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The Impact of Competition on Cooperation: Evidence from a Series of Bargaining Game Experiments

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The Impact of Competition on Cooperation: Evidence from a Series of Bargaining Game Experiments

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Abstract

Rationality has long been one of the key principles of economics because it seeks to explain patterns of behavior and preferences in economic interactions. The belief that economic agents interact to maximize individual gain as a means of making themselves better off helps to explain the motivations underlying exchange as a fundamental concept of economics. Specific to game theory, theories of rationality predict that individuals are so-called “rational” agents who behave in such a way as to maximize individual gain in social dilemmas even at the expense of others. However, both laboratory experiments and everyday behavior challenge these existing theories by demonstrating that humans do in fact cooperate in competitive social situations at a cost to themselves. These findings call into question the theoretical framework of rationality foundational to game theory and suggest the presence of external factors that may influence our willingness to cooperate in competitive environments.

The goal of this research is to analyze the impact of three of these potential factors—intensity of competition, game duration, and group size—on cooperation through a series of bargaining game experiments. Analysis of earnings and claims across several iterations of a Traveler’s Dilemma bargaining game allowed for conclusions to be drawn about the relationship between these factors and cooperation. Our results show this relationship to be significant in the cases of game duration and group size, but insignificant for intensity of competition. Of notable importance is the clear impact of increasing group size in our experiments as a model of the Tragedy of the Commons theory of shared resources. Our results offer strong support for the Tragedy of the Commons in that they reflect a significant decrease in earnings and claims as group size increased. These results are consistent with the predictions of the Tragedy of the

Commons in suggesting that cooperation for the sustenance of a common resource becomes increasingly difficult to maintain the more agents are simultaneously responsible for it.

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Contents

Chapter 1: Introduction

The existence of cooperation in social dilemmas is an inherently puzzling aspect of human nature that has become a subject of recent interest to a wide range of disciplines—most notably including economics, biology, political science, and anthropology—that all offer unique means of identifying and analyzing preferences for cooperation. Theories of rationality in economics claim that individuals are rational agents who behave in such a way as to maximize individual gain even at the expense of others, while evolutionary biology has similar roots in the "survival of the fittest" belief of competition as the central determinant of individual and group fitness (Darwin, 1871). However, both laboratory experiments and everyday behavior challenge these existing theories by demonstrating that humans do in fact cooperate in competitive social situations, even at a cost to themselves. These findings call into question the theoretical framework of rationality underlying game theory and suggest the presence of external factors that may influence our willingness to cooperate in competitive environments.

The goal of this research is to analyze the impact of three of these factors—intensity of competition, game duration, and group size—on cooperation through a series of Traveler's Dilemma bargaining game experiments. Each experiment was used to model a social dilemma in which participants were presented with a fundamental choice between cooperation and defection. In the Traveler's Dilemma, players are grouped together for a series of rounds in which they simultaneously claim a dollar amount from $0.80-$2.00. The player who declares the lower amount is rewarded, while the player who declares the higher amount is penalized. Players who declare the same amount receive no reward or penalty. The payoff structure is set such that a claim of $2.00 allows individuals to avoid penalty but exposes them to the possibility of being undercut by their partners. Cooperation is thus paradoxical in that it is simultaneously a means of earning the highest average payoff per round, while also being a necessarily risky strategy due to the risk of defection. Such is the nature of the common resource social dilemma: the decision to cooperation contributes to the benefit of the entire group, but the choice to defect offers participants the opportunity to maximize individual benefit at the expense of the others.

Game theory predicts deviation from the cooperative outcome to be the dominant strategy, yet collective action experiments consistently demonstrate that human beings are willing to forgo some level of payoff to cooperate in social dilemmas. Our experiments allowed us to observe the extent to which this holds true under a variety of conditions, with the goal of commenting on the factors that play a significant role in determining when we choose to defy theoretical predictions of rationality. For intensity of competition, we modeled how the frequency of cooperative behavior is impacted by an increasingly competitive environment through the elimination of low-earning players. We hypothesized that increasing the competitive nature of the game would cause players to cooperate more in order to avoid elimination. For game duration, we observed how participants behaved when matched for different amounts of time under the belief that longer interactions would yield greater cooperation. Finally, for group size we tested the frequency with which participants chose to cooperate in groups of different sizes.

This final experiment was especially significant in that it was used to model the Tragedy of the Commons theory of shared resources presented by Garrett Hardin in 1968. Hardin's essay discusses the difficulty in maintaining a common resource in the absence of coercive mechanisms under the assumption that individuals will choose behavior for the maximization of individual benefits at the expense of the common good. This theory has become especially relevant in recent history as a model for modern issues such as overfishing and climate change that require collective action to avoid consequences of international magnitude. We found examining this theory to be especially notable considering its game-theoretical roots and modern implications for economic and political policy.

Ultimately, we hope to identify potential motivations underlying cooperative behavior in order to provide a foundation on which greater insight into what drives cooperation can be utilized to generate cooperation in competitive environments. In order to do so we must first understand the role of cooperation throughout our species' history, the mechanisms for its evolution, and why our behavior so consistently deviates from theoretical predictions.

Chapter 2: Literature Review

2.1 Rationality

With a breadth of disciplines interested in understanding how competition and cooperation relate to the evolution of human nature—specifically economics, anthropology, evolutionary biology, and ecology—it is unsurprising that there is little consensus among scholars as to their importance and impact on patterns of human behavior. The theory that human nature is inherently competitive has been supported by the assumptions of rationality that have existed as the foundation of behavioral game theory since the discipline's inception (von Neumann & Morgenstern, 1944). These theories of rationality assume that humans act as selfish agents capable of identifying strategies to maximize individual payoff without regard for the outcomes of others or their failure to do "the right thing" (Dawes & Thaler, 1988). Under these predictions, human behavior is necessarily competitive and cooperation is dismissed as irrational, as any attempts at cooperative behavior are understood to be impracticable considering the assumed selfish behavior of other players in competitive social dilemmas.

However, much of the existing literature identifies the myriad shortcomings of these assumptions and the restrictions that they place on understandings within behavioral game theory. As Cosmides and Tooby (1994) explain, the tacit assumption of rationality assumes that so-called rational behavior is the state of nature, and thus explanations that invoke the cognitive processes underlying human choices are only required when behavior deviates from this assumed state. They instead argue that the true state of human nature is in fact not behaving *at all*, and as such all behaviors represent a departure from this state of inaction and consequently require explanation. Humans make decisions by virtue of neural computational devices, and thus explanation of any behavior—rational or not—is rooted in theories of the architecture of such devices.

Cosmides and Tooby (1994) note that the problems that have shaped these devices were those characteristic of our ancestors' hunter-gatherer past rather than those of the modern world. The authors argue that it can be demonstrated that "rational" decision-making methods are incapable of solving the natural adaptive problems our ancestors faced in order to reproduce, thus making them computationally very weak. This is the primary reason why mechanisms for specialized problem-solving were favored by natural selection over those for general-purpose problem-solving. The natural selection of specialized problem solving over our evolutionary history suggests that the human mind may not be irrational but may instead be *better* than rational, outperforming artificial problem-solving systems that are programmed to apply the same problem-solving methods to every problem and are unable to incorporate special assumptions into the process. Natural selection has equipped humans with cognitive specializations and problem-solving strategies that allow us to incorporate problem-specific regularities into the decision-making process (Cosmides & Tooby, 1994). Compared to generalized problem-solving, specialized decision-making methods perform in a manner better than rational in that they can arrive at successful outcomes that general-purpose methods reach either less efficiently, or not at all. Such a conclusion suggests that the traditional and normative approaches to rationality are inherently flawed and may explain the inability of existing economic theory to accurately predict patterns of human behavior.

Stanovich (2013) similarly claims that flaws within our traditional understandings of rationality are responsible for the perceived irrationality of human behavior, specifically when compared to that of animals. Stanovich argues that the view of human behavior as less rational than that of animals is unfair and a product of the shortcomings of the so-called “axioms of rational choice” that human behavior so often seems to violate. These axioms represent patterns of preferences that model behavior considered to be utility-maximizing, and while studies have shown that nonhuman animals are largely rational in the axiomatic sense, Stanovich argues that the principles of rational choice are easier to follow when the cognitive structure of the organism is simpler (Stanovich, 2013). Human cognition is complicated by the role of contextual complexity, symbolic complexity, and higher-order evaluations of preferences, which Stanovich sees as three significant exclusions from basic assumptions of rationality responsible for the perception of human behavior as irrational.

This perception is reinforced under the axiomatic approach by the incorporation of instrumental rationality, defined as adherence to consistent and coherent relationships (Stanovich, 2013). The use of instrumental rationality allows the rationality of animals to be compared to that of humans (Kacelnick, 2006), but this assessment fails to account for contextual information and symbolic utility that humans code into decisions and use to both layer and evaluate preferences. Unlike other animals, humans appear capable of structuring preferences such that they can model a preference for a particular set of "first-order" preferences. In order to satisfy potentially conflicting preferences, humans attempt to integrate rationally across all vertical levels of preference, which can result in an instability of instrumental rationality that does not challenge nonhuman animals (Stanovich, 2013). As Stanovich argues, it is thus not paradoxical for humans to be understood as less axiomatically rational than animals considering the complexity of information that humans are able and often required to code into their decisions.

This idea that preferences should not be constrained by traditional understandings of rationality is similarly built upon by Sobel (2005). Sobel discusses the ways in which one can expand the notion of preferences and pays particular attention to the impact on decision-making of reciprocity, which he defines as "a tendency to respond to perceived kindness with kindness and perceived meanness with meanness and to expect this behavior from others." Sobel uses a model of intrinsic reciprocity—which he claims to be a property of preferences—and is operating under the theory that (1) individual preferences depend on the consumption of others, and (2) that the rate at which one values the consumption of others is dependent on both past and anticipated actions.

Sobel's (2005) model builds on the more traditional view of instrumental reciprocity in which cooperation acts as a strategy for establishing a reputation as a reliable partner in order to maintain a profitable long-term relationship with others. The author's theoretical model suggests that while defection may be a dominant short-term strategy, cooperation in repeated interactions can lead to long-term profitability when players have established a reputation of reliability (Sobel, 2005). Sobel argues that this approach is powerful considering nearly all natural exchanges can be viewed as part of a long-term interaction, thus providing constant incentive to be perceived as reliable. Under this theory, the potential long-term gains from cooperative interaction facilitated by a reliable reputation outweigh the short-term opportunity for defection at the expense of harming one's reputation and the possibility of cooperation in the future.

The conclusion of reciprocity as an underlying motivator of so-called "irrational" behavior developed by Axelrod (1984) is one of the most consistent in the literature and is adopted by Dawes and Thaler (1988) as a factor of "reciprocal altruism." Dawes and Thaler suggest that free riding, a form of defection in which an individual benefits from the contribution of others to a common resource but does not contribute themselves, may be a less fruitful strategy when factoring in the probable future response of others. When a social dilemma persists for numerous rounds, cooperators ultimately benefit considering that a cooperative act contributes to one's reputation as a cooperative person and is reciprocated with cooperation a high percentage of the time.

One apparent flaw of this theory is that while it may be considered rational to cooperate in repeated interactions, one-shot social dilemmas offer no opportunity for cooperative reciprocity and should result in low levels of cooperation. However, Isaac and Walker (1988) observe 50 percent cooperation rates even in single trial experiments, which suggests that reciprocity may be insufficient in challenging understandings of rationality. Dawes and Thaler (1988) argue that this insufficiency may be filled by altruism—some combination of "taking pleasure in others' pleasure" and "doing the right thing." In this context, the payoff of cooperation is complemented by the individual benefit derived from the altruistic act. This benefit is non-monetary and is thus excluded from a generalized calculation of rationality in which the payoff of defection is compared to the payoff of cooperation, yet it contributes to the idea that a strategy of defection may not be purely rational even when payoff-dominant.

In *Theory of Games and Economic Behavior* (1944), the foundational text in game theory, authors John von Neumann and Oskar Morgenstern initiate a movement to conceptualize rationality as the maximization of expected utility by an individual. This laid the groundwork for the assumptions of rationality present in modern game theory, but Colman (2003) believes that the school of thought they established has created significant problems for both normative and positive interpretations of game theory. Rational assumptions of orthodox game theory are not characteristic of social interactions because they cannot guide players to *focal points*, equilibrium points in coordination dilemmas seen as "intuitive" choices by players that are payoff-indifferent under utility maximization (Colman, 2003). Colman offers the example of a Heads or Tails coordination game in which two players benefit from predicting the same result, resulting in a payoff matrix of two Nash Equilibria. Consequently, game theory predicts players will engage in mixed strategies, yet nearly 87% of individuals chose Heads. This suggests a tendency to see Heads as the better of two strategies and thus a focal point in mixed strategies, yet under the theory of utility maximization there is no incentive to pick one option over the other. Theoretical predictions are naturally handicapped due to their inability to incorporate external information into the payoff matrix, and as a result are unable to accurately predict patterns of human behavior.

The inability of rationality theory to guide players to focal points or explain why individuals choose them in practice is one of the major flaws challenging its accuracy and validity as a foundation of game theory. The shortcomings of rationality in social contexts is not merely a matter of accuracy in explaining individual behavior but also of restricting behavior by simplifying it to a series of rules frequently violated in social interaction. The assumptions that seek to predict the behavior of humans fail to account for the myriad constraints that humans face in everyday decision-making and the heuristic rules necessitated by those constraints. Bounded rationality has long been concerned with the constraints we face when making decisions (most notably cognitive) and the home-grown rules of thumb that we use to make decisions in the face of these constraints (Simon, 1982).

Simon (1982) argues that theories of bounded rationality require a relaxation of one or more of the assumptions of expected utility theory. Rather than assume a fixed set of alternatives to choose from, bounded rationality postulates the generation of alternatives on the individual level, procedures for estimating unknown probability distributions of outcomes, and satisfying strategies for maximizing utility. These are drawn from evidence about human thought and choice processes, including our cognitive capacity for generating alternatives, computing their consequences under varying levels of certainty, and ultimately making comparisons among them. Theories of bounded rationality are theories of decision-making and assume that the decision-maker uses their mind as well as possible to attain goals, but that they face in the decision process the true capacities of the human mind overlooked by assumptions of rationality.

In response to Simon (1982), Selten (1990) accepts bounded rationality as a deviation from traditional rationality and utility maximization theory but cautions that modeling bounded rationality merely as optimization under constraints of memory size and computational capacities based on abstract principles rather than empirical evidence is doomed to fail. In addition to the use of empirical evidence, Selten argues that there exists a series of *motivational* limits on rationality that result from a view of decision emergence. Decisions are made on several levels within the brain, with the final decision guided by simple learnings processes. The decision alternatives that occur on levels throughout the brain do not necessarily produce a clear recommendation, however, resulting in certain motivational constraints. The decision emergence view emphasizes that rationality's view over behavior is limited and diminished further by the influences of emotion. Emotions narrow attention to a restricted selection of alternatives related to temporary goals and fears, and in doing so control the direction and thinking of imagination (Selten, 1990). This is counterbalanced to some extent by the conscious mind's visualization of future consequences of actions which shifts the motivational system towards more long run goals, but it nevertheless inhibits the sort of rational processes that game theory is predicated on.

Cooperation has remained puzzling throughout human history due to the inability of theoretical predictions to accurately model human behavior. However, it may be the case that how we have conceived of these theories of rationality is fatally flawed, and that our continued acceptance of the normative views of the subject restricts the ability of game theory to achieve its goal in predicting human behavior and decision making. A closer look at how these predictions play out in experimental and real-world settings, as well as an examination of the evolution of cooperation discussed in the next section, may be necessary in addressing these constraints.

2.2 **The Evolution of Cooperation**

One of the most common understandings of evolution is that of the "survival of the fittest" theory presented most notably by Darwin (1871), that predicates evolution on the maintenance and reproduction of only the strongest organisms. Over time, the competitive nature of evolution should reward only selfish behavior that increases individual fitness and makes one more likely to be selected for by natural selection, while simultaneously phasing out cooperative behavior that comes at a personal cost to the cooperator. However, we frequently observe cooperation across a range of biological level: genes cooperate in genomes, cells cooperate in multicellular organisms, and humans cooperate so frequently that it is the organizing principle of human society (Nowak, 2006). No other organism on Earth engages in the same complex interactions of cooperation and defection as humans, and it is understandable why: in the simplest sense, evolution via natural selection only favors costly, prosocial behavior when it directly increases the chances of propagating one's own genes (Boyd, 2008). Cooperation in nonhuman primates is limited to relatives and small groups of cooperators with which one is more likely to share genetic information, setting them apart from humans that frequently display cooperative tendencies and interactions with individuals that share no genetic information. That cooperation is so central to human nature is confounding to evolutionary biologists considering the behaviors of other primates, and the question of how natural selection can lead to cooperative behavior has remained a topic of discussion within the discipline for decades.

A cooperator is someone who incurs a personal cost to provide some benefit to another individual, whereas defectors choose not to incur these costs and in doing so provide no additional benefit to others (Nowak, 2006). Cost and benefit in an evolutionary context are measured by fitness; rationality in this sense implies maximizing one's individual fitness at the expense of others. In a mixed population of cooperators and defectors, defectors have a higher average fitness than cooperators and are thus chosen through natural selection, gradually decreasing the relative population of cooperators over time until they vanish entirely from the population (Nowak, 2006). A population of only cooperators has the highest average fitness, but the introduction of one defector will gradually decease the fitness of the population over time until no cooperators remain. Under these assumptions, cooperation is not an evolutionary stable strategy because it can be invaded and ultimately eliminated by a strategy of defection.

That humans frequently cooperate, then, is confounding considering the constant threat of defection throughout evolutionary history. It is possible, however, that the level of cooperative behavior observed today has been borne out of necessary collaboration required to solve adaptive problems inherent to social interaction. Tomasello, Melis, Tennie, Wyman, and Herrmann (2012) propose that humans' unique forms of cognition, communication, and social life all derive from our species' foraging history in which mutualistic collaboration became necessary for the well-being of both the individual and the partner on whom they were interdependent. In this context, humans developed new skills and a motivation of joint intentionality that reinforced cooperative behavior with protection against cheaters.

The authors believe that a second step followed in our evolutionary history in which these new skills and motivations because scaled up to the group level as human groups began facing competition from other groups. Collaboration within one's group became necessary for the survival of the community and the fitness of its members. The new group-mindedness that resulted led to the creation of culture, norms, and institutions driven by shared intentionality that required a previously unseen level of collaboration and altruism necessary to sustain human sociality (Tomasello, et al., 2012).

The belief that modern cooperative tendencies have been borne out of our species' history of necessary collaboration is supported by Tooby, Cosmides, and Price (2006), albeit with some variations as to the evolutionary process they believe ultimately led to these behaviors. Taking an approach rooted in evolutionary psychology, the authors propose that species-typical mechanisms have become incorporated into human architecture by natural selection after reliably demonstrating procedures and solutions to adaptive problems faced throughout our evolutionary history. The functional logic embodied by these mechanisms is a form of evolutionary rationality that the authors call *ecological rationality*. Their theory of ecological rationality deviates from ordinary rationality in several ways, most notably that the human mind has become equipped with psychological adaptations for realizing gains in trade that occur in collective action exchanges. In their application of evolutionary psychology, Tooby, et al. (2006) find that the traditional view of trade as mechanism of economic rationality is false; rather, exchange is a product of evolutionary reasoning specializations tailored by natural selection to enable collective parties to solve computational problems specific to social exchange. Social exchange is not merely a mechanism for maximizing one's individual benefit as it is believed to be under traditional economics, but instead allows for the emergence of solutions to adaptive problems via collective action.

General collaborative behavior is insufficient, however, because cooperation is not an evolutionary stable strategy; cooperation naturally leads to exposure of defection which can invade a population of cooperators and gradually decrease group well-being over time (Nowak, 2006). While the fitness advantages of exchange are relatively obvious—exchange serves to make two parties better off—cooperative behavior must necessarily incorporate the ability to detect and defend against cheaters in order to be successful (Tooby, et al., 2006). The evolutionary perspective predicts that in order to be selected for, evolutionary mechanisms for exchange must incorporate complex, conditional strategies to defend against being outcompeted by free riders in collective action. What emerges is strategies that do not simply pick the highest absolute payoff, but instead favor practices that lead to higher relative payoffs against exploitive strategies even at the expense of some additional payoff. Computational elements designed to defend against exploitation are thus an indispensable feature of the mechanisms adapted for cooperation and have allowed these complex and seemingly suboptimal strategies to emerge and remain stable over time (Tooby, et al, 2006; Danielson, 2002).

Much of the relevant literature on the evolution of cooperation agrees that cooperation has only been able to evolve via the development of computational mechanisms necessary to solve adaptive problems with defenses against cheaters built in. One of the major contributing sources to this body of literature is that of Martin Nowak (2006) who not only includes the necessary components of these mechanisms (specifically protection against cheaters) but outlines a series of specific conditions that have enabled cooperation to be selected for by natural selection in mixed populations that would otherwise be dominated by defectors. These five mechanisms—kin selection, direct reciprocity, indirect reciprocity, network reciprocity, and group selection—are established based on a series of ratios derived from a 2x2 matrix used to model the relevant condition for the evolution of cooperation. For example, for natural selection to favor cooperation in kin selection, the coefficient of relatedness, r, must be greater than the cost-to-benefit ratio of a cooperative act, such that: $r > c/b$ (Nowak, 2006). Relatedness in this case is defined as the probability of sharing a gene with the recipient of the altruistic act. Similarly, for direct reciprocity to yield stable cooperative strategies the probability of another encounter between two individuals, w, must exceed the cost-to-benefit ratio of an altruistic act such that: $w > c/b$. This comparison of the cost-to-benefit ratio to another situational variable is consistent for each mechanism.

The contributions of Nowak (2006) are significant because they build on existing theories of the evolution of cooperation by modeling the adaptive problems discussed in Tomasello, et al. (2012) and Tooby, et al., (2006), and exemplify the situational mechanisms at work that have allowed cooperative behavior to evolve. From these mechanisms, Nowak concludes that evolution is constructive because of cooperation that allows for specialization and promotes biological diversity. New levels of organization are only able to evolve when competing units on lower levels are able to cooperate, thus making cooperative behavior the underlying factor of the "open-endedness of the evolutionary process" and helping to explain why it should not be surprising that cooperation has evolved so successfully throughout our species' history.

Evolution is often understood to be naturally driven by competition, yet cooperation observed on various biological levels suggests that at some point in our species' history collaborative behavior became necessary for solving adaptive problems faced by our ancestors. The solutions produced by the complex mechanism of this collaboration allowed these behaviors to be advanced by natural selection, despite the misconception that only selfish behavior serving to increase individual fitness should have persisted throughout evolutionary history. Based on the evidence suggesting otherwise, Nowak (2006) argues that perhaps "natural cooperation" should hereafter be considered as a fundamental principle of evolution for its role as a catalyst of evolutionary progress. The experimental results observed in the literature presented in the next section support such a fundamental change to our understanding of how behavior has evolved throughout our species' history.

2.3 **Social Dilemma Experiments**

The Prisoner's Dilemma has long been game theory's foundational social dilemma model because it lends itself to a relatively simple 2x2 matrix in which each player is presented with a choice between cooperation or defection. If both players cooperate, they achieve the highest collective payoff, but in choosing a cooperative strategy one becomes exposed to the possibility of defection from the other player seeking to achieve the highest *individual* payoff. This is the problem characteristic of social dilemmas: cooperation results in the highest collective benefit, but individually rational behavior leads to an outcome in which everyone is worse off than they otherwise may have been (Kollock, 1998).

Surging interest in social dilemmas in recent decades has resulted in a significant body of experimental research attempting to model such situations in which individual and collective interests are at odds. Among the popular experimental designs used to do so are the Traveler's Dilemma, Public Goods game, and Trust game. Due to the apparent payoff of individually beneficial strategies, game theory predicts that instances of cooperation will be low and defective strategies will be common, as it is assumed that individuals are both rational and selfish and will identify and adhere to strategies for individual utility-maximization (Dawes & Thaler, 1988). However, as has been discussed in previous sections, these theoretical predictions are notoriously unsuccessful at predicting human behavior in the real world, and a growing body of academic disciplines have begun to attempt to identify the reasons for this gap between theoretical understandings and observed behavior. This section discusses several social dilemma models and laboratory experiments that have produced such results that contradict the so-called "rational" predictions of game theory.

Studies of human behavior in social dilemmas typically explain tendencies to cooperate by dividing people into pro-self and prosocial types, or by appealing to forms of external control (Capraro 2013). However, numerous experiments have shown that humans may act cooperatively even in one-shot social dilemmas without external control, and that the rate of cooperation is typically payoff dependent. This eliminates a division between pro-self and prosocial individuals as a predictor of human behavior and provides evidence that humans instead possess cooperative attitudes by nature.

Capraro (2013) examines the existence of these natural cooperative attitudes and suggests that humans do not act as single agents as assumed by economics, but rather develop forecasts used to predict how a social dilemma will evolve if coalitions are formed. Humans then act according to their most optimized forecast, derived from an evaluation of the probability that other players abandon the collective interest. This evaluated probability accounts for the likelihood of defective strategies considering the tradeoff between the incentive and risk of doing so. As an attempt to model the mental processes that real subjects perform in social dilemmas, Capraro believes his model is the first to successfully predict population average behaviors in social dilemmas and explain experimental findings in game theory such as those discussed in the remainder of this section.

Capraro (2013) also cites that the rate of cooperation in experimental games may depend on the payoff, and that the same person may change their attitude towards cooperation when the payoff of doing so is higher or lower. This phenomenon was examined by Capra, Goeree, Gomez, and Holt (1999) using a Traveler's Dilemma game. The Traveler's Dilemma—explained in greater detail in Chapter 3—involves two players simultaneously claiming a dollar amount within a defined interval, with the lower-claiming player being rewarded and the higher-claiming player receiving an equal penalty (players who claim the same amount receive neither reward nor penalty). Capra et al. used this structure to observe the level of cooperation at different penalty/reward values, and found that cooperation in the form of higher claims was greatest at lower values (i.e. when the risk and reward of defecting was the smallest) and that as the potential penalty for claiming the higher value increased, claims gradually approached the lower bound of the interval. One of the key takeaways from this study—both in the scope of this paper as well as the broader discussion of rationality within economics—is their observation that cooperation was to an extent maintained at different level depending on the risk of doing so. Backward induction in the Traveler's Dilemma predicts immediate and universal defection that results in a Nash equilibrium equal to the minimum possible claim; however, Capra et al. (1999) show that the decision between cooperation and defection occurs on a case-by-case basis and may incorporates contextual factors that drive us to cooperate even when presented with an opportunity to maximize individual benefit via a strategy of defection.

Like the Traveler's Dilemma, the Public Goods game has been used to model the anomalous existence of cooperation in social environments according to theoretical predictions. One of the most common predictors of behavior in the provision of public goods is the free rider hypothesis—that self-interested individuals lack incentives to voluntarily contribute to the provision of public goods, and that their failure to contribute is rational (Asch and Gagliotti, 1991)—though at the time of Marwell and Ames (1981) its acceptance was based on theoretical argument rather than empirical results. In their study, Marwell and Ames examined the success of two variations of the free rider hypothesis in predicting behavior in a single-trial Public Goods game—the *strong* free rider hypothesis, which predicts that all players will defect and nothing will be contributed to the public good, and the *weak* free rider hypothesis, which predicts some players will contribute to the provision of the public good while others will not. The strong free rider hypothesis follows the outcome predicted by rational theory, while the weak hypothesis does not yield very precise predictions.

What Marwell and Ames (1981) found was that the strong free rider hypothesis was repeatedly contradicted by their experimental results. Regardless of changes in situational variables, players voluntarily contributed an average of 40-60 percent of their resources to the public good even though all conditions of the experiment were designed to maximize the occurrence of self-interested strategies. That participants did not contribute the entirety of their resources supports the weak free rider hypothesis and proves that free riding does exist on some level, but the rate of contribution largely contradicts predictions of universal defection.

Similar results were produced in a repeated Public Goods game by Isaac, Walker, and Thomas (1984), who found that the level of contributed resources in the first round of a repeated game was similar to that of the single trial experiment seen in Marwell and Ames (1981). However, the results of Isaac, Walker, and Thomas show a decline in contribution rate over the course of these repeated interactions. Dawes and Thaler (1988) suggest that these experiments are significant in that they contradict the excessively harsh assumptions of rational game theory. While it has been shown that a free rider problem exists, the hypothesis that everyone free rides all the time is clearly wrong, as evidenced by the repeated contribution of individuals in a series of Public Goods games. There exists a divergence between universal free riding and universally optimal contribution, but the motivations for behavior in this middle ground remain controversial.

Further supporting this disparity are a series of Trust Game experiments, most notably those of Deck (2009) and Fehr and Rockenbach (2003). The Trust Game has historically been a popular experiment in game theory because it lends itself to a relative limited set of strategies. In the Trust Game, two players are given an equal endowment of money and a role as either the "Investor" or the "Trustee" (Fehr & Rockenbach, 2003). Moving sequentially, the Investor chooses how much of their endowment to send to the Trustee, which is increased by a predetermined multiplier. Once the money is received by the Trustee, they decide how much of this new allocation (equal to their initial endowment plus any contribution by the Investor) to send back to the Investor. Game theory predicts that the Investor will keep their entire endowment and send nothing, considering that a “rational” Trustee would simply keep their new endowment and return nothing to the Investor (Fehr & Rockenbach, 2003). Any exchange between the two players is thus predicated on an Investor’s trust that a share of the new endowment will be returned such that both players receive higher earnings than the situation in which the Investor sends nothing to the Trustee. However, this initial cooperation by the Investor is necessarily risky, leading game theory to predict a Nash equilibrium of zero exchange between the two participants.

Deck (2009) experimented with the Trust Game in two iterations that differed only in the individual payoffs available in each game. The author used different payoff structures to observe the frequency of cooperation depending on which player was “productive” (meaning the player whose contribution increased total available surplus), and while her specific research question is not relevant to this paper, the underlying logic of the game nevertheless remained the same: both players benefitted from mutual cooperation, but in sending a share of their endowment to the Trustee, the Investor risks losing some or all of their contribution.

In the first game, 56% of Investors trusted and 30% of Trustees returned a share of the endowment (Deck, 2009). This was statistically similar to the 52% trust and 29% cooperation observed in Deck (2001). In the second trust game roughly 26% of Investors trusted, but of those 53% of Investors received a share of the endowment back. Consistent in these results is that a percentage of participants—more than half in the initial trust game—were willing to trust their partner despite the risks of doing so. Also of note is that all games lasted only one round, so no future benefit of cooperating was present.

A trust game similar to the first experiment in Deck (2009) was used by Fehr and Rockenbach (2003), though one iteration of this study featured the ability for the Investor to declare a desired “back-transfer” amount and could threaten a fine equal to four monetary units if the Trustee sent back less than the desired amount. This added a new dimension to that of the traditional Trust game in that now Trustees could be penalized for sending less than the amount desired by the Investor, but the Investor’s choice to levy punishment was optional upon sending their endowment to the Trustee.

Of the 24 total Trustees in the “trust” condition (no option to punish), 19 sent back a share of their endowment, while in the “incentive” condition (punishment allowed) 29 of the 45 Trustees sent back more than four monetary units (equal to the amount of the punishment for not returning the desired amount)(Fehr and Rockenbach, 2003). What was interesting is that Trustees in the incentive condition were far more generous when Investors chose not to fine them: no Trustee who received no threat of punishment sent back zero, and 47% sent back more than 15 monetary units. The average back transfer in these cases was 12.5 monetary units, compared to 7.8 and 6 monetary units in the trust condition and the incentive condition with punishment chosen, respectively. Thirty-three percent of Trustees threatened with punishment sent back nothing, with only 13% electing to return more than 15 monetary units.

The results of Fehr and Rockenbach (2003) are especially interesting because they violate rationality theory on two distinct levels. Much like in Deck (2009), the results show that first-mover players *are* willing to send some or all of their initial endowment to their partner with the hopes of increasing surplus for both players despite the inherent risks of doing so, and that their partners frequently returned a portion of this endowment despite the cost to themselves. Fehr and Rockenbach (2003) believe that these results support the reciprocal nature of human altruism and prove that altruism was a significant motivator of behavior in their experimental setting. This differs from the idea of “reciprocal altruism” since there was no future interactions between players and thus nothing to be gained from cooperation in the future; however, the significance of altruism in this experiment contradicts the predictions of game theory and aligns with the analysis of Capraro (2013) in suggesting that individuals possess natural tendencies to cooperate that are simply dismissed as irrational by traditional game theory.

Fehr and Rockenbach (2003) also observed an added level of seemingly irrational behavior within the incentive condition of their experiment. The optional punishment in this experiment was used to measure the potential impact of detrimental sanctions on altruistic cooperation, measured as the amount sent by the Investor and the amount returned by the Trustee (Fehr and Rockenbach, 2003). The authors found that Trustees returned higher back-transfers on average when their Investor chose not to fine. Once the initial decision to send money to the Trustee was made, experimental results suggest that choosing not to punish would be the payoff-maximizing behavior for an Investor, yet 30 of 45 Investors chose to punish. The authors hypothesized that Investors choosing to threaten punishment despite this resulting in lower back-transfers on average was the product of two potential factors: preferences for strong reciprocity leading Investors to threaten punishment in order to ensure a more even distribution of earnings, and the possibility that Investors may not have anticipated the effects of threatening to punish their partners.

To control for the latter possibility, Fehr and Rockenbach (2003) designed an experiment identical to the incentive case but in which players were shown beforehand the effect that threatening punishment had on back-transfers in the initial experiment. If Investors' decisions to punish in the initial experiment were caused by false conceptions of the impact of their decision, a lower incidence of punishment would likely be observed in the second experiment. However, in 50 pairs of participants, 34 Investors chose to punish their partner if they did not receive their desired back-transfer. This led the authors to conclude that preferences for strong reciprocity and the desire to punish those seen as cheaters was the motivating factor for players who elected to punish their partners. As mentioned in Chapter 2.2, the ability to protect against cheaters in social settings has been a fundamental aspect in the evolution of cooperation, and the results of Fehr and Rockenbach (2003) support the notion that the desire to punish perceived cheaters is one reason why observed behavior frequently deviates from theoretical predictions.

These experiments have all been used to model the behavior of individuals in collective action situations in which the group derives the maximum benefit from universal cooperation, but where the benefit-maximizing strategy for the individual is defection. Many of the studies discussed thus far modeled collective action dilemmas occurring in small groups, but a significant body of literature exists analyzing the “Tragedy of the Commons” theory proposed by Garrett Hardin in 1968. Hardin’s essay posed concern about the ability of groups to maintain common resources considering the potential for personal gain available at minimal cost for those who exploit the freedom of usage that is characteristic of common goods. This essay served as a catalyst for investigation of cooperative behavior in collective action problems, most notably those such as climate change and the overharvesting of fish that occur on an international scale (Diekert, 2012). Hardin’s concern that “freedom in a commons brings ruin to all” is derived from Mancur Olson’s “zero contribution thesis” that rational, self-interested individuals in large groups in the absence of coercive mechanisms will not act in the interest of the group (i.e. will contribute nothing to the collective good) (Olson, 1965). This theory is consistent with those fundamental to game theory that predict universal defection in collective action problems.

In response to this pessimistic view, Ostrom (2000) points out that both laboratory and field studies confirm that a large number of collective action problems have been resolved successfully, and that the notion that groups can find a way to act in their own interest is not entirely misguided. That collective action situations may be resolved on their own provides an optimistic view compared to that of Olson (1965) and Hardin (1986), and is supported by the existing body of experiments that have repeatedly shown that human behavior in the experimental setting rarely follows the predictions of rational game theory. The challenge facing economists now is identifying the source of this divergence between theory and behavior and rethinking the fundamental assumptions that repeatedly fail to predict the behavioral motivations of humans. Ostrom calls for future empirical and theoretical work to question the contextual variables that affect the processes of evoking, adhering to, and rewarding the use of social norms such that we may understand the impact of institutional, cultural, and biophysical contexts on collective action situations. Dawes and Thaler (1988) suggest that exploring issues normally ignored by economics—specifically what factors determine the rate of cooperation—can help establish a better understanding of the problems presented by the Traveler’s Dilemma, Public Goods game, Trust game, and other social dilemmas. This is precisely what the rest of this paper sets out to do: by exploring potential factors of cooperation in the experimental setting, we hope to help explain the motivations of cooperative human behavior that underlie the divergence between economic predictions and experimental results.

Chapter 3: Methodology

The participants and procedures of the experiments are explained in this chapter, followed by a detailed outline of the Traveler’s Dilemma games used to test our three research questions.

3.1 Participants and Procedures

The experiments were conducted at Trinity College in Hartford, Connecticut throughout the 2019 fall academic semester running from September 2019 to December 2019. Participants were students in Professor Arthur Schneider's College Course 210: Theory of Games and Experimental Game Theory, a laboratory worth 0.5 academic credits that met for 75 minutes once a week for 14 weeks. All experiments were conducted within these weekly class periods in a computer laboratory. College Course 210 is not classified under a certain major discipline, so participants were students of a variety of majors who had voluntarily chosen to register for the class.

Upon attending the first class, students were informed that their participation would be part of a series of experiments and were asked permission to use their data, to which all provided written consent. At the start of each game, players were given a description of the rules, including the length of the game (number of rounds), number of partners they would be matched with, and payoff structure. This was then followed by a short exercise with review questions designed to ensure that all participants understood the parameters of the game. Students were also given the opportunity to ask for clarification regarding these parameters.

3.2 Incentives

During the first class, students were offered the opportunity to pay an optional laboratory fee of $50 which would contribute to a "prize fund." At the end of the semester, the highest-placing player from each game who had paid the lab fee at the start of the semester would receive a portion of the prize fund, equal to:

$$\frac{Total\ Dollars\ in\ Prize\ Fund}{Total\ Number\ of\ Games\ Played}$$

Students were informed that the average payout per game has historically averaged roughly $100.

Students were also told that the grading structure of the class would correlate with participants' performance across all games. Fifty percent of participants' grades were determined by their average final placement in all games, with the top 20% of players receiving an A, top 21-40% receiving an A-, top 41-60% receiving a B+, top 61-80% receiving a B, and the bottom 20% of players receiving a B-. In addition, a series of grade boosters were in place to reward students for individual game performances. This included a "next grade up" boost for accomplishments such as first-place finishes, five top-three finishes, and two top-two finishes. Thus, while not all participants chose to pay the laboratory fee and had money at stake, all players had a similar academic incentive to be competitive.

3.3 Traveler's Dilemma

The data for these experiments were drawn from seven Traveler's Dilemma games conducted over the course of the semester. The first five weeks of the class were designed to familiarize students with social dilemma games. During these initial five weeks participants played version of the Trust game and Ultimatum game before transitioning to the Traveler's Dilemma from which the experimental data used in this paper were collected.

In the most basic version of the Traveler' Dilemma used, groups of two are anonymously matched for one treatment lasting six rounds, after which players are randomly assigned a new partner. In each round, players simultaneously claim a dollar amount X such that $\$0.80 \leq X \leq$

$2.00. The player who claims the lower amount receives the amount of their claim plus a "reward" equal to $0.20, while the player who claims the higher amount receives the *lower* claim, minus a "penalty" of $0.20. If both players claim the same amount, both are awarded the amount of their claim with no additional penalty or reward. An example of the payoff matrix can be seen in Figure 1.

Player 2's Claim

Player 1's Claim

	$0.80	$1.20	$1.50	…	$1.99	$2.00
$0.80	$0.80 ; $0.80	$1.00 ; $0.60	$1.00 ; $0.60	…	$1.00 ; $0.60	$1.00 ; $0.60
$1.20	$0.60 ; $1.00	$1.20 ; $1.20	$1.40 ; $1.00	…	$1.40 ; $1.00	$1.40 ; $1.00
$1.50	$0.60 ; $1.00	$1.00 ; $1.40	$1.50 ; $1.50	…	$1.70 ; $1.30	$1.70 ; $1.30
…	…	…	…	…	…	…
$1.99	$0.60 ; $1.00	$1.00 ; $1.40	$1.30 ; $1.70	…	$1.99 ; $1.99	$2.19 ; $1.79
$2.00	$0.60 ; $1.00	$1.00 ; $1.40	$1.30 ; $1.70	…	$1.79 ; $2.19	$2.00 ; $2.00

Figure 1. Payoff matrix for the Traveler's Dilemma.

From this payoff matrix we observe that a claim X=$2.00 is the cooperative outcome because it awards both players $2.00 with no penalty or reward. However, this strategy is necessarily risky because it exposes a player to being undercut by their partner with a claim X=$1.99, which yields the highest possible individual payoff of $2.19 (and leaves the "cooperating" player with a payoff of only $1.79). Players quickly identify both the cooperative outcome and profit-maximizing strategy of undercutting their partner, eventually leading the game to converge on the game-theoretical Nash equilibrium claim X=$0.80.

Our research was conducted over the course of seven weeks using seven unique Traveler's Dilemma games. A "game" in the following sections constitutes a series of "treatments", defined as consecutive rounds in which participants were matched with the same partner. A round refers to each individual instance in which a decision was made by all players. All games were played using Veconlab, a website created by Professor Charles Holt of the University of Virginia (Holt, 2005). The website offers roughly 60 experimental games from which researchers can choose and customize the default setting and parameters to fit their specific research. In order to test for the effects of intensity of competition, duration, and group size, we customized various games by changing number of participants, number of rounds per game, and number of players in each group, respectively. All variations of the Traveler's Dilemma used the same base structure mentioned previously—including identical claim interval as well as penalty and reward amounts—and differed only in the controlled variable being observed.

The goal of these experiments was to test the impact of intensity of competition, game duration, and group size on cooperative behavior in the competitive environment. For the purpose of our study, level of cooperation was determined by players' earnings and claims in each game. This is based on the observation that while deviation from the cooperative outcome is the individually dominant strategy, defection generally triggers a response of constant undercutting that gradually decreases players' earnings over the course of the game and causes per round earnings and claims to converge on a Nash equilibrium of $0.80. In this case, all group members are ultimately worse off compared to a situation in which they maintain the cooperative outcome of $2.00, leading us to conclude that higher average earnings and claims signal a greater level of cooperation.

3.3.1 **<u>Intensity of Competition</u>**

To test for the effect of intensity of competition on cooperation we used three Traveler's Dilemma games with elimination rounds. All three games conducted began with an initial group of 24 players, and each treatment lasted for a total of six rounds. At the start of each game, players were informed that they would be randomly assigned a new group after each treatment, and that after the completion of three treatments individual earnings would be aggregated and a predetermined number of players with the lowest earnings would be eliminated and would be unable to participate for the rest of the game. Participants were also informed that all players' earnings would be reset to zero after each elimination round. The incorporation of elimination enabled us to observe the impact on cooperation of increasing the competitiveness of the game by periodically eliminating the players with the lowest earnings.

Game 1 was played in groups of two for 12 six-round treatments. After every three treatments, the four participants with the lowest earnings were eliminated and all players' earnings were reset to zero. This process was repeated three times: after the first elimination stage, 20 players remained; after the second elimination stage, 16 players remained; and after the third elimination stage, 12 players remained. Finally, the 12 remaining players competed for three more treatments, and the player with the highest accumulated earnings in those 18 rounds was declared the winner.

Games 2 and 3 followed similar structures but differed in group size and number of players eliminated at each elimination stage. Game 2 was played in groups of three for nine six-round treatments. Every three treatments the six players with the lowest earnings were eliminated and all earnings were reset to zero. Eliminating six players at each elimination stage instead of four as in Game 1 was necessary to ensure remaining players could be divided into groups of three. After the first elimination stage, 18 players remained, and after the second elimination stage, 12 players remained. Similar to Game 1, these 12 players then competed for three final treatments, and the player with the highest earnings in those treatments was declared the winner.

Game 3 was played for nine six-round games in groups of four, with the four lowest earners eliminated at each elimination stage such that the remaining players could be divided into groups of four participants each. After the first elimination stage, 20 players remained, and after the second elimination stage, 16 players remained. The final 16 players then competed for three more treatments, and the player with the highest earnings was declared the winner.

3.3.2 Game Duration

Using two Traveler's Dilemma games of different lengths, our goal was to observe the impact of longer treatments on cooperation. The parameters in Game 1 were identical to the base version of the Traveler's Dilemma outlined in Chapter 3.3. Twenty-eight initial participants played in groups of two for six rounds treatments before being assigned a new partner. This was repeated six times for a total of 36 rounds. After the first six treatments were completed, the four players with the lowest earnings were eliminated, resulting in 24 remaining players. The remaining 24 players then completed six more treatments under an identical structure.

Game 2 differed only in the number of rounds in each treatment. Instead of six rounds as in Game 1, each participant was matched with a partner for 10 rounds before being assigned a new partner. Beginning with 28 participants, this was repeated six times for a total of 60 rounds, after which the four lowest earners were eliminated. The 24 remaining players then completed an additional 60 rounds with a total of six different partners. Increasing the duration of each treatment enabled us to observe how cooperation was impacted by the length of interaction between partners. Due to the greater overall quantity of rounds in Game 2, we were required to use average earnings and claims per round as a measure for cooperation considering that these cumulative values were naturally greater when treatments consisted of 10 rounds.

3.3 Group Size

To test for the impact of group size on cooperation we used three basic Traveler's Dilemma games that differed only in the number of players that each participant was grouped with in each game. Increasing group size allowed us to observe the effect that working with a greater number of players had on cooperation. We used this to study the Tragedy of the Commons theory in practice.

All three games included 24 participants and were played for six treatments of 10 rounds each for a total of 60 rounds. In Game 1, participants played with one partner and received a new partner every 10 rounds. In Game 2, participants were matched with two partners and played the game in groups of three, with new groups assigned every 10 rounds. Finally, in Game 3 players were assigned three partners and participated in groups of four, which were randomly assigned every 10 rounds. Participants were never grouped with the same player two treatments in a row; however, due to the random nature of group assignment some players were grouped together more than once, but groups were always anonymous and players had no means of identifying members of their group.

Chapter 4: Results

This chapter presents the results of our three experiments and analyzes the impact of intensity of competition, game duration, and group size on cooperation. One of the drawbacks of our study was that the experiments were conducted over the course of several class periods, which occasionally resulted in different participants for each individual game within a specific experimental test due to student absences that were outside of our control. In order to control for this, all data used were taken only from players who participated in every game used to test a specific factor of cooperation. As such, all results and sample sizes presented in this chapter represent the number of common participants in each experimental test.

4.1 <u>Intensity of Competition</u>

Pairwise comparisons between individual treatments within each game were computed using a series of repeated measures ANOVA tests. These tests were designed to measure the significance of difference in mean earnings and mean claims for the 12 common players who participated in all three games. We consider results to be statistically significant at $p<.05$. Results for intensity of competition are reported in Appendix A.

The results for intensity of competition were largely inconsistent and did not support out initial hypothesis that increasing the intensity of competition would have a significant impact on level of cooperation. In Game 1, we observed a downward trend in both earnings and claims as the game progressed and fewer players remained, suggesting that cooperation was negatively correlated with the intensity of competition. This decline was shown to be statistically significant only for claims, however, as the difference in average earnings across 12 treatments was not statistically significant in any case. All pairwise comparisons of mean earnings reflected a significance $p>.05$ (Table 1). We found the decline in average claims to be statistically significant ($p<.05$) in 9 of 16 cases when comparing Treatments 1-4 with Treatments 9-12 (Table

2). These results reflect more frequent deviation from the cooperative claim of $2.00 as players were eliminated and the intensity of competition increased.

Similar downward trends were observed in Game 2 with groups of three participants. We found the decline in average earnings and average claims over the course of Game 2 to be statistically significant in both cases. As shown in Table 3, when comparing average earnings in Treatments 1-4 with Treatments 6-9 we observe statistical significance in 12 of 16 cases. When comparing those same treatments for average claims, this relationship is found to be statistically significant in 14 of 16 pairwise comparisons (Table 4). These results suggest that the intensity of competition did have an impact on level of cooperation when the game was played in groups of three.

However, the results found in Game 3 with groups of four deviated considerably from those observed in Games 1 and 2. In Game 3, we observed an *increase* in earning and claims over the course of the game, which is especially puzzling as this suggests that cooperation became more common in larger groups as the intensity of competition increased. While puzzling, the upward trend in earnings and claims shown in Figure 2 and Figure 3 (Appendix D) was found not to be statistically significant ($p>.05$) in all cases for both average earnings and average claims (Table 5, Table 6). One explanation for this pattern may be that players expected cooperation to disappear quickly in groups of four and believed their only chance to win was through sustained cooperation. However, this explanation is contradicted by the results presented in Chapter 4.3.

4.2 <u>Game Duration</u>

Using paired sample T-Tests to compare average earnings and average claims per round for the 19 common players in Games 1 and 2 (N=19), we observed that both average earnings per round and average claims per round were positively correlated to number of rounds, and that this correlation was statistically significant ($p<.05$) in three out of four cases. In treatments of 28 players this relationship was shown to be statistically significant for both average earnings and average claims (Table 7, Table 8, Appendix B). We observed nearly identical results for both relationships ($p<.01$), leading us to conclude that duration had a strong impact on cooperation in treatments of 28 participants.

Similar results were observed for average earnings in treatments of 24 players. Comparing average earnings across Games 1 and 2, we found the increase in average earnings in Game 2 to be statistically significant ($p=.015$). These results can be seen in Table 9. However, unlike in treatments of 28 participants, the relationship between game duration and average claims per round did not follow a similar pattern. While average claims per round were slightly higher in Game 2, this increase was not statistically significant ($p=.249$), as shown in Table 10.

That average claims per round in treatments of 24 players were not significantly impacted by game duration is puzzling considering the significance between duration and average earnings for those same treatments. One possible explanation is the role of learning, that the remaining 24 players in each game had developed an understanding of how to successfully cooperate and had adopted strategies for doing so, resulting in only slight increases in average claims in Game 2. Unfortunately, this explanation fails to address the significant relationship between duration and average earnings per round for those same treatments. However, the fact that average earnings and average claims increased in Game 2 for treatments of 28 and 24, and that this increase was found to be statistically significant in three out of four cases leads us to conclude that game duration has a significant impact on cooperation.

4.3 Group Size

Consistent with the fundamental predictions of the Tragedy of the Commons, our results show a negative relationship between group size and individuals' total earnings and claims per game. This follows the theory that cooperation becomes increasingly difficult to maintain as additional agents are added to a social dilemma. Our findings suggest that as group size increases, players defect from the cooperative claim of $2.00 in earlier rounds, resulting in lower earnings and claims when compared with groups of two.

The significant difference in earnings across the three treatments is confirmed by the repeated measures ANOVA test for the 14 players who participated in all games (N=14). The decrease in earnings was statistically significant for all pairwise comparisons of the three games conducted ($p<.01$, Table 11, Appendix C), and the downward trend in earnings as group size increased is shown in Figure 4 (Appendix D). The increasing difficulty in maintaining cooperation as group size increased can be attributed to the fact that the defection of one player penalizes all other groupmates, thus establishing an incentive to be the first to defect as a means of ensuring reward and avoiding the penalty incurred by not claiming the lowest amount.

Nearly identical results are presented in Table 12, which shows the negative relationship between group size and total claims. This relationship was statistically significant for all pairwise comparisons ($p<.01$) and can be observed in Figure 5. The significant difference in claims across the three games is consistent with our hypothesis that players in larger groups will deviate from the cooperative claim X=$2.00 in earlier rounds when compared to groups of two and three, resulting in lower cumulative claims over the course of the game. The results for earnings and claims demonstrate a strong negative relationship between group size and total earnings and claims and have led us to conclude that group size has a significant impact on cooperation.

Chapter 5: Discussion

5.1 Intensity of Competition

Overall, the direction of the correlation between intensity of competition and cooperation observed was inconsistent across the three experimental games conducted. In Games 1 and 2, players cooperated less as participants with the lowest earnings were gradually eliminated and the game became more competitive. This resulted in both lower average earnings and average claims as the intensity of competition increased, which was consistent with our hypothesis that increasing the intensity of competition would put greater pressure on players to try and undercut their partners in order to earn the reward of $0.20 each round, thus ensuring higher per-round earnings than their partners.

However, this pattern did not hold for Game 3, in which we observed increasing average earnings and average claims as players were gradually eliminated. In groups of four, players cooperated more frequently as the game progressed and players were eliminated, as evidenced by higher earnings and average claims per round in later treatments. However, that the increase in average claims and earnings in Game 3 was not statistically significant in any case suggests that the cooperative behavior observed may be attributable to the small sample size used. With only 16 participants split into four groups in the final three treatments of Game 3, it is possible that the behavior of one group could have had a considerable impact on overall results. Due to the small sample size, a high level of cooperation in one group may have skewed the results and undermines the confidence of our conclusions.

While the positive correlations between earnings, claims, and intensity of competition observed in Game 3 were found not to be statistically significant, their stark deviation from the results of Games 1 and 2 led us to conclude that the relationship between intensity of competition and cooperation was too inconsistent to be confidently determined as significant. However, that the negative correlation between the intensity of competition and cooperation was statistically significant in Games 1 and 2 suggests that future tests of larger sample size may yield results in support of our initial hypothesis. A larger sample size would reduce the impact of an individual group's behavior on the overall results, thus allowing for more confident conclusions to be drawn about the significance of any perceived relationships.

5.2 Duration

The direction of correlation between game duration and cooperation was consistent across all four cases analyzed. Players maintained a higher level of cooperation with their partner when matched with them for 10 rounds (Game 2) as opposed to six rounds in Game 1. These findings support our hypothesis that players cooperate with greater frequency in longer interactions, as more extensive interactions provide players with greater opportunity to establish a reputation as a cooperative partner. Additionally, early defection in longer interactions leads to a more drawn-out pattern of retaliatory defection in response to the initial deviation, which serves to greatly reduce the overall earnings of both players. Thus, it is unsurprising that the positive correlation between duration and cooperation was statistically significant in three out of four cases.

The one case in which this relationship was found not to be statistically significant—average claims of the final 24 participants (Table 10, Appendix B)—is puzzling considering that earnings and claims often mirror one another, with per-round earnings rarely deviating much from claims. Over the course of the game, total earnings and claims tend to converge on one another; however, a considerable disparity between the two can occur in cases where a player is consistently undercut by their partners, causing that player to receive the lower claim minus the penalty of $0.20. A more likely explanation for the observed insignificance is that by the final rounds of Game 2, players understood the general strategy of the game, resulting in players consistently choosing the cooperative claim of $2.00. The mean claim in Game 2, round of 24 players was higher than that of Game 1, reflecting the positive correlation between duration and earnings and claims observed in all cases. Thus, while statistical significance was observed in only three of four comparisons, this consistent positive relationship has led us to conclude that length of social interaction has a significant impact on cooperation in social dilemmas.

5.3 Group Size

The negative correlation observed between cooperation and group size reflects that players claimed and subsequently earned less on average when partnered with a greater number of players. These results support our hypothesis that cooperation would become increasingly difficult to maintain as groups gradually increased in size and players began participating with more players simultaneously in each round. These results are unsurprising considering that larger groups increase the chance that another player defects from the cooperative claim, resulting in penalty for every other member of the group. This added pressure makes cooperation difficult by incentivizing players to ensure they avoid being penalized by being the first person to defect.

While deviating from the cooperative outcome makes all players worse off, a strategy of consistently claiming the lowest amount guarantees that a player earns no less than the other members of their group.

One of the major differences observed across the three games was the speed and severity of defection following the initial deviation from the cooperative claim. In Game 1, players were often able to maintain cooperation for as many as seven rounds, after which we observed a gradual deviation from $2.00 over the course of the remaining rounds. In only a few rare instances we observed the minimum claim of $0.80. However, as group size increased, the initial defection occurred earlier, and the undercutting that followed happened much more quickly. In Game 3, cooperation often survived for as many as five rounds, but what followed was a swift decline in claims that quickly resulted in the Nash equilibrium of $0.80. Our observation that claims declined much more quickly in larger groups is unsurprising considering that to avoid penalty a player must claim a lower amount than all other group members, causing them to decrease their claims by a greater degree when competing against a larger number of players.

That cooperation became so difficult to maintain in larger groups offers clear support for the Tragedy of the Commons theory of shared resources presented by Garret Hardin (1968). Our experiment on group size modeled the sort of collective action problem Hardin is concerned with in which the benefit-maximizing behavior of the individual differs from that which is in the best interest of the group (behavior that contributes to the maintenance of the common resource). We observed players deviate from the cooperative claim in pursuit of self-interest, and this defection triggered similar strategies in other participants that ultimately made all players worse off. This was precisely what Hardin (1968) predicted with his famous line "freedom in a commons brings ruin to all," the implications of which still exist today in modern collective actions dilemmas such as overfishing and climate change. While our experiments demonstrate support for the Tragedy of the Commons, they do not address potential solutions to the seemingly inevitable consequences of common resource dilemmas. Questions for future research regarding the Tragedy of the Commons may focus on potential mechanisms or institutions necessary to mitigate the effects of such problems by aligning individual interests with that of the collective group.

Our results also support Ostrom (2000) in suggesting that the concerns of Olson (1965) are overly pessimistic in predicting that individuals in large groups will never contribute for the benefit of the group in the absence of coercive mechanisms. Even in Game 3, we observe a period of cooperation before the initial defection, which offers reason for optimism that some level of cooperation can be maintained even when individual interests are at odds with those of the collective group. This is further supported by a significant body of experimental literature including Isaac, Walker, and Thomas (1984), Isaac and Walker (1988), Deck (2001; 2009), and Fehr and Rockenbach (2003) that all demonstrate cooperation in competitive environments. These results support Ostrom's calls for greater empirical and theoretical work regarding the factors of cooperation, a topic that will hopefully see continue exploration in the future. Doing so will allow us to grow our understanding of cooperative behavior and how we can incentivize cooperation in the face of individual maximization encouraged by natural competition.

Chapter 6: Conclusion

Game theory predicts that rational agents in collective action dilemmas will behave in such a way as to maximize individual benefit at the expense of others (Dawes & Thaler, 1988). Under such assumptions, cooperation is seen as impossible to maintain, as it exposes the group to the risk of so-called “rational” defection. However, both laboratory experiments and everyday behavior have repeatedly demonstrated that humans *are* willing to cooperate in competitive environments even when that cooperation comes at a personal cost. While this cooperative behavior has been identified, the motivators of such behavior have remained largely speculative.

The results of our experiments support the existing body of literature in suggesting that cooperation can exist even in competitive environments. We observed periods of cooperation in each game regardless of game parameters, and only observed the Nash equilibrium of $0.80 in a few rare cases under greater pressure. This supported our general hypothesis that participants would exhibit tendencies to cooperate that contradict the behavioral predictions of game theory.

We also found evidence to support two of our three hypotheses regarding potential factors that contribute to cooperation in competitive environments. We found the impact on cooperation to be significant for both game duration and group size. Our results from these two experiments showed that players were more willing to cooperate when length of interaction was longer, and when group sizes were smaller. Our findings for game duration suggest that players in longer interactions are aware of the lasting consequence of deviation from the cooperative claim, leading to a longer period of sustained cooperation compared to shorter games in which the consequences of defecting are not as extensive.

Our findings for group size—that cooperation disappeared much more quickly as groups got larger—supports both our initial hypothesis as well as the Tragedy of the Commons theory regarding the maintenance and sustainability of common resources. We observed a period of cooperation in all games regardless of group size, but as group sizes increased, we saw deviation from the cooperative claim occur earlier and with much greater consequences. The increasing pressure of additional groupmates led players to defect earlier to avoid incurring the penalty, and heightened competition caused per-round claims to decline rapidly following the initial deviation. These findings were especially notable as a model for common resource dilemmas in which the agents responsible for the maintenance of a common resource have a personal incentive to deviate from the cooperative outcome, either through overuse or free-riding on the contributions of others. Further research into this topic should include investigation of potential mechanisms that may offer a solution to these collective action problems such that we may be able to mitigate their seemingly inevitable consequences in the future.

Finally, while our results were inconclusive regarding the impact of intensity of competition on cooperation, it is possible that the lack of significance was a product of our limited sample size, and that a relationship between the two may still exist. We observed negative correlation between intensity of competition and cooperation in Games 1 and 2, but these results were not consistent with those of Game 3. The drawbacks of our experiment did not allow us to confidently conclude intensity of competition to be a factor of cooperation, but future investigation into this relationship may be better positioned to observe a more significant relationship.

Overall, our results have shown broadly that cooperation is possible to an extent in competitive environments, while also demonstrating a significant relationship between both duration of interaction and group size on cooperative behavior. We believe these findings provide foundation for future study into the underlying motivations of cooperation that will allow for better understanding of (1) why we behave cooperatively and (2) how we can use these patterns of cooperation to encourage similar behavior in competitive social settings.

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Appendix A

Table 1. Repeated Measures ANOVA for Intensity of Competition Game 1: Average Earnings Per Treatment.

Pairwise Comparisons						
Treatment		Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	.190	.219	1.000	-.818	1.198
	3	.122	.224	1.000	-.910	1.153
	4	.108	.216	1.000	-.889	1.104
	5	.443	.237	1.000	-.649	1.536
	6	.452	.240	1.000	-.655	1.558
	7	.475	.271	1.000	-.775	1.725
	8	.377	.298	1.000	-.996	1.749
	9	.505	.229	1.000	-.551	1.561
	10	.496	.213	1.000	-.486	1.477
	11	.554	.172	.536	-.238	1.346
	12	.873	.294	.847	-.482	2.227
2	1	-.190	.219	1.000	-1.198	.818
	3	-.068	.193	1.000	-.955	.819
	4	-.083	.204	1.000	-1.023	.858
	5	.253	.262	1.000	-.953	1.460
	6	.262	.225	1.000	-.775	1.299
	7	.285	.198	1.000	-.628	1.198
	8	.187	.259	1.000	-1.008	1.381
	9	.315	.209	1.000	-.650	1.280
	10	.306	.207	1.000	-.648	1.259
	11	.364	.181	1.000	-.471	1.199
	12	.682	.224	.736	-.350	1.715
3	1	-.122	.224	1.000	-1.153	.910
	2	.068	.193	1.000	-.819	.955
	4	-.014	.157	1.000	-.739	.710
	5	.322	.208	1.000	-.634	1.278
	6	.330	.240	1.000	-.774	1.434
	7	.353	.136	1.000	-.275	.982
	8	.255	.243	1.000	-.866	1.376
	9	.383	.158	1.000	-.344	1.111
	10	.374	.192	1.000	-.509	1.258
	11	.432	.191	1.000	-.446	1.311

	12	.751	.246	.722	-.381	1.883
4	1	-.108	.216	1.000	-1.104	.889
	2	.083	.204	1.000	-.858	1.023
	3	.014	.157	1.000	-.710	.739
	5	.336	.230	1.000	-.722	1.393
	6	.344	.207	1.000	-.610	1.298
	7	.367	.223	1.000	-.659	1.394
	8	.269	.119	1.000	-.278	.817
	9	.398	.157	1.000	-.324	1.119
	10	.388	.222	1.000	-.632	1.409
	11	.447	.208	1.000	-.512	1.405
	12	.765	.203	.204	-.169	1.699
5	1	-.443	.237	1.000	-1.536	.649
	2	-.253	.262	1.000	-1.460	.953
	3	-.322	.208	1.000	-1.278	.634
	4	-.336	.230	1.000	-1.393	.722
	6	.008	.255	1.000	-1.165	1.182
	7	.032	.197	1.000	-.874	.938
	8	-.067	.325	1.000	-1.563	1.430
	9	.062	.146	1.000	-.609	.733
	10	.053	.197	1.000	-.857	.962
	11	.111	.212	1.000	-.865	1.087
	12	.429	.219	1.000	-.579	1.437
6	1	-.452	.240	1.000	-1.558	.655
	2	-.262	.225	1.000	-1.299	.775
	3	-.330	.240	1.000	-1.434	.774
	4	-.344	.207	1.000	-1.298	.610
	5	-.008	.255	1.000	-1.182	1.165
	7	.023	.204	1.000	-.917	.964
	8	-.075	.274	1.000	-1.337	1.187
	9	.053	.192	1.000	-.830	.937
	10	.044	.187	1.000	-.819	.908
	11	.102	.256	1.000	-1.076	1.281
	12	.421	.269	1.000	-.820	1.662
7	1	-.475	.271	1.000	-1.725	.775
	2	-.285	.198	1.000	-1.198	.628
	3	-.353	.136	1.000	-.982	.275
	4	-.367	.223	1.000	-1.394	.659
	5	-.032	.197	1.000	-.938	.874

	6	-.023	.204	1.000	-.964	.917
	8	-.098	.311	1.000	-1.531	1.334
	9	.030	.149	1.000	-.658	.718
	10	.021	.160	1.000	-.715	.757
	11	.079	.231	1.000	-.983	1.141
	12	.398	.238	1.000	-.700	1.495
8	1	-.377	.298	1.000	-1.749	.996
	2	-.187	.259	1.000	-1.381	1.008
	3	-.255	.243	1.000	-1.376	.866
	4	-.269	.119	1.000	-.817	.278
	5	.067	.325	1.000	-1.430	1.563
	6	.075	.274	1.000	-1.187	1.337
	7	.098	.311	1.000	-1.334	1.531
	9	.128	.246	1.000	-1.003	1.259
	10	.119	.287	1.000	-1.204	1.442
	11	.177	.287	1.000	-1.143	1.498
	12	.496	.249	1.000	-.651	1.643
9	1	-.505	.229	1.000	-1.561	.551
	2	-.315	.209	1.000	-1.280	.650
	3	-.383	.158	1.000	-1.111	.344
	4	-.398	.157	1.000	-1.119	.324
	5	-.062	.146	1.000	-.733	.609
	6	-.053	.192	1.000	-.937	.830
	7	-.030	.149	1.000	-.718	.658
	8	-.128	.246	1.000	-1.259	1.003
	10	-.009	.169	1.000	-.787	.768
	11	.049	.235	1.000	-1.033	1.131
	12	.367	.156	1.000	-.349	1.084
10	1	-.496	.213	1.000	-1.477	.486
	2	-.306	.207	1.000	-1.259	.648
	3	-.374	.192	1.000	-1.258	.509
	4	-.388	.222	1.000	-1.409	.632
	5	-.053	.197	1.000	-.962	.857
	6	-.044	.187	1.000	-.908	.819
	7	-.021	.160	1.000	-.757	.715
	8	-.119	.287	1.000	-1.442	1.204
	9	.009	.169	1.000	-.768	.787
	11	.058	.204	1.000	-.879	.996
	12	.377	.249	1.000	-.770	1.523

11	1	-.554	.172	.536	-1.346	.238
	2	-.364	.181	1.000	-1.199	.471
	3	-.432	.191	1.000	-1.311	.446
	4	-.447	.208	1.000	-1.405	.512
	5	-.111	.212	1.000	-1.087	.865
	6	-.102	.256	1.000	-1.281	1.076
	7	-.079	.231	1.000	-1.141	.983
	8	-.177	.287	1.000	-1.498	1.143
	9	-.049	.235	1.000	-1.131	1.033
	10	-.058	.204	1.000	-.996	.879
	12	.318	.261	1.000	-.882	1.519
12	1	-.873	.294	.847	-2.227	.482
	2	-.682	.224	.736	-1.715	.350
	3	-.751	.246	.722	-1.883	.381
	4	-.765	.203	.204	-1.699	.169
	5	-.429	.219	1.000	-1.437	.579
	6	-.421	.269	1.000	-1.662	.820
	7	-.398	.238	1.000	-1.495	.700
	8	-.496	.249	1.000	-1.643	.651
	9	-.367	.156	1.000	-1.084	.349
	10	-.377	.249	1.000	-1.523	.770
	11	-.318	.261	1.000	-1.519	.882

Table 2. Repeated Measures ANOVA for Intensity of Competition Game 1: Average Claims Per Treatment.

Pairwise Comparisons						
Treatment		Mean Difference	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.010	.013	1.000	-.050	.070
	3	.015	.017	1.000	-.063	.093
	4	.022	.012	1.000	-.032	.075
	5	.061	.018	.450	-.024	.145
	6	.042	.014	.773	-.022	.105
	7	.082	.026	.603	-.038	.201
	8	.065	.028	1.000	-.064	.194
	9	.086*	.018	.042	.002	.170
	10	.081	.020	.114	-.010	.171
	11	.091*	.015	.006	.021	.161
	12	.132	.029	.053	-.001	.264
2	1	-.010	.013	1.000	-.070	.050
	3	.005	.009	1.000	-.038	.048
	4	.012	.014	1.000	-.054	.077
	5	.051	.021	1.000	-.046	.148
	6	.032	.010	.563	-.014	.077
	7	.072	.021	.398	-.026	.169
	8	.055	.026	1.000	-.065	.175
	9	.076	.017	.052	.000	.152
	10	.071	.016	.068	-.003	.145
	11	.081*	.010	.001	.033	.128
	12	.122*	.021	.007	.026	.217
3	1	-.015	.017	1.000	-.093	.063
	2	-.005	.009	1.000	-.048	.038
	4	.007	.015	1.000	-.062	.075
	5	.046	.019	1.000	-.039	.131
	6	.027	.012	1.000	-.026	.080
	7	.067	.018	.214	-.015	.149
	8	.050	.027	1.000	-.075	.175
	9	.071*	.014	.028	.005	.137
	10	.066*	.013	.018	.008	.124
	11	.076*	.013	.009	.015	.137
	12	.117*	.018	.003	.032	.201

4	1	-.022	.012	1.000	-.075	.032
	2	-.012	.014	1.000	-.077	.054
	3	-.007	.015	1.000	-.075	.062
	5	.039	.017	1.000	-.041	.119
	6	.020	.014	1.000	-.043	.083
	7	.060	.019	.607	-.028	.148
	8	.043	.030	1.000	-.095	.181
	9	.064*	.012	.021	.007	.122
	10	.059	.016	.217	-.014	.132
	11	.069	.018	.150	-.012	.150
	12	.110	.026	.088	-.009	.229
5	1	-.061	.018	.450	-.145	.024
	2	-.051	.021	1.000	-.148	.046
	3	-.046	.019	1.000	-.131	.039
	4	-.039	.017	1.000	-.119	.041
	6	-.019	.020	1.000	-.110	.071
	7	.021	.018	1.000	-.064	.105
	8	.004	.028	1.000	-.125	.134
	9	.025	.012	1.000	-.030	.080
	10	.020	.013	1.000	-.040	.080
	11	.030	.018	1.000	-.053	.113
	12	.071	.024	.952	-.042	.183
6	1	-.042	.014	.773	-.105	.022
	2	-.032	.010	.563	-.077	.014
	3	-.027	.012	1.000	-.080	.026
	4	-.020	.014	1.000	-.083	.043
	5	.019	.020	1.000	-.071	.110
	7	.040	.022	1.000	-.063	.143
	8	.023	.024	1.000	-.088	.135
	9	.044	.015	.959	-.026	.114
	10	.039	.015	1.000	-.028	.106
	11	.049	.013	.250	-.013	.111
	12	.090*	.019	.047	.001	.179
7	1	-.082	.026	.603	-.201	.038
	2	-.072	.021	.398	-.169	.026
	3	-.067	.018	.214	-.149	.015
	4	-.060	.019	.607	-.148	.028
	5	-.021	.018	1.000	-.105	.064
	6	-.040	.022	1.000	-.143	.063

	8	-.017	.036	1.000	-.183	.150
	9	.004	.013	1.000	-.057	.066
	10	-.001	.017	1.000	-.078	.076
	11	.009	.022	1.000	-.092	.110
	12	.050	.021	1.000	-.049	.149
8	1	-.065	.028	1.000	-.194	.064
	2	-.055	.026	1.000	-.175	.065
	3	-.050	.027	1.000	-.175	.075
	4	-.043	.030	1.000	-.181	.095
	5	-.004	.028	1.000	-.134	.125
	6	-.023	.024	1.000	-.135	.088
	7	.017	.036	1.000	-.150	.183
	9	.021	.029	1.000	-.113	.154
	10	.016	.022	1.000	-.087	.119
	11	.026	.023	1.000	-.080	.132
	12	.067	.025	1.000	-.051	.184
9	1	-.086*	.018	.042	-.170	-.002
	2	-.076	.017	.052	-.152	.000
	3	-.071*	.014	.028	-.137	-.005
	4	-.064*	.012	.021	-.122	-.007
	5	-.025	.012	1.000	-.080	.030
	6	-.044	.015	.959	-.114	.026
	7	-.004	.013	1.000	-.066	.057
	8	-.021	.029	1.000	-.154	.113
	10	-.005	.010	1.000	-.049	.039
	11	.005	.014	1.000	-.062	.072
	12	.046	.021	1.000	-.050	.142
10	1	-.081	.020	.114	-.171	.010
	2	-.071	.016	.068	-.145	.003
	3	-.066*	.013	.018	-.124	-.008
	4	-.059	.016	.217	-.132	.014
	5	-.020	.013	1.000	-.080	.040
	6	-.039	.015	1.000	-.106	.028
	7	.001	.017	1.000	-.076	.078
	8	-.016	.022	1.000	-.119	.087
	9	.005	.010	1.000	-.039	.049
	11	.010	.013	1.000	-.050	.070
	12	.051	.016	.529	-.022	.123
11	1	-.091*	.015	.006	-.161	-.021

	2	-.081*	.010	.001	-.128	-.033
	3	-.076*	.013	.009	-.137	-.015
	4	-.069	.018	.150	-.150	.012
	5	-.030	.018	1.000	-.113	.053
	6	-.049	.013	.250	-.111	.013
	7	-.009	.022	1.000	-.110	.092
	8	-.026	.023	1.000	-.132	.080
	9	-.005	.014	1.000	-.072	.062
	10	-.010	.013	1.000	-.070	.050
	12	.041	.021	1.000	-.055	.137
12	1	-.132	.029	.053	-.264	.001
	2	-.122*	.021	.007	-.217	-.026
	3	-.117*	.018	.003	-.201	-.032
	4	-.110	.026	.088	-.229	.009
	5	-.071	.024	.952	-.183	.042
	6	-.090*	.019	.047	-.179	-.001
	7	-.050	.021	1.000	-.149	.049
	8	-.067	.025	1.000	-.184	.051
	9	-.046	.021	1.000	-.142	.050
	10	-.051	.016	.529	-.123	.022
	11	-.041	.021	1.000	-.137	.055

Table 3. Repeated Measures ANOVA for Intensity of Competition Game 2: Average Earnings Per Treatment.

Pairwise Comparisons

Treatment		Mean Difference	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.324	.209	1.000	-.560	1.208
	3	.626	.230	.719	-.350	1.602
	4	.628	.231	.722	-.352	1.607
	5	1.006*	.204	.016	.142	1.870
	6	1.657*	.196	.000	.828	2.487
	7	1.519*	.183	.000	.743	2.296
	8	1.343*	.174	.000	.605	2.080
	9	1.755*	.207	.000	.878	2.632
2	1	-.324	.209	1.000	-1.208	.560
	3	.302	.228	1.000	-.666	1.270
	4	.303	.176	1.000	-.444	1.051
	5	.682	.185	.129	-.102	1.465
	6	1.333*	.278	.020	.154	2.512
	7	1.195*	.248	.019	.142	2.248
	8	1.018*	.221	.027	.083	1.954
	9	1.431*	.277	.011	.254	2.607
3	1	-.626	.230	.719	-1.602	.350
	2	-.302	.228	1.000	-1.270	.666
	4	.002	.223	1.000	-.944	.947
	5	.380	.193	1.000	-.439	1.199
	6	1.032	.315	.265	-.302	2.366
	7	.893	.334	.775	-.522	2.308
	8	.717	.217	.251	-.202	1.635
	9	1.129*	.165	.001	.428	1.831
4	1	-.628	.231	.722	-1.607	.352
	2	-.303	.176	1.000	-1.051	.444
	3	-.002	.223	1.000	-.947	.944
	5	.378	.249	1.000	-.679	1.435
	6	1.030*	.240	.045	.014	2.046
	7	.892	.234	.104	-.100	1.884
	8	.715*	.127	.005	.178	1.252
	9	1.127*	.200	.005	.281	1.974
5	1	-1.006*	.204	.016	-1.870	-.142

	2	-.682	.185	.129	-1.465	.102
	3	-.380	.193	1.000	-1.199	.439
	4	-.378	.249	1.000	-1.435	.679
	6	.652	.334	1.000	-.764	2.068
	7	.513	.321	1.000	-.846	1.873
	8	.337	.245	1.000	-.701	1.375
	9	.749	.260	.542	-.355	1.853
6	1	-1.657*	.196	.000	-2.487	-.828
	2	-1.333*	.278	.020	-2.512	-.154
	3	-1.032	.315	.265	-2.366	.302
	4	-1.030*	.240	.045	-2.046	-.014
	5	-.652	.334	1.000	-2.068	.764
	7	-.138	.114	1.000	-.620	.344
	8	-.315	.205	1.000	-1.182	.552
	9	.098	.227	1.000	-.865	1.060
7	1	-1.519*	.183	.000	-2.296	-.743
	2	-1.195*	.248	.019	-2.248	-.142
	3	-.893	.334	.775	-2.308	.522
	4	-.892	.234	.104	-1.884	.100
	5	-.513	.321	1.000	-1.873	.846
	6	.138	.114	1.000	-.344	.620
	8	-.177	.204	1.000	-1.043	.689
	9	.236	.278	1.000	-.943	1.415
8	1	-1.343*	.174	.000	-2.080	-.605
	2	-1.018*	.221	.027	-1.954	-.083
	3	-.717	.217	.251	-1.635	.202
	4	-.715*	.127	.005	-1.252	-.178
	5	-.337	.245	1.000	-1.375	.701
	6	.315	.205	1.000	-.552	1.182
	7	.177	.204	1.000	-.689	1.043
	9	.412	.147	.625	-.213	1.038
9	1	-1.755*	.207	.000	-2.632	-.878
	2	-1.431*	.277	.011	-2.607	-.254
	3	-1.129*	.165	.001	-1.831	-.428
	4	-1.127*	.200	.005	-1.974	-.281
	5	-.749	.260	.542	-1.853	.355
	6	-.098	.227	1.000	-1.060	.865
	7	-.236	.278	1.000	-1.415	.943
	8	-.412	.147	.625	-1.038	.213

Table 4. Repeated Measures ANOVA for Intensity of Competition Game 2: Average Claims Per Treatment.

Pairwise Comparisons						
Treatment		Mean Difference	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.065	.021	.375	-.024	.154
	3	.118*	.021	.006	.028	.208
	4	.114*	.024	.024	.011	.218
	5	.181*	.029	.002	.058	.303
	6	.271*	.029	.000	.148	.394
	7	.223*	.036	.002	.073	.374
	8	.228*	.023	.000	.131	.325
	9	.034*	.020	.000	.220	.388
2	1	-.065	.021	.375	-.154	.024
	3	.053	.020	.785	-.031	.138
	4	.049	.022	1.000	-.044	.142
	5	.116*	.022	.009	.023	.208
	6	.026*	.027	.000	.093	.319
	7	.158*	.031	.013	.026	.290
	8	.163*	.015	.000	.098	.228
	9	.239*	.020	.000	.156	.322
3	1	-.118*	.021	.006	-.208	-.028
	2	-.053	.020	.785	-.138	.031
	4	-.004	.022	1.000	-.097	.088
	5	.063	.018	.175	-.013	.138
	6	.153*	.025	.003	.045	.260
	7	.105	.033	.329	-.036	.246
	8	.110*	.019	.004	.030	.190
	9	.186*	.020	.000	.100	.272
4	1	-.114*	.024	.024	-.218	-.011
	2	-.049	.022	1.000	-.142	.044
	3	.004	.022	1.000	-.088	.097
	5	.067	.023	.542	-.032	.165
	6	.157*	.024	.002	.054	.259
	7	.109	.031	.116	-.021	.240
	8	.114*	.013	.000	.058	.170
	9	.190*	.020	.000	.105	.275
5	1	-.181*	.029	.002	-.303	-.058

	2	-.116*	.022	.009	-.208	-.023
	3	-.063	.018	.175	-.138	.013
	4	-.067	.023	.542	-.165	.032
	6	.090*	.020	.031	.006	.174
	7	.042	.029	1.000	-.081	.166
	8	.047	.018	.841	-.029	.124
	9	.123*	.025	.015	.018	.229
6	1	-.271*	.029	.000	-.394	-.148
	2	-.206*	.027	.000	-.319	-.093
	3	-.153*	.025	.003	-.260	-.045
	4	-.157*	.024	.002	-.259	-.054
	5	-.090*	.020	.031	-.174	-.006
	7	-.048	.022	1.000	-.141	.046
	8	-.043	.022	1.000	-.135	.050
	9	.033	.033	1.000	-.108	.175
7	1	-.223*	.036	.002	-.374	-.073
	2	-.158*	.031	.013	-.290	-.026
	3	-.105	.033	.329	-.246	.036
	4	-.109	.031	.166	-.240	.021
	5	-.042	.029	1.000	-.166	.081
	6	.048	.022	1.000	-.046	.141
	8	.005	.027	1.000	-.108	.118
	9	.081	.033	1.000	-.060	.222
8	1	-.228*	.023	.000	-.325	-.131
	2	-.163*	.015	.000	-.228	-.098
	3	-.110*	.019	.004	-.190	-.030
	4	-.114*	.013	.000	-.170	-.058
	5	-.047	.018	.841	-.124	.029
	6	.043	.022	1.000	-.050	.135
	7	-.005	.027	1.000	-.118	.108
	9	.076*	.017	.032	.005	.147
9	1	-.304*	.020	.000	-.388	-.220
	2	-.239*	.020	.000	-.322	-.156
	3	-.186*	.020	.000	-.272	-.100
	4	-.190*	.020	.000	-.275	-.105
	5	-.123*	.025	.015	-.229	-.018
	6	-.033	.033	1.000	-.175	.108
	7	-.081	.033	1.000	-.222	.060
	8	-.076*	.017	.032	-.147	-.005

Table 5. Repeated Measures ANOVA for Intensity of Competition Game 3: Average Earnings Per Treatment.

Pairwise Comparisons						
Treatment		Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.376	.451	1.000	-2.139	1.387
	3	-.864	.378	1.000	-2.343	.615
	4	-.593	.321	1.000	-1.850	.664
	5	-1.009	.300	.154	-2.183	.165
	6	-.734	.314	1.000	-1.964	.495
	7	-.679	.317	1.000	-1.920	.561
	8	-.752	.251	.325	-1.733	.230
	9	-.944	.287	.180	-2.068	.180
2	1	.376	.451	1.000	-1.387	2.139
	3	-.488	.346	1.000	-1.841	.866
	4	-.217	.352	1.000	-1.592	1.159
	5	-.633	.341	1.000	-1.966	.700
	6	-.358	.289	1.000	-1.488	.772
	7	-.303	.368	1.000	-1.742	1.136
	8	-.376	.329	1.000	-1.662	.911
	9	-.568	.363	1.000	-1.987	.851
3	1	.864	.378	1.000	-.615	2.343
	2	.488	.346	1.000	-.866	1.841
	4	.271	.312	1.000	-.948	1.489
	5	-.146	.285	1.000	-1.259	.968
	6	.129	.214	1.000	-.708	.966
	7	.184	.256	1.000	-.818	1.187
	8	.112	.283	1.000	-.993	1.217
	9	-.081	.285	1.000	-1.195	1.034
4	1	.593	.321	1.000	-.664	1.850
	2	.217	.352	1.000	-1.159	1.592
	3	-.271	.312	1.000	-1.489	.948
	5	-.416	.207	1.000	-1.228	.395
	6	-.141	.256	1.000	-1.141	.858
	7	-.086	.216	1.000	-.932	.760
	8	-.159	.277	1.000	-1.244	.926
	9	-.351	.234	1.000	-1.267	.565
5	1	1.009	.300	.154	-.165	2.183

	2	.633	.341	1.000	-.700	1.966
	3	.146	.285	1.000	-.968	1.259
	4	.416	.207	1.000	-.395	1.228
	6	.275	.200	1.000	-.506	1.056
	7	.330	.160	1.000	-.298	.958
	8	.258	.186	1.000	-.471	.986
	9	.065	.190	1.000	-.677	.807
6	1	.734	.314	1.000	-.495	1.964
	2	.358	.289	1.000	-.772	1.488
	3	-.129	.214	1.000	-.966	.708
	4	.141	.256	1.000	-.858	1.141
	5	-.275	.200	1.000	-1.056	.506
	7	.055	.205	1.000	-.747	.857
	8	-.018	.205	1.000	-.819	.784
	9	-.210	.214	1.000	-1.047	.627
7	1	.679	.317	1.000	-.561	1.920
	2	.303	.368	1.000	-1.136	1.742
	3	-.184	.256	1.000	-1.187	.818
	4	.086	.216	1.000	-.760	.932
	5	-.330	.160	1.000	-.958	.298
	6	-.055	.205	1.000	-.857	.747
	8	-.073	.178	1.000	-.769	.624
	9	-.265	.148	1.000	-.844	.314
8	1	.752	.251	.325	-.230	1.733
	2	.376	.329	1.000	-.911	1.662
	3	-.112	.283	1.000	-1.217	.993
	4	.159	.277	1.000	-.926	1.244
	5	-.258	.186	1.000	-.986	.471
	6	.018	.205	1.000	-.784	.819
	7	.073	.178	1.000	-.624	.769
	9	-.192	.227	1.000	-1.080	.695
9	1	.944	.287	.180	-.180	2.068
	2	.568	.363	1.000	-.851	1.987
	3	.081	.285	1.000	-1.034	1.195
	4	.351	.234	1.000	-.565	1.267
	5	-.065	.190	1.000	-.807	.677
	6	.210	.214	1.000	-.627	1.047
	7	.265	.148	1.000	-.314	.844
	8	.192	.227	1.000	-.695	1.080

Table 6. Repeated Measures ANOVA for Intensity of Competition Game 3: Average Claims Per Treatment.

Pairwise Comparisons						
Treatment		Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.042	.059	1.000	-.291	.206
	3	-.101	.060	1.000	-.356	.154
	4	-.089	.049	1.000	-.298	.120
	5	-.125	.050	1.000	-.337	.087
	6	-.077	.048	1.000	-.279	.125
	7	-.083	.046	1.000	-.276	.111
	8	-.053	.047	1.000	-.253	.147
	9	-.122	.031	.088	-.255	.010
2	1	.042	.059	1.000	-.206	.291
	3	-.058	.040	1.000	-.226	.109
	4	-.047	.057	1.000	-.290	.196
	5	-.083	.051	1.000	-.298	.133
	6	-.034	.044	1.000	-.220	.152
	7	-.040	.054	1.000	-.269	.189
	8	-.011	.039	1.000	-.176	.154
	9	-.080	.060	1.000	-.335	.175
3	1	.101	.060	1.000	-.154	.356
	2	.058	.040	1.000	-.109	.226
	4	.012	.059	1.000	-.238	.261
	5	-.024	.048	1.000	-.229	.181
	6	.024	.034	1.000	-.121	.170
	7	.018	.044	1.000	-.167	.204
	8	.047	.041	1.000	-.125	.220
	9	-.022	.055	1.000	-.253	.210
4	1	.089	.049	1.000	-.120	.298
	2	.047	.057	1.000	-.196	.290
	3	-.012	.059	1.000	-.261	.238
	5	-.036	.032	1.000	-.173	.102
	6	.012	.043	1.000	-.169	.194
	7	.007	.040	1.000	-.164	.177
	8	.036	.043	1.000	-.148	.220
	9	-.033	.046	1.000	-.226	.160
5	1	.125	.050	1.000	-.087	.337

	2	.083	.051	1.000	-.133	.298
	3	.024	.048	1.000	-.181	.229
	4	.036	.032	1.000	-.102	.173
	6	.048	.021	1.000	-.040	.137
	7	.042	.021	1.000	-.045	.130
	8	.072	.027	.774	-.042	.185
	9	.003	.030	1.000	-.125	.130
6	1	.077	.048	1.000	-.125	.279
	2	.034	.044	1.000	-.152	.220
	3	-.024	.034	1.000	-.170	.121
	4	-.012	.043	1.000	-.194	.169
	5	-.048	.021	1.000	-.137	.040
	7	-.006	.019	1.000	-.087	.076
	8	.023	.028	1.000	-.096	.142
	9	-.046	.032	1.000	-.182	.090
7	1	.083	.046	1.000	-.111	.276
	2	.040	.054	1.000	-.189	.269
	3	-.018	.044	1.000	-.204	.167
	4	-.007	.040	1.000	-.177	.164
	5	-.042	.021	1.000	-.130	.045
	6	.006	.019	1.000	-.076	.087
	8	.029	.029	1.000	-.092	.150
	9	-.040	.029	1.000	-.163	.083
8	1	.053	.047	1.000	-.147	.253
	2	.011	.039	1.000	-.154	.176
	3	-.047	.041	1.000	-.220	.125
	4	-.036	.043	1.000	-.220	.148
	5	-.072	.027	.774	-.185	.042
	6	-.023	.028	1.000	-.142	.096
	7	-.029	.029	1.000	-.150	.092
	9	-.069	.039	1.000	-.235	.097
9	1	.122	.031	.088	-.010	.255
	2	.080	.060	1.000	-.175	.335
	3	.022	.055	1.000	-.210	.253
	4	.033	.046	1.000	-.160	.226
	5	-.003	.030	1.000	-.130	.125
	6	.046	.032	1.000	-.090	.182
	7	.040	.029	1.000	-.083	.163
	8	.069	.039	1.000	-.097	.235

Appendix B

Table 7. Paired Differences T-Tests for Duration: Average Earnings of 28 Participants.

	Mean	N	Std. Deviation	Std. Error Mean
Game 1	1.7032	19	.13548	.03108
Game 2	1.9284	19	.02192	.00503

	Paired Differences					t	Df	Sig.
				95% Confidence Interval				
	Mean	Std. Deviation	Std. Mean Error	Lower	Upper			
Game 1 – Game 2	-.22526	.13640	.03129	-.29100	-.15952	-7.199	18	.000

Table 8. Paired Differences T-Tests for Duration: Average Claims of 28 Initial Participants.

	Mean	N	Std. Deviation	Std. Error Mean
Game 1	1.7700	19	.14036	.03220
Game 2	1.9421	19	.01718	.00394

	Paired Differences					t	Df	Sig.
				95% Confidence Interval				
	Mean	Std. Deviation	Std. Mean Error	Lower	Upper			
Game 1 – Game 2	-.17211	.14339	.03290	-.24122	-.10299	-5.232	18	.000

Table 9. Paired Differences T-Tests for Duration: Average Earnings of Final 24 Participants.

	Mean	N	Std. Deviation	Std. Error Mean
Game 1	1.8853	19	.04812	.01104
Game 2	1.9174	19	.03016	.00692

	Paired Differences					t	Df	Sig.
				95% Confidence Interval				
	Mean	Std. Deviation	Std. Mean Error	Lower	Upper			
Game 1 – Game 2	-.03211	.05192	.01191	-.05713	-.00708	-2.696	18	.015

Table 10. Paired Differences T-Tests for Duration: Average Claims of Final 24 Participants.

	Mean	N	Std. Deviation	Std. Error Mean
Game 1	1.9189	19	.03928	.00901
Game 2	1.9305	19	.02094	.00480

	Paired Differences					t	Df	Sig.
				95% Confidence Interval				
	Mean	Std. Deviation	Std. Mean Error	Lower	Upper			
Game 1 – Game 2	-.01158	.04233	.00971	-.03198	.00882	-1.192	18	.249

Appendix C

Table 11. Repeated Measures ANOVA for Group Size: Total Earnings Per Game.

Pairwise Comparisons						
Treatment		Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	13.799*	.703	.000	11.869	15.728
	3	22.155*	1.479	.000	18.093	26.217
2	1	-13.799*	.703	.000	-15.728	-11.869
	3	8.356*	1.060	.000	5.445	11.267
3	1	-22.155*	1.479	.000	-26.217	-18.093
	2	-8.356*	1.060	.000	-11.267	-5.445

Table 12. Repeated Measures ANOVA for Group Size: Total Claims Per Game.

Pairwise Comparisons						
Treatment		Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	11.966*	.485	.000	10.6333	13.299
	3	17.830*	1.331	.000	14.176	21.484
2	1	-11.966*	.485	.000	-13.299	-10.633
	3	5.864*	1.188	.001	2.602	9.127
3	1	-17.830	1.331	.000	-21.484	-14.176
	2	-5.864	1.188	.001	-9.127	-2.602

Appendix D

Figure 2. Intensity of Competition Game 3: Average Earnings Per Treatment.

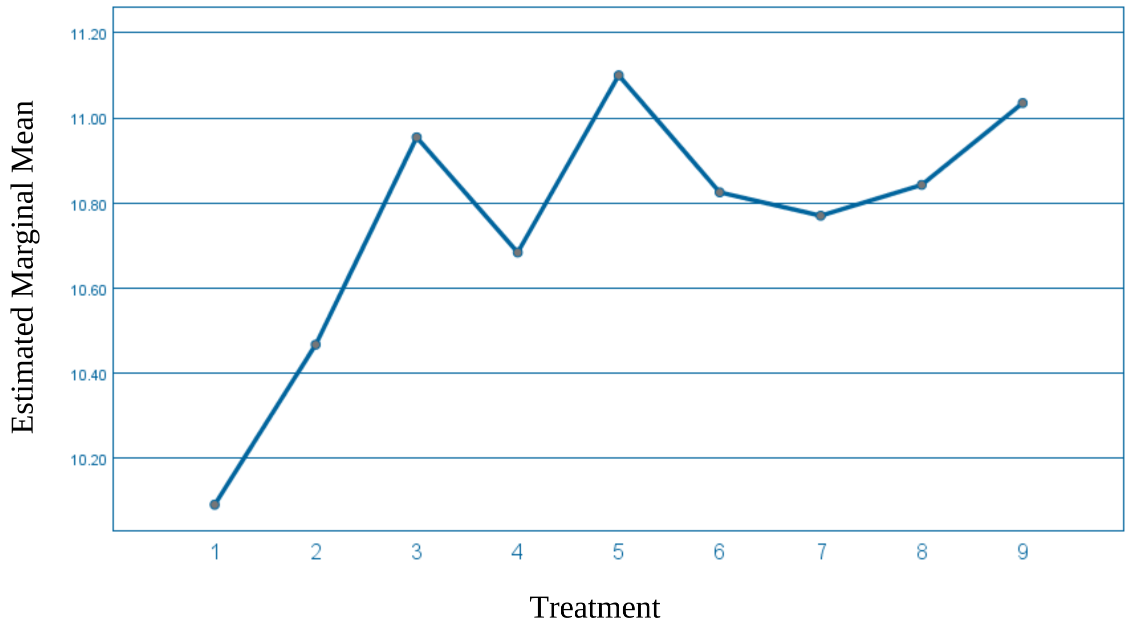

Figure 3. Intensity of Competition Game 3: Average Claims Per Treatment.

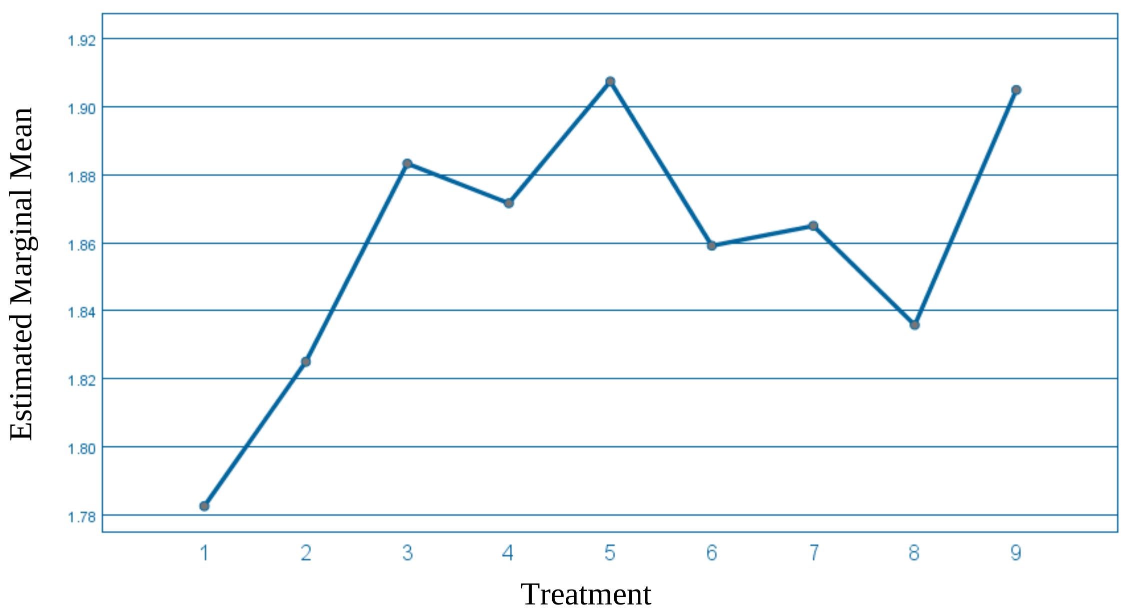

Figure 4. Group Size: Total Earnings Per Game.

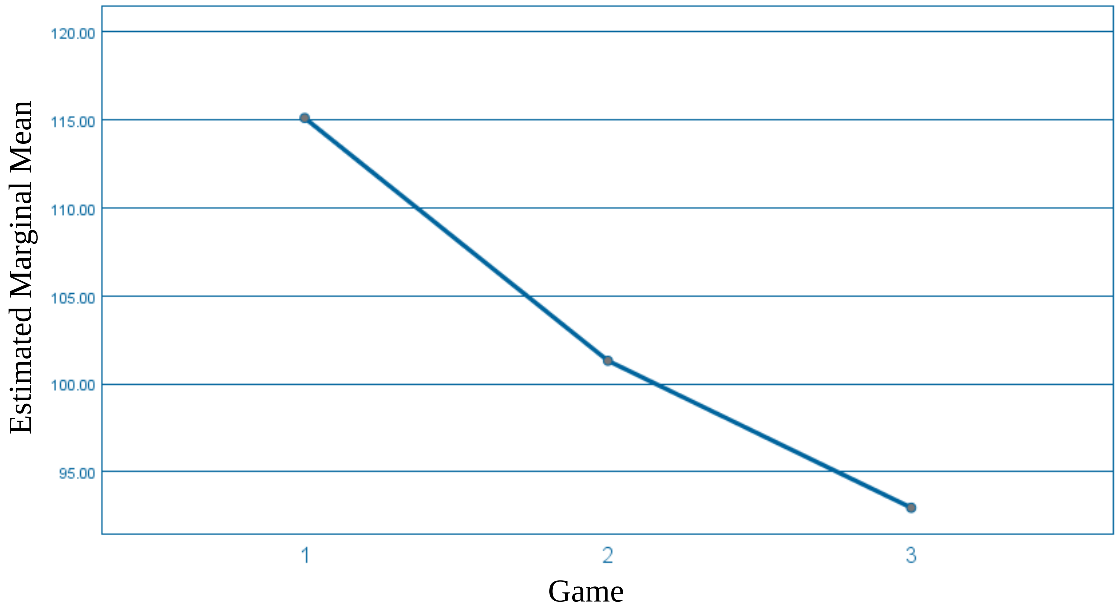

Figure 5. Group Size: Total Claims Per Game.