allocations, the difference between the predicted number based on ideal free distribution and the observed number was generally greater for reinforcement ratios with a higher difference in points available for the rich and lean patches. Reinforcement ratios with a greater difference in points between the rich and lean patches (20:100, 100:20, 15:105, 105:15) were characterized by a higher degree of undermatching and a corresponding greater difference between ideal free distribution and actual allocation of participants.

The ideal free distribution is based on the assumption that participants make choices to maximize their points earned. Figures 3 and 4 show the points participants earned on trials 2-20, one histogram for each block. With the exception of the blocks with reinforcement ratios 15:105 and 105:15, a point award of 10 indicates ideal free distribution (120 points / 12 participants). Therefore, degree of group matching is the degree to which the highest bars in the histogram occur in the center. It is visually apparent that block 8 of Experiment 2 had an exceptional rate of group matching, so much so that the y-axis labels were adjusted to fit the high 10-value. The degree to which

Table 8

Summary of Experiment 1 & 2 Trial Blocks

							a < 1 by 1		*a* = 1		*a* >1 by 1	
Trial block	*n*	Card color	Shared points	Predicted number based on IFD	Observed number	Difference between observed and predicted	% of trials	Earned points	% of trials	Earned points	% of trials	Earned points
Experiment 1												
1	12	Red	30	3	3.5	+0.5	29	8	29	10	29	15
		Blue	90	9	8.6	-0.4		11		10		9
2	12	Red	20	2	3	+1.0	29	7	29	10	7	20
		Blue	100	10	9	-1.0		11		10		9
3	12	Red	40	4	4.2	+0.2	21	8	43	10	7	13
		Blue	80	8	7.9	-0.1		11		10		9
4	12	Red	15	1.5	2.5	+1.0	36	8			29	15
		Blue	105	10.5	9.6	-0.9		11				10
5	12	Red	80	8	7.6	-0.4	7	11	36	10	14	9
		Blue	40	4	4.4	+0.4		8		10		13
6	12	Red	105	10.5	9.6	-0.9	14	11			43	10
		Blue	15	1.5	2.4	+0.9		8				15
7	12	Red	20	2	2.5	+0.5	14	7	43	10	7	20
		Blue	100	10	9.6	-0.4		11		10		9
8	12	Red	90	9	8.6	-0.4	29	11	36	10	14	9
		Blue	30	3	3.4	+0.4		8		10		15
Experiment 2												
1	12	Red	30	3	3.9	+0.9	14	8	29		14	15
		Blue	90	9	8.2	-0.8		11				9
2	12	Red	100	10	8.6	-1.4	50	11	21	10	0	9
		Blue	20	2	3.5	+1.5		7		10		20
3	12	Red	40	4	4.5	+0.5	21	8	29	10	14	13
		Blue	80	8	7.5	-0.5		11		10		9
4	12	Red	15	1.5	2.4	+0.9	29	8			14	15
		Blue	105	10.5	9.7	-0.8		11				10
5	12	Red	80	8	7.6	-0.4	36	11	21	10	14	9
		Blue	40	4	4.5	+0.5		8		10		13
6	12	Red	105	10.5	9.5	-1.0	57	11			0	10
		Blue	15	1.5	2.5	+1.0		8				15
7	12	Red	20	2	2.7	+0.7	43	7	14	10	14	20
		Blue	100	10	9.4	-0.6		11		10		9
8	12	Red	90	9	8.7	-0.3	14	11	86	10	0	9
		Blue	30	3	3.4	+0.4		8		10		15

there are smaller, shorter bars demonstrates variance in point earnings per trial, indicating fluctuation in group matching. Overall, Figures 3 and 4 indicate that participants made choices to optimize points earned, as evidenced by most histogram bars clustered in the center.

To take a closer look at degree of matching, each block of Experiment 1 (Figure 5) and Experiment 2 (Figure 6) were plotted as the log ratio of points as a function of the log ratio of choosers. The diagonal line cutting through the graphs signifies perfect matching. A linear regression line is fit to each graph showing the actual degree of matching between proportion of reinforcement and proportion of responding for each choice. Group matching across conditions for Experiment 1 is evidenced by a slope of 0.80 with 98.7% of the variance in choices accounted for by the reinforcement ratio. For Experiment 2, group matching is evidenced by a slope of 0.74 with 98.5% of the variance in choices accounted for by the reinforcement ratio. Perfect matching, or ideal free distribution, would yield a slope of 1 with 100% of the variance in choices accounted for by the reinforcement ratio.

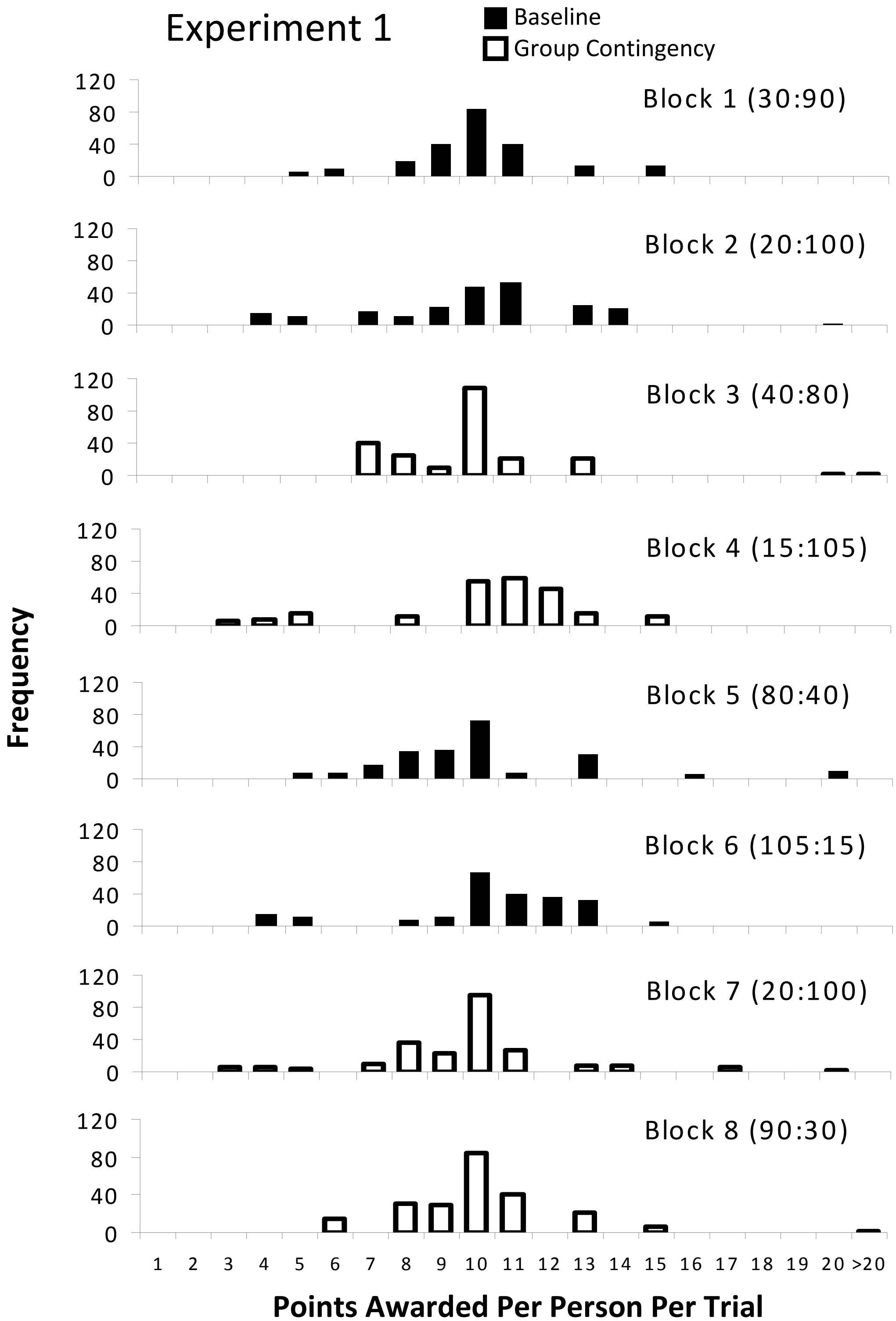

Figure 3. Histograms of the points individuals earned on trials 2-20 of each block of Experiment 1. Frequencies across participants are reported.

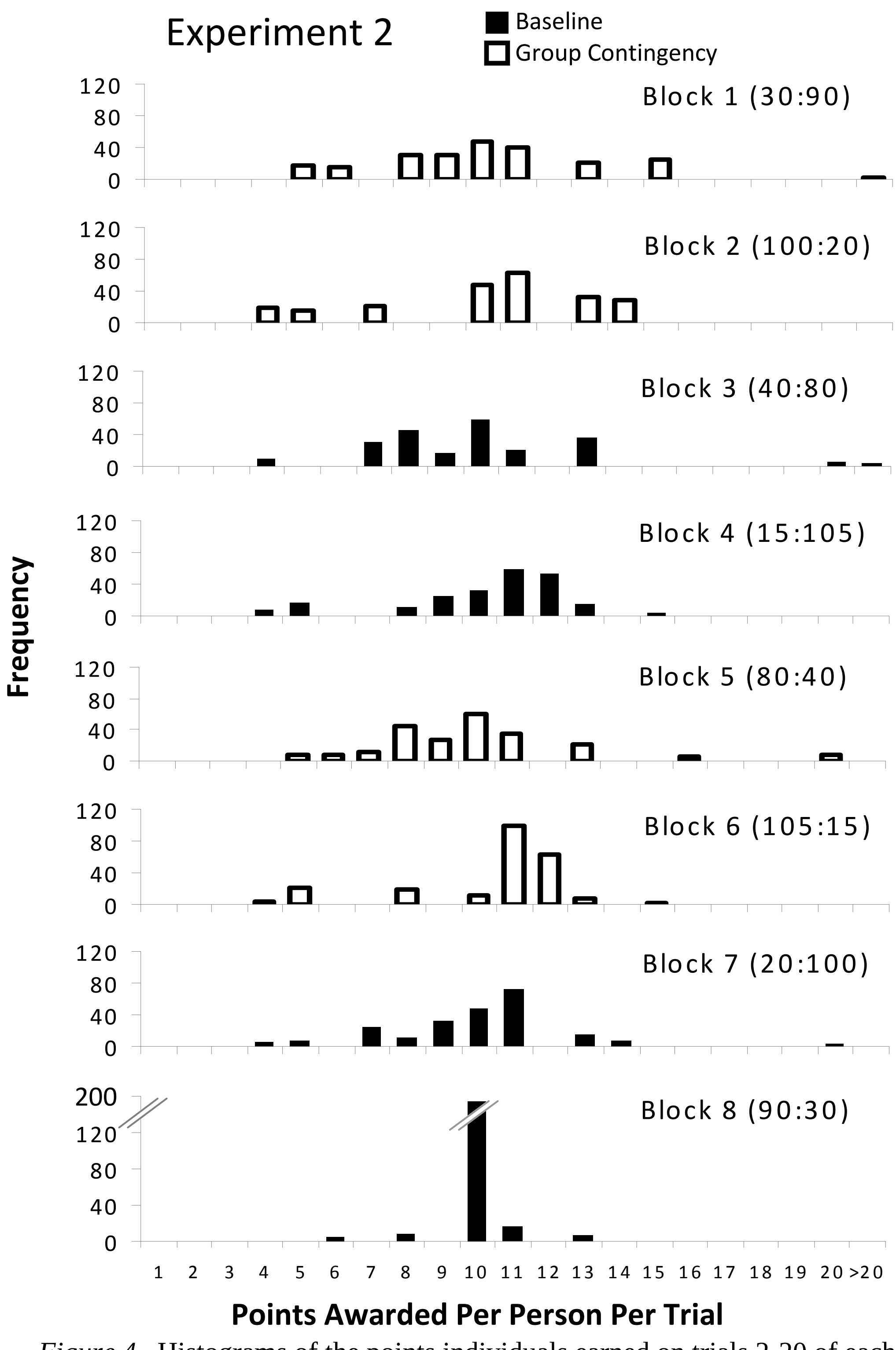

Figure 4. Histograms of the points individuals earned on trials 2-20 of each block of Experiment 2. Notice the y-axis labels for block 8 are extended for the high frequency of the 10 point-value.

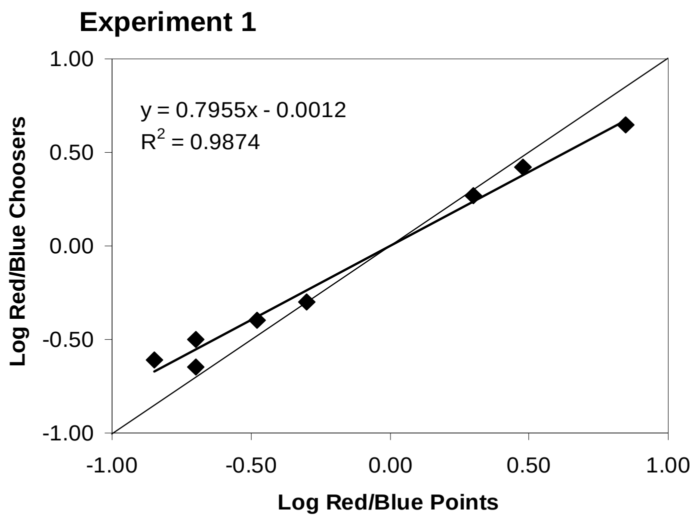

Figure 5. Experiment 1 log ratio of points as a function of the log ratio of choosers. Each data point is a block of 20 trials.

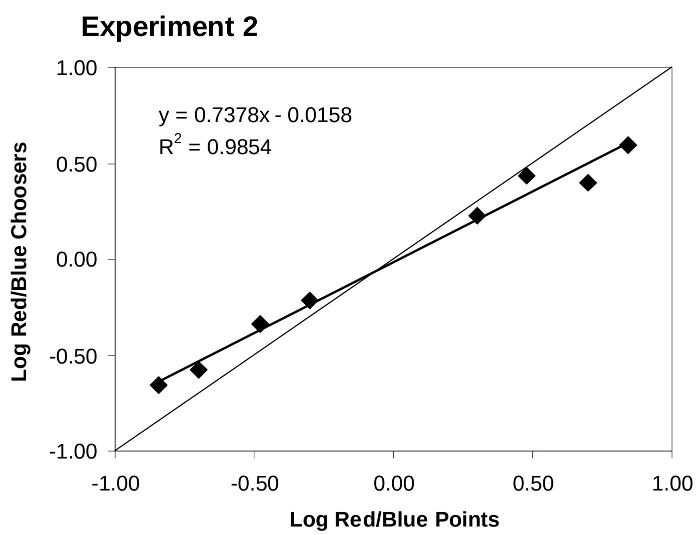

Figure 6. Experiment 2 log ratio of points as a function of the log ratio of choosers. Each data point is a block of 20 trials.

Figures 7 and 8 display sensitivity to the choice contingencies, as defined by the log ratio of choosers to the log ratio of reinforcement. Notice that Experiment 1 was an ABAB design and Experiment 2 was a BABA design, noted by the condition labels between phase change lines. For Experiment 1, no visual difference between the phase change lines can be detected. There does appear to be a difference in block order, as the first block and second block of each condition show a trend (see below). The difference in data between phase change lines does indicate some degree of difference between conditions for Experiment 2. The highest point within the group contingencies conditions is 0.72, close to the lowest value in the baseline conditions, 0.75. Except for the highest value of the group contingencies condition and the lowest value of the baseline condition, the values for the baseline condition exceed the values of the group contingency conditions. This analysis suggests that group matching was most accurate (closest to IFD) when the baseline condition was in effect. The BABA design of Experiment 2 was specified to account for differences in order effects. With all procedures except condition order constant across the two experiments, these data suggest a difference in group choice performance due to the order in which the conditions were presented.

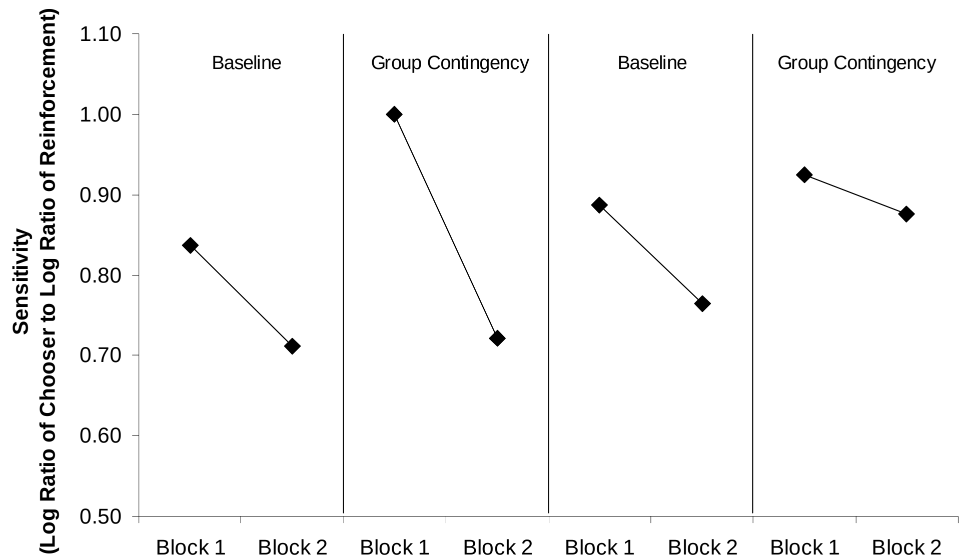

Figure 7. Experiment 1 sensitivities across conditions with phase change lines.

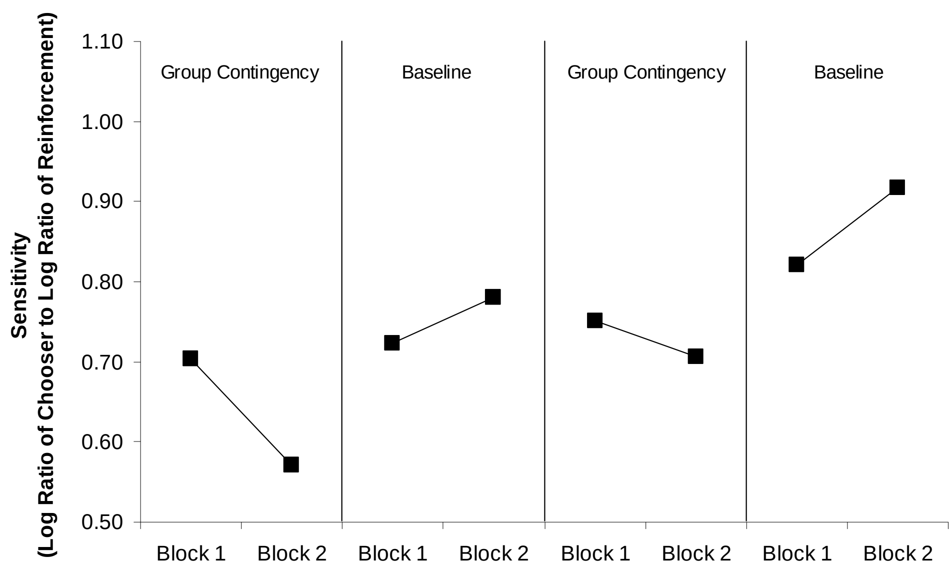

Figure 8. Experiment 2 sensitivities across conditions with phase change lines.

As noted above, a difference in sensitivity to reinforcement ratios is observed in the block order in Experiment 1 (Figure 7). For a closer look, the graphs were re-drawn, organized by block order.

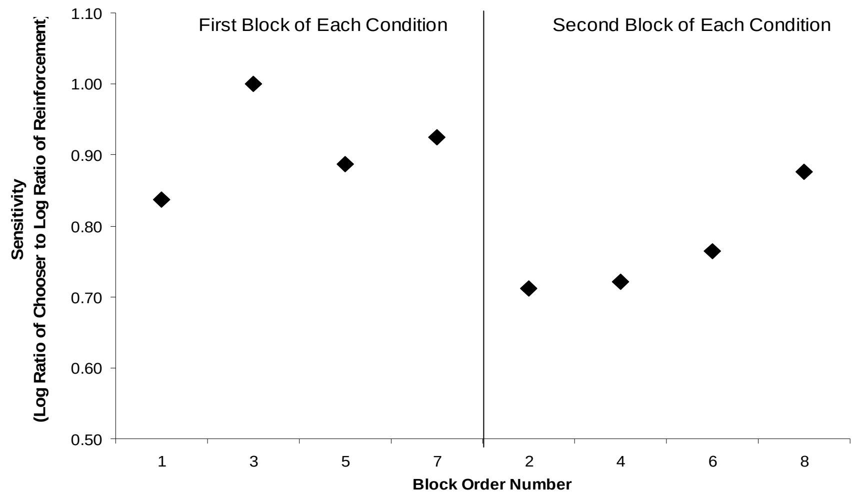

Figure 9. Experiment 1 group choice, sensitivity presented by block order.

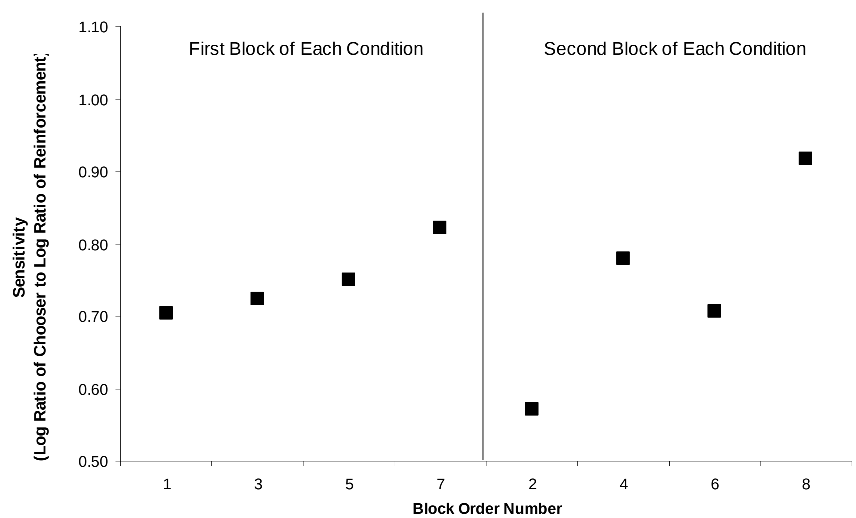

Figure 10. Experiment 2 group choice, sensitivity presented by block order.

As expected based on initial review of Figure 7, an order effect for the block presentations is reflected in the graph for Experiment 1 but not for Experiment 2. The procedural difference between the first and second block of a condition is the change of contingency in effect. Also, there is a non-systematic difference in the reinforcement ratio between each block, which does not explain why it is consistently the first block of a condition that is higher than the second.

Regarding Experiment 2 data, there was a slight trend with the direction of block 2 relative to block 1 (Figure 8). For the experimental conditions, the sensitivity of block 2 was consistently lower than block 1. The opposite was true of the baseline conditions (the sensitivity of block 2 is higher than block 1). If a line were placed through the data points of the first two conditions and the data points of the second two conditions, both would be shaped roughly like a semicircle. At either end of each semicircle is an event; the first block of the experiment, the last block before the reinforcement prize drawing, the first block following the reinforcement prize drawing, the final block of the study and the last block before the final drawing.

To analyze the difference in undermatching by reinforcement ratio in effect noted in Table 8, sensitivities are arranged by reinforcement ratio in Figure 11 below. The caption notes that mean sensitivities of blocks grouped by reinforcement ratio decrease as the difference between points available for the rich and lean patch increases.

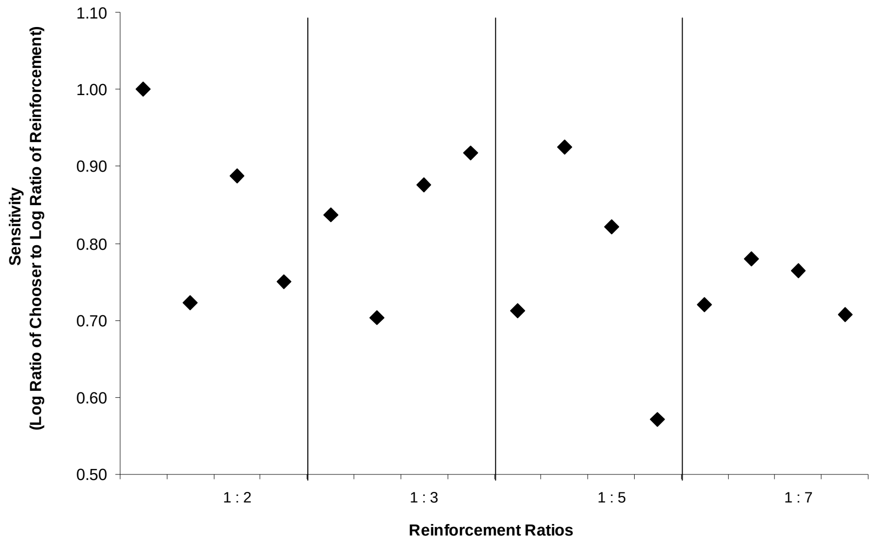

Figure 11. Experiments 1 and 2 group matching sensitivity by reinforcement ratio. Mean sensitivity of blocks grouped by reinforcement ratio decreases as rich patch points increase: 1:2 = 0.84; 1:3 = 0.83, 1:5 = 0.76; 1:7 = 0.74.

To further analyze the difference between baseline and group contingency matching, data from the conditions were combined across experiments. Figure 12 displays all baseline data from Experiments 1 and 2 (solid squares) and all interdependent group contingency data from experiments 1 and 2 (empty squares). Each data point represents an entire block of trials. For both conditions, 99% of the variance in choices is accounted for by the reinforcement ratio. Slope (*a*) provides a more sensitive measure than variance accounted for (r^2). The slope of the combined conditions across both experiments is 0.78 for baseline and 0.77 for group contingency. When analyzed by experiment, the difference in slope between baseline (*a* = 0.77) and group contingency (*a* = 0.82) remains modest for Experiment 1 (0.05, Figure 13). A greater difference in found in Experiment 2 data, with the slope of the baseline condition (*a* = 0.84) exceeding the group contingency condition (*a* = 0.67) by 0.17. These data provide further support that the order of condition presentation influenced a difference in the group matching performance. The difference found in Experiment 2 indicates a better group performance during group contingency when the procedures are introduced using the group contingency.

Table 9 summarizes the group matching findings of the entire study. Group matching was found for both experiments and conditions.

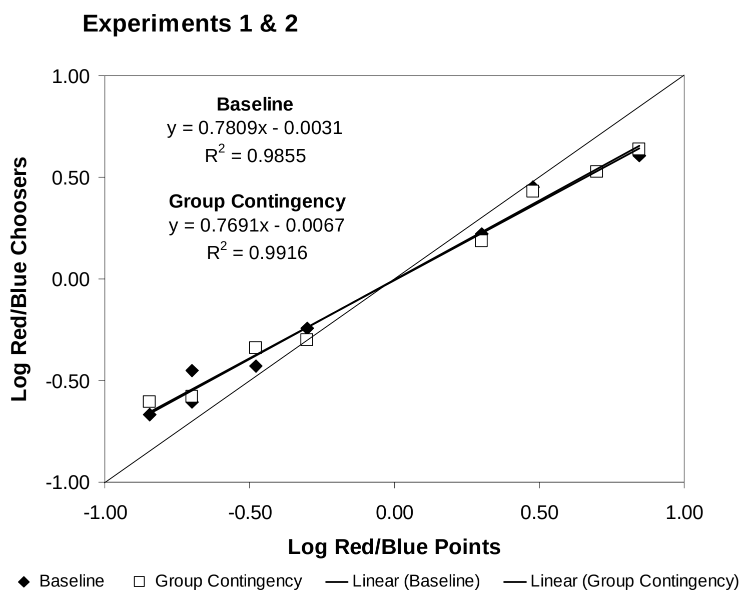

Figure 12. Ratio of choosers by ratio of points. Data from the baseline and experimental conditions were summed across experiments. Scatter plot examines the difference between the two conditions in degree of matching.

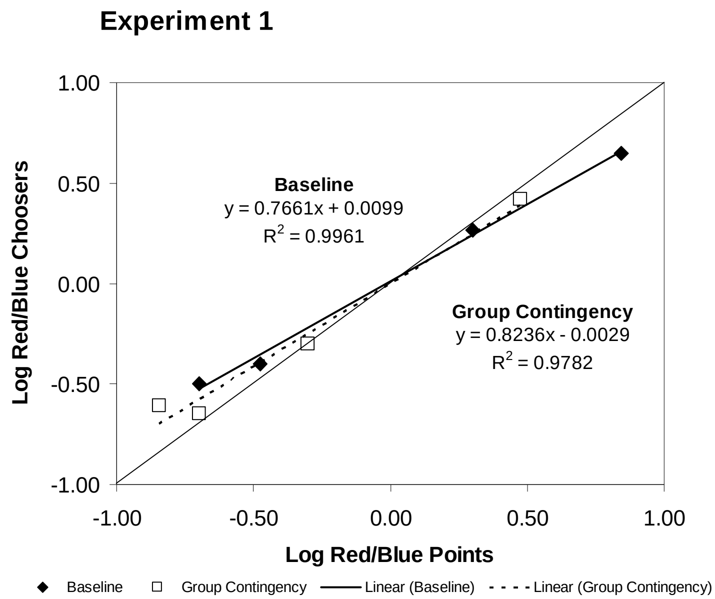

Figure 13. Analysis of different between baseline and group contingency conditions for Experiment 1.

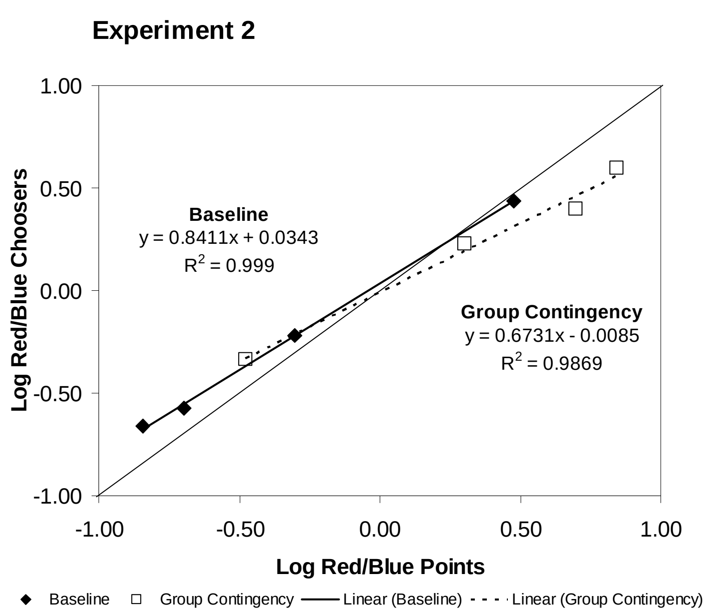

Figure 14. Analysis of different between baseline and group contingency conditions for Experiment 2.

Table 9
Summary of Group Matching Findings

		a	log *b*	R^2 (%)
Experiment 1				
	Baseline	0.77	0.01	99.6
	Group Contingency	0.82	0.00	97.8
	All Data	0.80	0.00	98.7
Experiment 2				
	Baseline	0.84	0.03	99.9
	Group Contingency	0.67	- 0.01	98.7
	All Data	0.74	- 0.02	98.5

Individual Matching

Individual slopes cannot be calculated for group matching procedures such as these because the behavior of the group will determine individual choices (Kraft & Baum, 2001). That is, participants may contribute to the group and their own scores in a way that does not follow the point allocations across choice options but does optimize points for the individual and the team. For example, for the 5:1 ratio, the six pilot participants allocated team members to choice options and remained with these choices for the duration of the block (the same participant repeatedly chose the lean option and the other participants chose the rich option). By maintaining with the same predictable team pattern, all earn more than if participants followed a 5:1 point allocation individually.

Alternatively, individual preferences for the rich cards were examined to better understand degree of discrepancy between individual and group behavior. To determine individual choice preference patterns, a preference index was calculated for each participant (Figures 15 & 16). Preference index was calculated as proportion of rich option choices minus 0.5 (Kraft & Baum, 2001). Exclusive rich option choices would equal a preference index of 0.5, exclusive lean option choices would equal a preference index of -0.5, and splitting choices evenly across options would equal a preference index of 0. Figures 15 and 16 show histograms of binned participant preferences by reinforcement ratio. Graphs are organized so that both the difference between individual matching and group matching and the difference between individual matching during baseline and group contingency conditions may be compared. To understand the difference between group matching and individual matching, the discrepancy between the preference indices corresponding to the ratio in effect (indicated in the caption) may be compared to the actual preference of participants. The preference index for each reinforcement ratio is the ratio of responding that follows the ratio of reinforcement and is what would be expected with individual matching outside of the group choice context. Reinforcement ratios are labeled on each graph, the first ratio is baseline and the second group contingency. As expected, the preference index corresponding to the reinforcement ratio is not a reliable predictor of where participant preferences will fall. The closest individual preferences came to the reinforcement ratio was the group contingency condition of the 1:5 ratio (n = 6). Rather, a better predictor of where participant preferences fell is the width of the reinforcement ratio. From the top graph going down, the distance between the points available for the lean and rich options increases. As it does, the preference indexes become less varied, with more participants falling on either extreme of the x-axis.

The lack of correspondence between the preference index determined by the point allocations and the actual preference indexes of participants distinguishes group matching behavior as distinct from individual matching behavior. It was the behavior of the group that determined where individual participants made selections, not the actual reinforcement ratio corresponding to the two choice options.

Regarding the effect the group contingency has on individual matching relations, there are no apparent differences on the graphs, as the bars seem to co-vary with the change in reinforcement ratios. The biggest discrepancy is with the second graph, ratios 1:3, 3:1. Choice preferences during the group contingency condition are more variable across participants and the baseline condition preferences are more bimodal. This observation is best explained by order effects, as group contingency 3:1 was the first block of the experimental session.

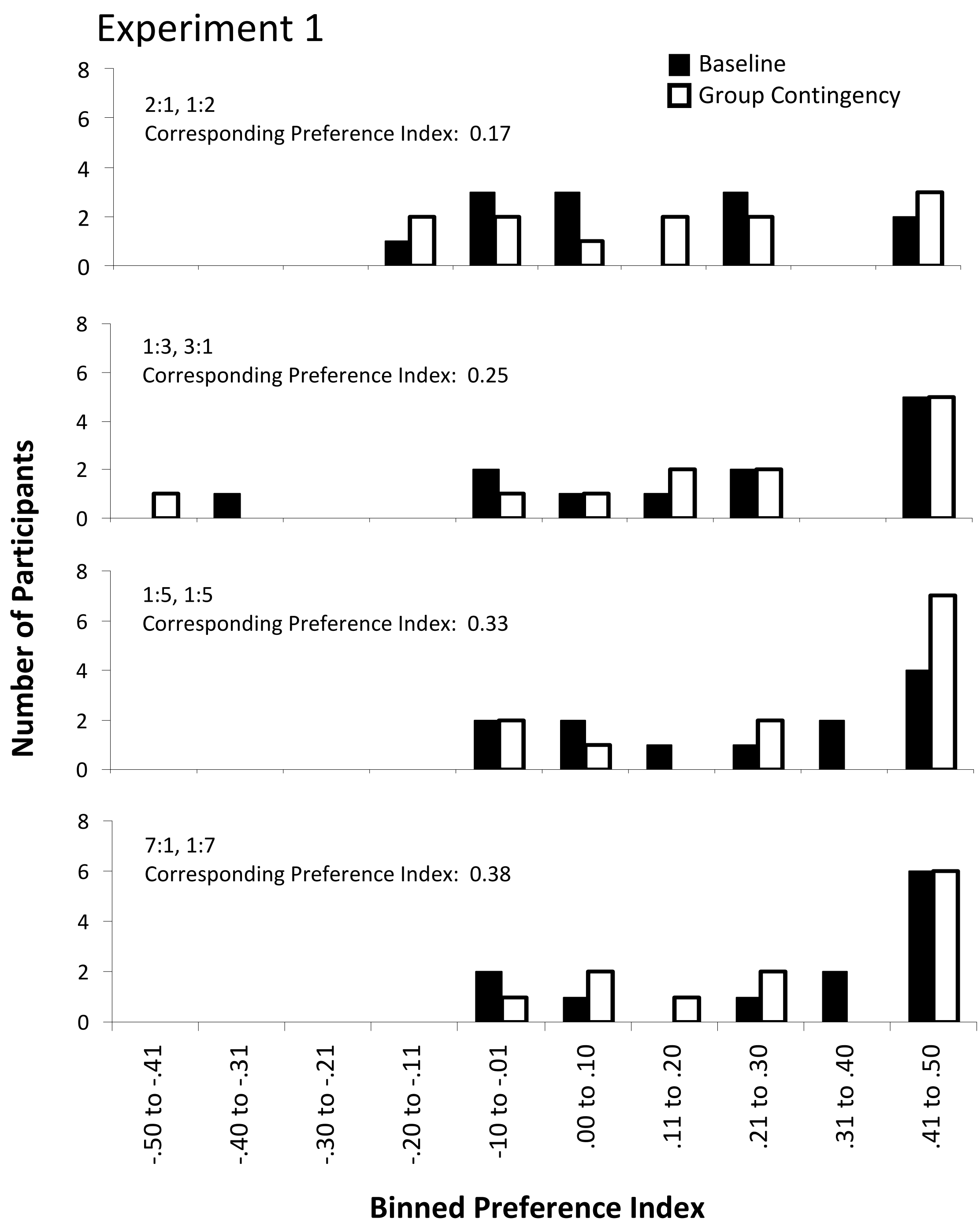

Figure 15. Experiment 1 binned preference index. Total participants in each binned preference index. Preference index was calculated as proportion of rich patch choices minus 0.5. Preference indices are as follows: 0.5 is exclusive preference for the rich option, -0.5 is exclusive preference for the lean option, and .00 is half rich and half lean choices. The preference indexes corresponding to each ratio are as follows: 2:1, 1:2 preference index is 0.17; 3:1, 1:3 preference index is 0.25, 5:1, 1:5 preference index is 0.33, 7:1, 1:7 preference index is 0.38.

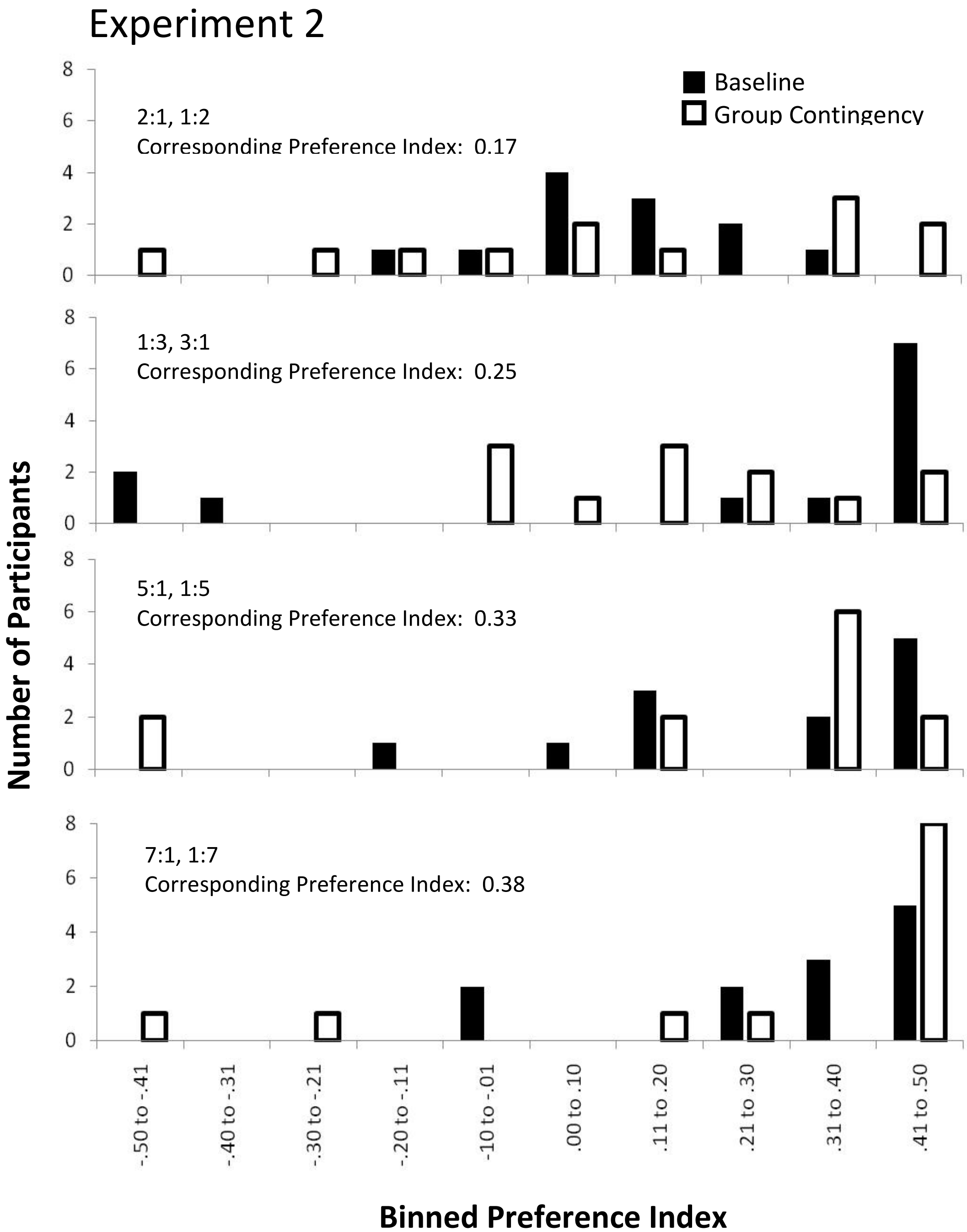

Figure 16. Experiment 2 binned preference index. Total participants in each binned preference index. Preference index was calculated as proportion of rich patch choices minus 0.5. Preference indices are as follows: 0.5 is exclusive preference for the rich option, -0.5 is exclusive preference for the lean option, and .00 is half rich and half lean choices. The preference indexes corresponding to each ratio are as follows: 2:1, 1:2 preference index is 0.17; 3:1, 1:3 preference index is 0.25, 5:1, 1:5 preference index is 0.33, 7:1, 1:7 preference index is 0.38.

Competitive Ability and Temporal Discounting

The data below include 13 of the 24 participants. Of the 14 participants with valid of temporal discounting measure scores, 1 was excluded (Participant 2-05) due to a strong bias for blue selections. Participant 2-05 selected blue on 96% of trials, which does not include enough variability to reflect responsiveness to change in point allocations. Though Participant 2-05's selections are included in the group matching analyses, as this participant's choices influenced the choices of others, it would not be useful to correlate this participant's data with the of temporal discounting score due to the fact that the choice decisions were based on color and not point allocations.

In this section, of temporal discounting scores will be analyzed as AUC values and correlated with point accumulations. To determine whether correct completion of the of temporal discounting measure is any indication of total points earned, participant of temporal discounting measures were scored dichotomously as completed correctly (response values consistently decrease as time increases with any degree of variability in responses; n = 13) or not (n = 10). A t-test found no difference in total points accumulated across conditions ($t(21) = -0.213$, $p = 0.83$, $d = 0.09$), or with total points from the baseline ($t(21) = -0.236$, $p = 0.82$, $d = 0.10$) or group contingency conditions ($t(21) = -0.187$, $p = 0.85$, $d = 0.08$). Finally, a paired-samples t-test of baseline and group contingency points earned was run for each group and no effect was found for participants completing the of temporal discounting measure correctly ($t(12) = -0.825$, $p = 0.43$, $d = 0.16$) and those participants who did not complete the measure correctly ($t(9) = -0.534$, $p = 0.61$, $d = 0.13$). These analyses support the assertion that total points earned could not be predicted by whether the participant completed the of temporal discounting measure correctly.

Prior to determining the relationship between individual degree of matching and valid temporal discounting scores, probability of winning was analyzed for both the lean patch and the rich patch. With undermatching more prevalent than overmatching (Table 8), foraging in the richer patch should produce higher individual point gains than foraging in the leaner patch. To avoid making assumptions about which patch produced the best results for participants, the obtained probability of a rich-patch win (rich-patch wins / total rich-patch choices) was plotted as a function of the same probability for the lean patch (Figure 17). A win was defined as receiving the higher of two point values on a given trial. When the distribution of points was equal (ideal free distribution), no wins were counted for any participant. Also, when all participants chose the same patch, no win was recorded for any participants because the highest point value was the color choice no one selected. The line running through the center of each scatter plot represents equal probabilities for the two patches. All participants' data fall below the line, indicating better rich-patch outcomes overall for each participant. This finding supports the assumption that the rich patch maintained better odds of winning for all participants than the lean patch.

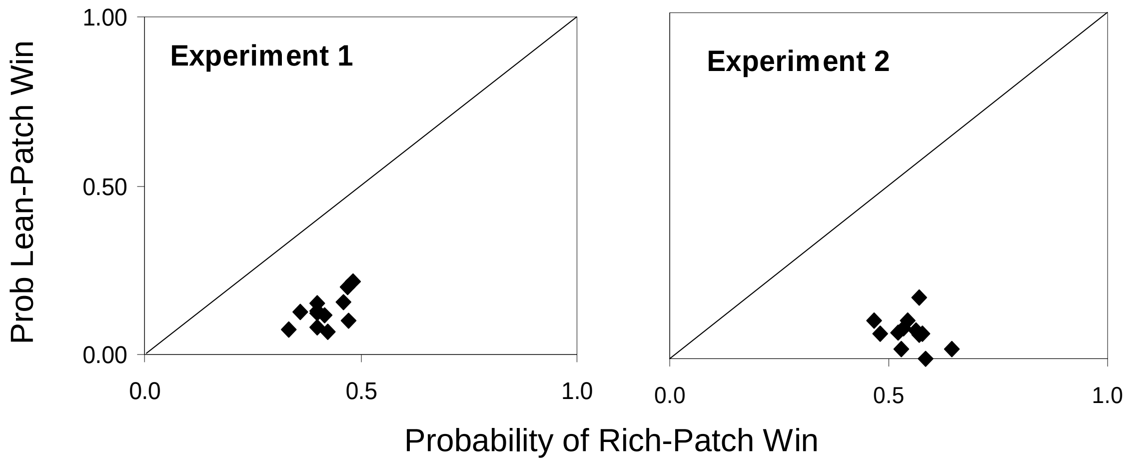

Figure 17. Probability of lean-patch win by probability of rich-patch win. Probabilities of a win by rich or lean patch choice were calculated for every participant. All participant choice-making resulted in better odds for the richer patch. Except for the first trial of each block, all data from all blocks were included in the analysis.

In addition to choosing the rich patch, successful competitors have additional outcomes that lead to their accumulated point gains. Replicating Critchfield and Atteberry (2003), four indicators of competitive success were analyzed using participant-level data. These indicators are rich:lean patch choices, total switches, better:worse outcomes, and points earned:minimum points (Figure 18). All data from Figure 18 are displayed as relative frequency, whereby the y-axis represents percent occurrence across all participants (note that the maximum y-axis value is 0.4 for 18A & 18B and 0.6 for 18C and 18D). To graph as percent occurrence, the values presented in Figure 18 are rounded and binned for a cleaner presentation. Figure 18A displays the ratio of each individual's rich-patch choices to lean-patch choices. Experiments 1 and 2 data show similar data trends, with prevalence peaking at 0.2 for Experiment 1 and 0.4 for Experiment 2. Total number of switches were binned and arranged by prevalence in

Figure 18B. Switching was much more variable for Experiment 1 than for Experiment 2. The data for Experiment 1 also has a greater range, with more than 10% of participants making less than 10 switches and more than 20% of participants making more than 50 switches. Figure 18C displays the ratio of better-yield choices to worse-yield choices calculated for each participant. A better-yield choice was defined as earning the maximum amount relative to other participants. Better-yield choices included all choices that yielded the same outcome as other participants, in the case of ideal distribution (everyone earns 10) or all participants choosing the same color (the higher option relative to other participants' earnings is the color option no one chose). Most participants across the two experiments experienced a better-yield ratio of greater than 20%. Finally, Figure 18D displays the ratio of total points earned to minimum total points that could be earned. All participants across the two studies had ratios greater than 1.1 and less than 1.5, or all participants earned between 10-50% more points than the minimum possible.
Collectively, the data from Figure 18 shows distribution of relative frequency across four measures of competitive success.

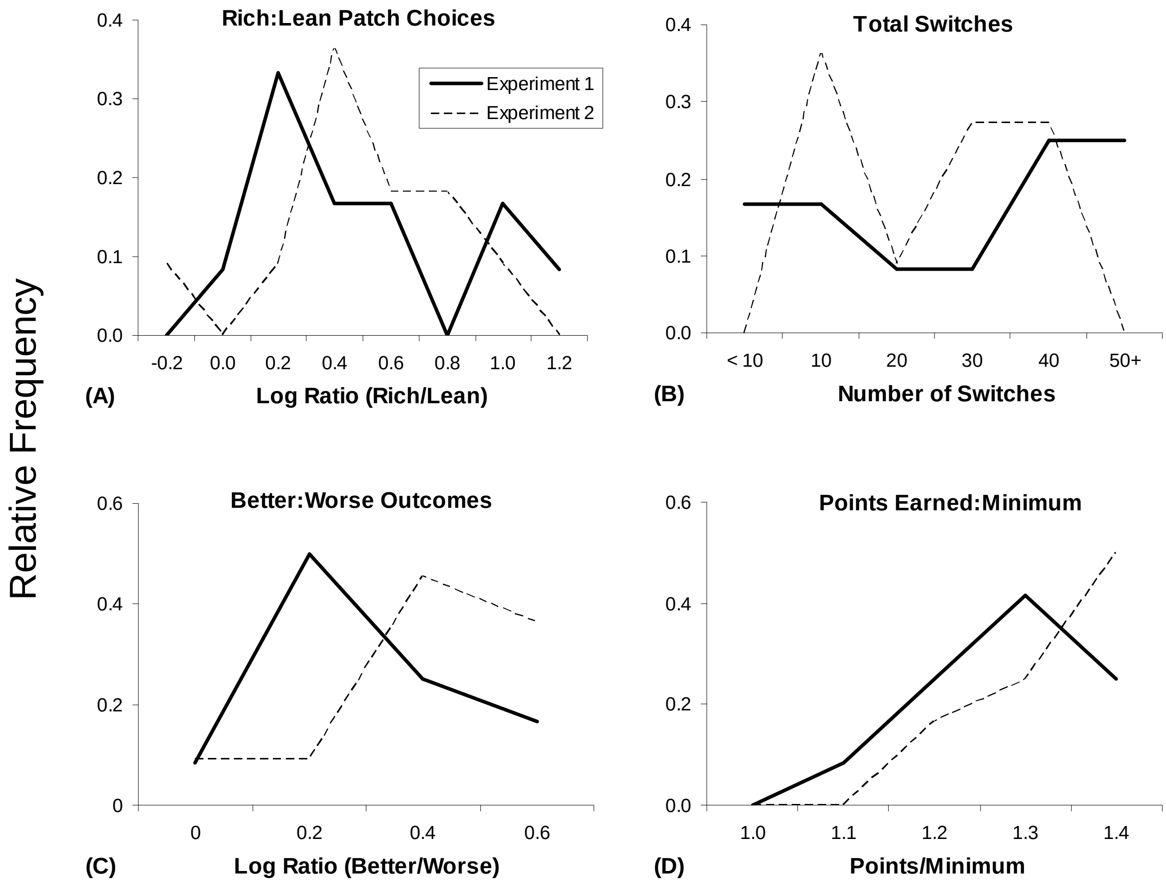

Figure 18. Relative frequencies of four measures of competitive success.

To determine the extent to which these data all measure the same performance tendency, they were correlated using the individual-level values (Table 10). Interestingly, all were significantly correlated at the 0.05 level or higher except total switches and rich/lean patch choices and total switches and points/minimum points available for Experiment 2. In contrast, the relation between total switches and rich/lean patch choices and points/minimum points available were significantly related for Experiment 1. Perhaps this has something to do with the lower range and variability of

Experiment 2 switch data, compared to Experiment 1 (Figure 18B), a difference that may be accounted for by the only methodological difference between the two experiments, the order of conditions.

Table 10
Correlations Between Four measures of Competitive Success

Experiment		Total Switches	Log better/worse	Points/Minimum
1	Log rich/lean	-0.795**	0.958**	0.897**
	Switches	---	-0.833**	-0.883**
	Log better/worse	---	---	0.965**
2	Log rich/lean	-0.585	0.962**	0.978**
	Switches	---	-0.640*	-0.597
	Log better/worse	---	---	0.985**

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

To allow for correlations with AUC score, analyses will continue with total points earned as the indicator for competitive success. Bivariate correlations were run for AUC score and total points earned, baseline points earned, group contingency point earned, the ratio of rich to lean patch choices, the ratio of better yield to worse yield choices, the ratio of total points to minimum points, trial per visit to the rich patch and trials per visit to the lean patch (Table 11). Findings show a relationship between AUC score and total points earned ($r = 0.55$, $p = 0.05$) and baseline total points earned ($r = 0.56$, $p = 0.05$). Of the four factors of competitive success reported in Figure 18, the ratios better yield to worse yield choices ($r = 0.53$, $p = 0.06$) and total points to minimum possible ($r = 0.56$, $p = 0.05$) showed a relationship with AUC score. When the participants were grouped based on AUC score (n=5, AUC < 0.7; AUC > 0.8), the high-AUC group had a higher mean total points earned. An independent-samples t-test comparing the two groups found some degree of difference in mean total points earned ($t(8) = 1.82$, $p = 0.11$, $d = 1.15$). When the absolute value of difference in points earned between the baseline and group contingency conditions were tested, no difference between the high-AUC group and low-AUC group was found ($t(8) = 0.30$, $p = 0.77$, $d = 0.19$).

Table 11
Bivariate Correlations with AUC Score and Indicators of Competitive Success

Factor Correlated with AUC Score (n = 13)	Strength of Relationship (*r*)	Statistical Significance (*p*)	Variance Accounted for by AUC Score ($100r^2$)
Total points earned	0.55	0.05	31%
Baseline points earned	0.56	0.05	31%
Group Contingency points earned	0.49	0.09	24%
Total Switches	-0.28	0.35	8%
Rich:Lean Patch Choices	0.42	0.15	18%
Better Yield : Worse Yield Choices	0.53	0.06	28%
Total Points : Minimum Possible	0.56	0.05	31%
Trials per Visit Rich	0.23	0.46	5%
Trials per Visit Lean	-0.28	0.36	8%

To help explain the difference in order effects shown in the visual analysis of mean sensitivities across all Experiment 1 participants (Figures 7 & 9) and some trend with regard to order for Experiment 2 (Figure 8), a relationship between AUC score and order effects was also investigated. Total points from the beginning two blocks were summed with the total points from the two blocks following the prize drawing break (blocks 1, 2, 5 & 6; referred to herein as first string blocks). These blocks were compared to the total points summed from the two blocks just before the prize drawing break and the two blocks at the end of each session (blocks 3, 4, 7 & 8, referred to herein as second string blocks). No significant relationship was found when second string blocks were related to AUC scores in a linear regression (r = 0.47, p = 0.11; 22% of variance in points accounted for by AUC score). When first string block totals were related on AUC score, a significant relationship was found (r = 0.58, p = .04) with 33% of the variance in first string block totals accounted for by AUC score. That is, participants that had a higher AUC value, assessed as the lower discounters, earned more points during the first string blocks than the higher discounters. To determine whether this difference explains a trend for which participants with high AUC scores earn more points during first string blocks than second-string block or whether the higher discounters had a decrease in total points earned during the first string blocks, the absolute value of difference in point earnings between block groupings were related to AUC scores in a correlation. No significant relationship was found (r = 0.2, p = .94).

Finally, participant trials per visit were explored for lean and rich patches. Trials per visit were calculated as the number of trials a participant stayed with a patch at a time, summed across trials blocks and divided by the number of visits to that choice. For example, if a participant chose only the rich patch across the trials in a block, the trials per visit would be 19 trials (the first trial was not counted) divided by one visit. If a participant visited the lean patch twice, once for three trials and again for five trials, the lean patch trials per visit for that block would be four. AUC score was found to be a significant predictor of neither the lean trials per visit ($r = -0.28$, $p = 0.36$) nor the rich trials per visit ($r = 0.23$, $p = 0.46$). When the participants were grouped and compared based on AUC score (n=5, AUC < 0.7; AUC > 0.8), the mean trials per visit at the rich patch was higher for the high-AUC group (7.3, difference of 0.8) and the mean trials per visit at the lean patch was higher for the low-AUC group (2.0, difference of 0.14). A t-test found no statistical difference in the means of the high-AUC group and low-AUC group trials per visit at the lean patch ($t(8) = 0.44$, $p = 0.67$, $d = 0.28$) or the rich patch ($t(8) = 0.24$, $p = 0.82$, $d = 0.15$).

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DISCUSSION

Summary of Purpose

The primary purpose for conducting this study was to continue research on group matching behavior in humans with the introduction of team collaboration as an independent variable. To ensure valid and reliable methods, prior research was closely replicated, a pilot was implemented, and the experiment was conducted twice. Though this study makes no direct claims to immediate applications, it was designed to simulate human collective efforts employed with team work. Matching relations provide the unique opportunity to precisely quantify efforts, using the actual reinforcement ratios as optimal performance. This precise quantification allows for difference in efforts to be compared across contingencies. Though individual matching could not be calculated, based on the methods, difference in group matching across conditions does suggest a collective change in sensitivity when the group contingency was in effect. To help identify individual differences, as Critchfield and Atteberry (2003) did, temporal discounting was measured and compared to total point earnings.

Findings

The findings of this study are consistent with many of the findings of past research, particularly Kraft and Baum (2001) and Critchfield and Atteberry (2003). Group matching was demonstrated with slopes of 0.80 for Experiment 1 (98.7% of variance in choice allocations accounted for by reinforcement ratios) and 0.74 for Experiment 2 (98.5% of the variance in choice allocations accounted for by reinforcement ratios), consistent with earlier research (slope range of 0.71 to 0.92, Kraft & Baum, 2001; median slope of 0.73, Critchfield & Atteberry, 2003). Undermatcing was found to be the most common deviation from ideal free distribution (Table 8), a common observation in the literature (i.e., Kraft & Baum 2001). Reinforcement ratios with a greater difference in points between the rich and lean patches were characterized by a higher degree of undermatching and a corresponding greater difference between ideal free distribution and actual allocation of participants (Table 8, Figures 11, 15, & 16).

Matching relations were demonstrated for an interdependent group contingency as evidenced by 98% and 99% of variance in responding accounted for by reinforcement distributions for group contingency conditions of Experiments 1 and 2, respectively (Figures 13 & 14). Investigation of interdependent foraging is a new addition to studies on group matching relations. Prior research on matching with groups has demonstrated group matching for individual contingencies exclusively, as a collective foraging effort with individual rewards. The slope and variance reported from these data demonstrate group matching is maintained when point accrual is reinforced using a group contingency.

When sensitivities were analyzed by condition, a difference between conditions was found for Experiment 2 (Figure 8), with all but one of the group contingency block sensitivities falling below baseline block sensitivities. This finding showed choice allocation closest to ideal free distribution when the baseline, or individual contingency, was in effect. The introduction of the group contingency was unique to this study and was based on common human group contexts, not prior research. The slope indicating the relationship between allocation of responses and allocation of points (point ratios), was lower for the group contingency conditions (a = 0.67) than the baseline conditions (a = 0.84).   This difference indicates a decrease in sensitivity to reinforcement ratios when a team approach is used and suggests that team arrangement is not the most effective approach to optimizing performance. Experiment 1 (Figure 7) did not show this trend. Analyzed together, data from both experiments suggest that difference in effect was due to the methodological difference between Experiments 1 and 2, order of condition presentation. Beginning with the group contingency condition created a greater difference in slope between conditions (Figures 13 & 14).

Individual-level data, analyzed as proportion of rich option choices to total choices (preference index) was consistent with prior findings (Kraft & Baum, 2001). Using a preference index calculated for each point ratio, it was found that the response preferences of individual participants did not follow the ratio of points available at either option (Figures 15 & 16). Rather, preferences were best predicted by the difference between the lean and rich patch and not individual allocation of responses per the reinforcement ratio. This has been reported by other research as well (Kraft & Baum, 2001). The lack of correspondence between the preference index determined by the point allocations and the actual preference indexes of participants distinguishes group matching behavior from individual matching behavior. Rather than the reinforcement ratio predicting individual behavior, it was the behavior of the group that determined where individual participants made selections. This finding supports the notion that group matching is distinct from simply the sum of individual matching efforts.

Measures of competitive success were analyzed by experiment (Figure 18). Findings show Experiment 1 participants switched between choice options to a greater degree and with a greater range in total switches than Experiment 2 participants. Switch data were correlated with rich to lean patch choices and total points to minimum available for Experiment 1 but not Experiment 2. These differences are most likely explained by the difference between the two experiments, order of condition presentation, and may provide some characterization of the sensitivity to the difference between contingencies found for Experiment 2. Switching often may describe group behavior that is less coordinated, searching for ideal free distribution but struggling to achieve it.

Though not all participants returned valid of temporal discounting measures (14 participants of 24), no difference in the demographic data or total points earned was found between participants who completed the measure correctly and those that did not. The performance of the teams arranged by the experimenter based on AUC score was not analyzed due to errors in completion of the of temporal discounting measure, rather total points earned and of temporal discounting score analyzed as AUC score were correlated at the individual level. Temporal discounting was related to total points earned by individuals in a bivariate correlation ($r = 0.55$).   Participants with higher AUC scores (alternatively described as less impulsive) accumulated more points over the duration of the experiment as evidenced by a high correlation between total points earned and AUC score. Additional correlations show a relationship between AUC score and baseline points earned ($r = 0.56$), ratio of better yield to worse yield choices ($r = 0.53$) and total points earned to minimum possible ($r = 0.56$). These correlations are considered very high for the field of Education Psychology, for which correlations of 0.10 are generally considered meaningful. When the participants with the highest five AUC scores were compared to participants with the lowest five AUC scores, some degree of difference in mean total points earned was found ($t(8) = 1.82$, $d = 1.15$). These findings support the findings of Critchfield and Atteberry (2003). Unlike Critchfield and Atteberry (2003), the difference in total points earned by participants with higher AUC scores could not be explained by difference in the trials per visit or total switches. This finding suggests that what might be considered impulsive behavior, such as changing options frequently, does not explain the difference in total points earned predicted by AUC score. Rather, the difference in point totals predicted by AUC score might have to do with the information on which is the best choice option, given the point allocations and the behavior of other group members, rather than indecisiveness and impulsive behaviors. This explanation suggests that individuals with higher temporal discounting scores are less responsive to contingencies and do not work as effectively within a group.

To examine the effect exposure to the task had on the relationship between AUC score and points earned, blocks were grouped by order, first-string and second-string. First-string blocks consisted of the set of blocks at the beginning of the study and the set of blocks following the reinforcement drawing break and the second-string blocks were those blocks just before the break and at the end of the study. This analysis was designed to examine whether practice or fatigue had an effect on the relationship between AUC score and points earned. AUC score was correlated with the first-string blocks ($r = 0.58$, $p = 0.04$). This means participants that had higher AUC scores, assessed as the lower discounters, earned more points during the first string blocks than the higher discounters. When the second-string blocks were correlated with total points earned, no relationship was found. Taken together, these findings suggest that the difference in performance between high-discounters and low-discounters is reduced with repeated trials. Put another way, the performance of high-discounters may improve with repeated trials without interruption.

Limitations

M*ethodological Issues*

All methodological considerations were based on the methods of Kraft and Baum (2001), Madden, Peden, and Yamaguchi (2002), or Critchfield and Atteburry (2003). The unique additions were the ABAB/BABA design to include the introduction of a group contingency and the selection of the Beck and Triplett (2009) temporal discounting measure. The methods of the study were tested in a pilot administration, the outcome of which was used to make minor modifications to the procedures. The biggest challenge regarding methods was low rate of participation. The study was designed so that each team would have six participants, 18 total for each experiment. To account for individuals registering and not coming to the study, 20 participants were scheduled. The rate of actual participation for students registered was 60% (12/20). The small group numbers combined with temporal discounting errors compromised analysis and comparison of team performances. Better incentives may have provided better participation.

Internal Validity Issues

The experimental design minimized threats to internal validity. Conducting the experiment twice, once as an ABAB and then again as a BABA provided additional evidence for the integrity of the experimental methods. Procedurally, the experiments were scripted, contained the same number of participants, took place on the same day of week, at the same time, with the same two experimenters in the same roles (experimenter and data collector). All the specifications regarding the reinforcers, prize drawing, and pre-session break were constant.

For both Experiment 1 and 2, there were differences in data trends across conditions. Experiment 1 showed an apparent order effect for the first block of each condition and was consistent across conditions (Figure 9). The effect was not maintained with the second experiment and is attributed to the only methodological difference between the two experiments, order of condition presentation. Experiment 2 also showed a pattern with regard to order that was unexplained by the data. The pattern was a slight trend with the direction of block 2 relative to block 1 (Figure 8). For the experimental conditions, the sensitivity of block 2 was consistently lower than block 1. The opposite was true of the baseline conditions, the sensitivity of block 2 was higher than block 1. The events occurring before the experimental conditions (beginning of study and reinforcement break) and occurring after the baseline conditions (reinforcement break and end of study) might offer an explanation if the same trend occurred in the Experiment 1 data. Since procedures were otherwise constant, order of condition presentation is the best explanation for the data trends of Experiment 2.

The inconsistencies observed across conditions are an indication that a reversal design is not the best design for studying degree of change in matching relations when switching from individual incentives to group incentives. Rather than returning to baseline when the independent variable was removed, data points followed trends by order of condition. This is an indication that participant learning occurred and an alternate design that does not require a return to baseline might provide better data.

Also related to the design, differences between data from Experiment 1 and 2 suggest an effect of presentation order. In addition to learning, the presentation order could have had an effect on variables related to participant motivation, such as effort and attention. Though this presents a threat to the validity of data collected for this study, it suggests that variables related to task presentation could have an influence on performance. Presentation variables and the effect they have on performance are key to understanding how to maximize human performance in applied contexts, such as education.

External Validity Issues

Based on basic research and conducted as such, this study can make only modest claims to external validity. Conducted in a laboratory with contrived reinforcers, the study's independent variable is its strongest claim to external validity. Humans work in groups as independent foragers, much like the pigeons of the first group matching study (Baum

& Kraft, 1998). However, unlike pigeons selecting bird feeders, humans also work in cooperative and competitive groups. Cooperative human foraging behavior for shared rewards has been recognized as having a long history in human behavior across many contexts. Hunting and gathering behavior of tribes has been documented to utilize group strategy and reward sharing (i.e., Winterhalder, 1996). Differences in individual and group incentives have been demonstrated for practical applications in such applied contexts as the workplace (Honeywell-Johnson & Dickinson, 1999). It is important to understand how collaborative efforts affect performance, both of the individual and the collective effort of the team.

Instrumentation

Though found to be valid and reliable by its authors (Beck & Triplett, 2009), the temporal discounting tool produced valid measurement of 14 of 24 participants (58%). These outcomes were with the narrative and changes to the layout following the pilot, for which two of six participants completed the measure with a valid score (33%). No citations for the measure were found beyond Beck and Triplett (2009), a single study of the instrument's validation conducted by the instrument's own authors. Also, Beck and Triplett (2009) was conducted at a private university with high admission standards, so its generality to the students of a large state university such as Temple is not necessarily supported. Further, the measure presented the participant with multiple hypothetical monetary choices but it was not a binary choice procedure. Rather, with all its response options the measure was more similar to a fill-in-the-blank task, a procedure that is more cognitively demanding than binary choice tasks (Smith & Hantula, 2008). More widely-used measures were available but this measure was chosen for its group administration, pencil-and-paper format, and short administration time. To prevent attrition that results in two-session experiments, the eight blocks were intentionally scheduled for a 2-hour session. Due to the tight scheduling, the Beck and Triplett (2009) measure seemed like the best option. If this study were replicated, the experimenter might consider either scheduling a pre-screening session or extending the session time and using a measure that has more publications demonstrating its effectiveness. A prescreening session would also allow for closer scrutiny of the completed temporal discounting measures, providing an opportunity to only select participants with valid of temporal discounting scores.

Implications for Educational Contexts

The effect found in Experiment 2 suggests that there is a difference in the performance of the individual based on team or individual endeavors. This finding applies across settings, but is especially pertinent to education. The classroom is arranged as a large group, with many opportunities for individual student decisions to be based on the behavior of the group. Further exploration of the variables that influence individual motivation in the context of interdependent group contingencies would inform teachers of how to maximize the effectiveness of collaborative learning groups and team projects.

The temporal discounting factor explains an individual difference that informs any aspect of education. These data suggest a difference in operant learning for individuals based on their tolerance for reinforcement delays. The findings of this study suggest that individuals assessed as high-discounters require repeated trials to close the performance gap between them and their low-discounter peers. Not only does this inform accommodation, but allows for the opportunity to teach students to tolerate delays, which might help them be more attentive learners. The relationship between temporal discounting and academic outcomes is documented, most notably as studies of preschooler's tolerance for delay in receiving a reward (i.e., Mischel & Ebbesen, 1970). Preschoolers from several such studies were reassessed as adolescents using various forms of parent feedback and SAT scores. Parents of the preschool participants reported social, academic, and coping competency that was significantly correlated with the time the length of the delay the participant tolerated as a preschooler (Mischel, Shoda, & Peake, 1988). Academic outcomes measured as SAT scores were also found to be positively related to tolerance for delay time (Mischel, Shoda, & Rodriguez, 1989). These findings support the influence of temporal discounting on educational outcomes.

More generally, research on performance of groups across contexts might inform how education is approached on a larger scale. Schooling is traditionally designed so that large groups of students receive information as a group but are tested and perform as individuals. Unlike the classroom setting, many jobs require working with a team and, at the very least, collaborating favorably with co-workers and supervisors. The findings of this study demonstrated a difference in performance when participants work as a team. Perhaps team collaboration is a skill that needs to be practiced more deliberately, preparing students for social efforts into adulthood.

Recommendations for Further Study

Though additional basic research is warranted to better understand the variables that affect group matching and individual performance, applied research will soon be within reach. Pulling together all the elements of this study, a nice start for applied research might be assessment of student temporal discounting and classroom behavior. Matching relations can be assessed using discrete trials. Intervention could focus on increasing tolerance of reinforcement delay, followed by reassessment of temporal discounting, classroom performance, and matching relations. Using matching relations and temporal discounting as an assessment tool in an applied setting will further clarify their relationship to academic performance in school.

Better understanding of how context affects individual and group performance has great utility for application in work and education settings. The difference between Experiments 1 and 2 suggest an order presentation effect. Future research might focus on defining the variables that enhance and hinder performance, optimizing productivity and learning. In addition to task presentation, reinforcement ratio in effect was a variable found to influence degree of under-matching. Participants were less likely to over-select the lean option with greater differences between the rich and lean options. This finding supports good classroom management technique, creating a large discrepancy between reinforcement available for the desired student choice, such as engagement in classroom activities, and reinforcement available for the less-desirable student choice, such as off-task behavior. Applied research might study reinforcement ratios of classroom activities to better define technique for creating learning environments that entice students to learn.

For this study, interaction between group members was discouraged so that group processes and group technique, such as strategizing, would not be a confound to the data. Future research might explore the difference group interaction makes on group point accumulations. There are many possibilities for a range of group interactions, such as assignment of a group leader, cultivation of group pride, and coordinated group efforts established from group-developed strategies. These studies might focus on contexts simulating group activity in the classroom and use school-age participants.

Future research might also focus on the manipulation of experimental variables within the basic research setting. The introduction of risk in choice-making, for which choice-makers may operate at a loss or a gain during any given trial, might influence the importance participants place on team efforts and performing well. Reciprocal cooperation in the form of sharing earned resources is another variable that could be expected to influence individual performance in the team context. This consideration would require high-earners to give points to low-earners. Taken together, risk and reciprocity could place new importance on team membership, motivating individuals to perform optimally despite reliance on team gains. The influence of risk in choice-making and the agreement to share earnings among foragers are observed in hunter- gather societies (Winterhalder, 1996) and have evolutionary importance to survival in these societies. These manipulations would help define the variables that influence individual performance in the group context. Studied and analyzed this way, it is the context for team efforts, and not the team membership itself, that determines individual performance.

Matching relations provide a precise and reliable measurement of effort and attentiveness. It is useful to employ matching relations when investigating individual and group efforts. Use of matching relations as a dependent variable in studies investigating learning or cognitive constructs such as information processing and arousal may prove to be quite valid. Unlike many other popular measures in educational psychology that require construct definitions and reliable implementation, which present a certain degree of error, matching relations rely on discrete choices relative to alternative discrete choices. Inclusion of a supplemental matching relations task in educational psychology studies might enhance the understanding of individual differences and provide behavioral meaning to cognitive constructs.

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APPENDIX A: Glossary of Terms

Glossary of Terms

Choice Allocations – in concurrent choice, the distribution of choices across the two options (Herrnstein, 1961)

Group Contingency – behavior-consequence relationships in which the receipt of reinforcing or aversive stimuli for one or more of the group members depends, at least in part, on the behavior of some other group members (Neumann, 1977)

Ideal Free Distribution - the tendency for animals to maximize foraging efforts by dispersing across areas relative to reinforcement available (Kennedy & Gray, 1993)

Interdependent Group Contingency – a type of group contingency whereby group outcomes are contingent on group performance (Axelrod, 1998)

Matching - a difference in response allocation as a function of reinforcement available at wither option (Herrnstein, 1970)

Temporal Discounting – the weakening of consequences due to delay (Critchfield & Kollins, 2001)

APPENDIX B: Group-Administered TEMPORAL DISCOUNTING Measure (Beck & Triplett, 2009)

	In each column below **circle just one number** to indicate the **most** money ($$) you would willing to pay right now if you had to wait for the amount of time shown to get the $1000 you bought.					
	$1000 delayed 1 WEEK	$1000 delayed 1 MONTH	$1000 delayed 3 MONTHS	$1000 delayed 6 MONTHS	$1000 delayed 1 YEAR	$1000 delayed 5 YEARS
$$	995	995	995	995	995	995
$$	990	990	990	990	990	990
$$	980	980	980	980	980	980
$$	960	960	960	960	960	960
$$	940	940	940	940	940	940
$$	920	920	920	920	920	920
$$	900	900	900	900	900	900
$$	850	850	850	850	850	850
$$	800	800	800	800	800	800
$$	750	750	750	750	750	750
$$	700	700	700	700	700	700
$$	650	650	650	650	650	650
$$	600	600	600	600	600	600
$$	550	550	550	550	550	550
$$	500	500	500	500	500	500
$$	450	450	450	450	450	450
$$	400	400	400	400	400	400
$$	350	350	350	350	350	350
$$	300	300	300	300	300	300
$$	250	250	250	250	250	250
$$	200	200	200	200	200	200
$$	150	150	150	150	150	150
$$	100	100	100	100	100	100
$$	80	80	80	80	80	80
$$	60	60	60	60	60	60
$$	40	40	40	40	40	40
$$	20	20	20	20	20	20
$$	10	10	10	10	10	10
$$	5	5	5	5	5	5
$$	1	1	1	1	1	1

APPENDIX C: Modified Beck and Triplett (2009) Measure used in Pilot

You win $1,000 in the lottery! What is the **least amount** of money you would accept **right now** if you had to wait *1 week, 1 month, 3 months, 6 months, 1 year, and 5 years* to receive the full $1,000? Circle one amount in each column.

	$1000 delayed 1 WEEK	$1000 delayed 1 MONTH	$1000 delayed 3 MONTHS	$1000 delayed 6 MONTHS	$1000 delayed 1 YEAR	$1000 delayed 5 YEARS
$$	995	995	995	995	995	995
$$	990	990	990	990	990	990
$$	980	980	980	980	980	980
$$	960	960	960	960	960	960
$$	940	940	940	940	940	940
$$	920	920	920	920	920	920
$$	900	900	900	900	900	900
$$	850	850	850	850	850	850
$$	800	800	800	800	800	800
$$	750	750	750	750	750	750
$$	700	700	700	700	700	700
$$	650	650	650	650	650	650
$$	600	600	600	600	600	600
$$	550	550	550	550	550	550
$$	500	500	500	500	500	500
$$	450	450	450	450	450	450
$$	400	400	400	400	400	400
$$	350	350	350	350	350	350
$$	300	300	300	300	300	300
$$	250	250	250	250	250	250
$$	200	200	200	200	200	200
$$	150	150	150	150	150	150
$$	100	100	100	100	100	100
$$	80	80	80	80	80	80
$$	60	60	60	60	60	60
$$	40	40	40	40	40	40
$$	20	20	20	20	20	20
$$	10	10	10	10	10	10
$$	5	5	5	5	5	5
$$	1	1	1	1	1	1

APPENDIX D: Modified Beck and Triplett (2009) measure used in Experiments 1 and 2

	You won $1,000 in the lottery! BUT you have to wait **1 WEEK** for the money. The lottery is giving you the option to accept a lesser amount *right now*, rather than having to wait for the full $1,000. What is the ***minimum amount*** of money you would accept **right now**, rather than waiting 1 week for the full $1,000? Circle one amount.	You won $1,000 in the lottery! BUT you have to wait **1 MONTH** for the money. The lottery is giving you the option to accept a lesser amount *right now*, rather than having to wait for the full $1,000. What is the ***minimum amount*** of money you would accept **right now**, rather than waiting 1 month for the full $1,000? Circle one amount.	You won $1,000 in the lottery! BUT you have to wait **3 MONTHS** for the money. The lottery is giving you the option to accept a lesser amount *right now*, rather than having to wait for the full $1,000. What is the ***minimum amount*** of money you would accept **right now**, rather than waiting 3 months for the full $1,000? Circle one amount.
$$	995	995	995
$$	990	990	990
$$	980	980	980
$$	960	960	960
$$	940	940	940
$$	920	920	920
$$	900	900	900
$$	850	850	850
$$	800	800	800
$$	750	750	750
$$	700	700	700
$$	650	650	650
$$	600	600	600
$$	550	550	550
$$	500	500	500
$$	450	450	450
$$	400	400	400
$$	350	350	350
$$	300	300	300
$$	250	250	250
$$	200	200	200
$$	150	150	150
$$	100	100	100
$$	80	80	80
$$	60	60	60
$$	40	40	40
$$	20	20	20
$$	10	10	10
$$	5	5	5
$$	1	1	1

APPENDIX D continued: Modified Beck and Triplett (2009) measure used in Experiments 1 and 2

	You won $1,000 in the lottery! BUT you have to wait **6 MONTHS** for the money. The lottery is giving you the option to accept a lesser amount *right now*, rather than having to wait for the full $1,000. What is the ***minimum amount*** of money you would accept **right now**, rather than waiting 1 week for the full $1,000? Circle one amount.	You won $1,000 in the lottery! BUT you have to wait **1 YEAR** for the money. The lottery is giving you the option to accept a lesser amount *right now*, rather than having to wait for the full $1,000. What is the ***minimum amount*** of money you would accept **right now**, rather than waiting 1 month for the full $1,000? Circle one amount.	You won $1,000 in the lottery! BUT you have to wait **5 YEARS** for the money. The lottery is giving you the option to accept a lesser amount *right now*, rather than having to wait for the full $1,000. What is the ***minimum amount*** of money you would accept **right now**, rather than waiting 3 months for the full $1,000? Circle one amount.
$$	995	995	995
$$	990	990	990
$$	980	980	980
$$	960	960	960
$$	940	940	940
$$	920	920	920
$$	900	900	900
$$	850	850	850
$$	800	800	800
$$	750	750	750
$$	700	700	700
$$	650	650	650
$$	600	600	600
$$	550	550	550
$$	500	500	500
$$	450	450	450
$$	400	400	400
$$	350	350	350
$$	300	300	300
$$	250	250	250
$$	200	200	200
$$	150	150	150
$$	100	100	100
$$	80	80	80
$$	60	60	60
$$	40	40	40
$$	20	20	20
$$	10	10	10
$$	5	5	5
$$	1	1	1