THE EFFECTS OF IMPLEMENTING A REWARD-BASED VERSION OF OSTROM'S EIGHT DESIGN PRINCIPLES AS AN INTERVENTION PACKAGE ON RESPONSES IN A COMMON POOL RESOURCE (CPR) GAME

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Nobel laureate and economist Elinor Ostrom earned a Nobel prize in economic sciences in 2009 for her research on a community's ability to self-govern a common pool resource with the use of eight design principles. While Ostrom's accumulated efforts to analyze these principles and apply them to community resources have earned widespread recognition, these principles have yet to take off on a grand scale as a blueprint for self-governance systems globally. There is also a lack of empirical evidence that supports these principles as empirical investigations have yet to manipulate the principles individually or as an intervention package as independent variables. The purpose of the present study is to empirically test Ostrom's eight design principles in a tabletop game model of a community utilizing a common pool resource (CPR) by implementing as well as removing the principles within an adapted version of the board game Catan. In three groups, the CPR almost always fully crashed in baseline but not when Ostrom's principles were in place as game rules. Results indicated that Ostrom's design principles may organize participant responses and maintain resource levels over time more effectively than without Ostrom's rules applied.

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INTRODUCTION

A common refrain among those practicing a science of behavior is that many of the problems that are most threatening to the human species are products of human behavior (e.g., Cihon & Mattaini, 2020). A primary enterprise of behavior analysis, therefore, has been to develop technologies that organize behavior in such a way as to ameliorate problems that have arisen as products of human behavior. The type of world considered possible when behavior science has been the architect of its design has long been considered an ideal one (Skinner, 1948) based on the efficacy of the experimental analyses of behavior (e.g., Skinner, 1938) and interpretations of their behavior analytic processes on society (e.g., Skinner, 1953). The world in which we find ourselves decades later, however, is far from an ideal one. The threats of nuclear war, climate change, and the depletion of critical resources are perhaps more dire now than they have ever been. Some attribute the persistence of these problems - even when a science of behavior could be employed to solve them - to a refusal to adopt the science itself due to other more reinforcing contingencies available to agencies and organizations (Skinner, 1987). Others have blamed practitioners of the science themselves for refusing to advance the science in ways that are necessary to address these problems (Dixon et al., 2018). Still more have suggested that the subject matter for the investigations necessary to address these problems lie in emergent, supra-operant processes and interdisciplinary collaboration (Cihon & Mattaini, 2020).

The fact that behavior analysis focuses on individual behavior could contribute to the lack of large-scale impact of the science onto global problems. A functional analysis of all the contingencies affecting problems on a global scale is a conceptual possibility, but the experimental control needed for this analysis is extremely difficult to guarantee. Some problems are, by definition, so complex that solutions may be practically out of reach for the current

science (e.g., Levin et al., 2012; Rittel & Webber, 1973). Researchers have produced far more post-hoc interpretations of relevant real-world events than empirical successes with attempts to change them (e.g., Ardila-Sanchez, 2019; Borba, 2019). However, interpretive work describing how behavior science might do so have been critically successful, particularly in addressing pressing social issues (e.g., smoking, sexual assault, gender issues, environmentalism; Biglan, 1995), designing efficient organizational structures (e.g., Malott, 2003), addressing governmental oppression and imbalances of power (e.g., Mattaini, 2013), common pool resource management (Borba, 2019), and community-led responses to environmental disasters (e.g., Ardila-Sanchez et al., 2019). Empirical explorations in laboratory microcultures have been successful but remain limited to simple preparations that do not seek to model complex, real-world global social structures (e.g., Borba et al., 2017; Ortu et al., 2012; Morford & Cihon, 2013; Smith, 2023; Vichi et al., 2009). Large-scale problems can themselves range in scale, for example across local, regional, national, and global resource pools or supply chains. Local problems that involve fewer players may be easier to model than global ones.

Even with barriers in place for applying a science of behavior to the solving of problems of social and global importance, hopes that practitioners might rise to the challenge still ring true. In his own words, “either we do nothing and allow a miserable and probably catastrophic future to overtake us, or we use our knowledge about human behavior to create a social environment in which we shall live productive and creative lives and do so without jeopardizing the chances that those who follow us will be able to do the same. Something like a Walden Two would not be a bad start (Skinner, 1976, p. xvi).”

Governing the Commons

One common social behavioral problem that has been documented across many scales is

the problem of the tragedy of the commons (Hardin, 1968; Ostrom, 1990/2015). The tragedy of the commons occurs when individuals over-extract resources from a limited common pool resource (CPR), causing the resource to become unavailable to the community as a result. A CPR is "a natural or man-made resource system that is sufficiently large as to make it costly, … to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom, 1990/2015, p. 30). This term broadly applies to any resource managed by more than one individual - and the range of potential CPRs is wide. An example of a common pool resource is an energy grid. Lately, too much withdrawal on an individual level has overtaxed the energy grid in Texas, causing many Texans to suffer during extreme heat- and cold-related weather events. The magnitude of the tragedy of the commons may be applied to those so small as to be merely inconvenient (e.g., a higher utility bill) to those so large as to occasion a social emergency (e.g., the crashing of an entire electric grid; Borba, 2019). The terminology of "the commons" was borrowed from earlier work in Ecology, originally described as the effect of overpopulation on the depletion of resource pool across a population (i.e., "the tragedy of the commons"; Hardin, 1968), and the definition of a CPR was further developed by economists and political scientists. The distinctions from those fields will be used throughout this paper, including the definitions of a CPR, "appropriators" (i.e., those who would withdraw resources from the pool), and "providers" (i.e., those who would contribute resources to the pool).

A community's effectiveness in designing self-governance systems for the management of CPRs was the subject of political scientist and economist Elinor Ostrom's body of work, for which she was ultimately awarded the Nobel Prize. Ostrom observed high variability in the success of such systems, seeing some systems work efficiently for decades and other systems lead to total social collapse. Through several interpretations and empirical assessments, Ostrom

developed eight essential principles by which a community might effectively self-govern a CPR (Ostrom, 1992; Ostrom, 1994, Ostrom, 1996, Ostrom, 2006; Ostrom, 1990/2015). Ostrom's conclusions could be behaviorally interpreted as a system of appropriate contingencies that lead individuals to interact with one another and the CPR in ways that produce CPR levels that are never depleted and rarely scarce, thereby providing an invaluable outcome to the participants acting upon the pool.

Ostrom's first principle for CPR management is that those who have access to the CPR must be clearly delineated from those who do not (i.e., Clearly Defined Boundaries). A behavioral approach would prescribe that this delineation is accomplished via clear and differential contingencies. This not only identifies the individuals and families who are granted the right to participate in managing the pool, but makes the physical boundaries of the resource itself explicit (1990/2015). In the example of the Texas energy grid, the boundaries of participants within that resource pool would be established via clear distinctions between appropriators or those who have active (i.e., non-delinquent) accounts with the energy company (i.e., participants) and non-appropriators, or those with delinquent accounts or no account at all (i.e. non-participants).

After the boundaries and access to the CPR have been clearly defined, rules for appropriating from or providing to the resource can be established. In Ostrom's second principle, "Environmental Congruence of Appropriation and Provision Rules", contingencies for interacting with the pool itself, including how many appropriators the CPR may allow and the magnitude of how much providers should be contributing to the pool, should be established in connection to the context of the physical contingencies provided by the natural environment (i.e. the renewal demands and fluctuations of the natural resource). The contingencies organizing the

behavior of human participants with respect to the management of a CPR are largely socially-mediated, and should organize human behavior with respect to the natural contingencies within the CPR. In a non example application of this principle, the isolation of the Texas Energy Grid from the other USA power grids imposes an inability to reallocate power from other states (e.g., Oklahoma) during times of intense heat or cold. These periods of intense weather have become more common, contributing to the overtaxing of the Texas Energy Grid and resulting in rolling blackouts during times of crisis. The CPR governance system of the grid, probably for political reasons, has failed to keep up with the changing physical needs of the CPR. The political reasons for keeping the grid isolated stand apart from the interests of the communities needing to shore up the CPR; such factors led Ostrom to emphasize that the rules for proper appropriation and provision of the CPR may best be made by those who will be affected by these localized contingencies, rather than those with conflicted interests further removed from CPR consequences. To address this, Ostrom proposes her third principle: Collective Choice Arrangements.

When the boundaries of the pool are clearly defined, the actors and their roles identified, and environmental congruence has been established, the question of who controls the contingencies for managing the CPR must be answered. Ostrom suggests that those identified as participants of the CPR (i.e., appropriators and providers) must be those that agree upon the rules by which their behavior affects the CPR. The principle of collective choice arrangements gives the actors within the CPR control over these contingencies via a process of “fair and inclusive decision-making” (Atkins et al., 2019, p. 32). In our example of the Texas Energy Grid, this would mean that not only would legislators and executives of energy companies make rules governing the energy grid, but also the customers of the energy companies would have a role.

After all actors within the CPR have been given agency to participate in collective choice arrangements for CPR use, a method for monitoring and ensuring the fidelity of these contingencies must be established - Ostrom's fourth principle. This principle was identified, but was not expanded upon thoroughly in the seminal text, however she did imply that the rules for monitoring a CPR would also be defined by collective choice arrangements by the appropriators and providers within the boundaries of the CPR. Energy companies in Texas already employ monitoring to some extent by sending employees to households to read the meters on the sides of residential and commercial buildings and use those data to determine the monthly bill for energy usage for their customers. Additionally, the Electric Reliability Council of Texas (ERCOT) monitors the CPR (the production of energy along with anticipated usage).

Monitoring, in behavioral terms, is an opportunity for at least some participants within the CPR to observe and respond to the condition of the CPR and the behavior of participants. In a small enough pool, a monitoring system could plausibly be arranged such that any individual might step into the monitoring role when the discriminative stimuli to perform monitoring arise. In larger pools, however, this role would need to be performed by either specific participants or independent observers. Automated monitoring processes are also suggested by Ostrom

With monitoring in place, the principle of graduated sanctions can be introduced. This involves the delivery of consequences (typically punishers) for interaction with the CPR. Relevant participants may deliver sanctions either formally or informally. According to the principle, the sanctions set against an individual interacting with the CPR must be balanced with the magnitude of the behavior itself. A first indiscretion may earn a minor consequence such as a verbal or written warning. However, as the indiscretion continues and/or grows in magnitude, more graduated sanctions should apply (e.g., fines, removal from the CPR). For energy

consumers, no such graded sanctions seem to be in place. An example of such sanctions may be high fines for energy use in excess of an agreed-upon ration during critical periods.

While behaviorists are well aware that control of behavior through reinforcement and punishment is possible (e.g., Skinner, 1938), we are also aware that control of behavior - especially through punishment - often produces countercontrol (Sidman, 2001). The individual will often behave in off-target ways that avoid the punishing consequence, for example through cheating or evading monitors. Ostrom proposed a sixth principle of CPR management that might be interpreted as providing a harmonious outlet for countercontrol to assure that it does not undermine CPR management: conflict resolution mechanisms. This principle dictates that individuals should have the opportunity to formally object to graduated sanctions on their behavior, and to propose new or amended sanctions in their place. Systems that fulfill this principle by allowing formal protest procedures could, for example, provide the participant the opportunity to explain their defection from the agreed-upon rules of the CPR, to compensate for it (e.g., providing back to the CPR to replace what had been over-appropriated), or request a change in consequences. In our power grid example this principle is not in operation since no CPR-maintaining consequences exist. However, if fees were assayed due to over-ration energy use, this principle may be fulfilled by, for example, allowing appeal of the fees on legal bases that can be judged by special committees, courts, etc. or by allowing participants to petition for retroactive rule changes on the basis of reasoned objections to assessed fees. Historically, labor movements have achieved great progress in challenging centralized authorities to change systems from more oppressive to less oppressive ones - but often at great cost. It has often been the case that labor movements have perhaps been more interpretable as cases of countercontrol rather than a feature of a system of governance. By including the right to organize as a principle

of self-governance, Ostrom offers a systemically designed way to address a centralized authority that is within the rights of a community. For example, the customers of a monopolistic energy company may have few other options to address a central authority (i.e., energy company executives) other than a boycott of their service or a class action lawsuit - neither of which would provide any immediate relief for the aggrieved individuals or address the concerns that occasioned the act of organization itself. By giving the rights to organize as a feature of the system of governance, countercontrol is directed, individual concerns are addressed, and the central authority over the individuals is more amenable to provide valuable solutions to problems.

Ostrom warns of the dangers of central governance systems in which the rules and contingencies set upon the actors in a CPR are controlled by those unaffected by the consequences of these contingencies (Ostrom, 1994). Self-governance, by its definition, removes the centralization of power over the contingencies of a community and disperses that power to a model of polycentric governance. The seventh principle of CPR management, the right to organize, addresses this. While the existence of an external authority is virtually inescapable in modern systems of government, this principle states that external authorities should not have the power to override the rules for CPR management as established by the other principles. This does not mean that external authorities may not have management powers over other aspects of community behavior and organization; it applies only to the domain within the boundaries of the CPR. In the example of the energy grid, this principle would be applied if the appropriation rules for a community could not be vetoed or changed by outside political or economic entities.

Finally, Ostrom proposes an eighth principle for self-governance: nested enterprises. It is often the case that a CPR is so large, variable, or complex that it cannot be managed by a single

system of contingencies across a group. Therefore, a system of systems could be needed to manage a larger pool of resources and actors. The principle of nested enterprises requires that local CPRs are organized according to the other principles, which may require variant rules and contingencies according to the variable needs of the CPR from location to location. It then states that these local subdivisions have some means of coordinating with one another, again in a manner in line with the other principles, so that those ways in which the overall CPR is affected by the whole of the subdivisions can be similarly governed. Again, there is no current example to draw from the Texas power grid since this principle has not been applied. However, one potential way to apply the principle would be to divide the grid locations up, either arbitrarily via county or zip code or via some other functional grouping. These "nested" groups would then be managed in a way that coordinates local needs and associated contingencies with overall needs and interactive contingencies.

Until recently, Ostrom's principles were mostly conceptual and had not been empirically tested as an independently manipulated variable. Smith & Becker (2023), in a preparation using a modified version of the board game Catan, tested the ability of the eight principles for self-management of a CPR to control the sustainability of a CPR. When applied, Ostrom's principles showed control over CPR levels for four groups. During baseline (i.e., in the absence of Ostrom's eight principles), a bank of five resources reliably depleted (i.e., "crashed") to zero. When Ostrom's principles were implemented, experimenters observed no total crash of the resource bank in any of the groups. Total depletion of the resource bank replicated during a reversal condition except for one group that had started with the rules instead of the no-rules condition. This study provides compelling evidence that Ostrom's principles have efficacy in

their potential to effectively organize individual behaviors when acting among a group tasked with self-governing a CPR.

Control, Punishment, and Countercrontrol

In Smith & Becker (2023), both rewards and sanctions for interacting with the CPR were utilized as part of Ostrom's 8 principles. It is unclear whether the effect of rewards (i.e., positive reinforcement) could have been sufficient to maintain the CPR or if graduated sanctions (i.e., punishment) were necessary as they were both implemented simultaneously.

While punishment has been shown to have a strong effect on reducing behavior, its lasting effects on behavior as well as its impact on other repertoires have been called into question (Sidman, 2001). According to Sidman, "Through laws and social customs, each of us has even agreed that punishment is an acceptable way for the community to control our own actions. We seldom ask whether punishment is the only or even the best way to get people to act as we want. We expect others to serve Justice and we agree to do so ourselves (p. 68)." In other words, many of the rules that organize our behavior in a social context are more about punishing unwanted behaviors than they are about rewarding behaviors that may benefit the communities maintained by these contingencies. In a social context, positive reinforcement, negative reinforcement, and punishment are often delivered concurrently, which can have problematic effects on the classes of behaviors affected by these consequences. Sidman (2001) explains this problem using a hypothetical example of a rat who receives a shock (i.e., an aversive stimulus) when a lever press occurs, but is still delivered food (i.e., an appetitive stimulus) immediately upon pressing the lever. The rat's lever pressing may decrease due to the punishing shock, but only until the rat's deprivation from food has become more aversive than the shock. Therefore, when multiple contingencies are mixed, we see the effect of punishment weaken over time, even

when the magnitude of the shock increases with each successive shock. Applying this to the observed effect of graduated sanctions on self-governance of a CPR, we would do well to heed Sidman's warning: "By using punishment in such a way as to convert it into positive reinforcement, a coercive community subverts its own rationale for resorting to punishment in the first place (2001, p. 75)".

When behavior is coerced, more coercion often follows (Sidman, 2001). In animal studies, when an animal is punished in the presence of a cage mate, it will often display aggression toward the other (Reynolds et al., 1963). If separated from a cage mate, but still in view, the animal will work to break through barriers to get to their cage mate. Even when a cage mate is absent, animal subjects have displayed aggression toward inanimate stimuli (e.g., bite bars) even when a preceding stimulus to a punishing consequence is delivered (i.e., prior to actually being punished). Using these experimental results to interpret human behavior might be easy to dismiss by many academic disciplines and laypersons throughout society, but Sidman (2001) succinctly states the fact that "[the] assignment of social responsibility to internal states instead of reinforcement contingencies imposed by the social environment makes it more difficult for us to recognize and deal with society's general acceptance of violence as an ultimate problem solver (p. 214)."

We may also see the same consequence take on negatively reinforcing or punishing effects, depending on the context (Sidman, 2001). In the Catan experiment, the players may decrease their resource extraction to avoid being sanctioned by the monitor (e.g., negative reinforcement), or because they received a sanction during a previous turn that caused them to lose resources from their own hand (e.g., punishment). Either way, the participant's behavior of "keeping the monitor happy" is devoid of any alternative contingency than to avoid an aversive

consequence, and they are therefore being coerced into performing well with respect to the CPR. While not directly displayed by the results of Smith & Becker (2023), it can reasonably be assumed that the countercontrol brought on by negative contingencies may have some effect on Ostrom's principles' efficacy in organizing behavior.

Experimental Question and Purpose

With the knowledge that the effects of punishing consequences weaken over time, the general negative effects of coercion on behavioral health and wellbeing, and the risk of those consequences occasioning countercontrol, it seems worthwhile to search for an alternative to their use (Sidman, 2001). In his own words, "If the effects of punishment were confined to the constructive objectives claimed for it, then to oppose its use would require a demonstration of noncoercive alternatives that accomplish the same ends (Sidman, 2001, pp. 79-80)." This study aims to do just that. Our purpose is to evaluate the effects of implementing Ostrom's eight principles as an intervention package, using the same preparation as Smith & Becker (2023), but limiting participants' rule-generation actions to only positive rule-generation in lieu of sanctions, to see if this approach still demonstrates the same experimental effects over CPR sustainability. If successful, the implications of this study might give us insight into methods to escape "society's nearly universal orientation toward coercive control (Sidman, 2001, p. 75)."

METHOD

Participants

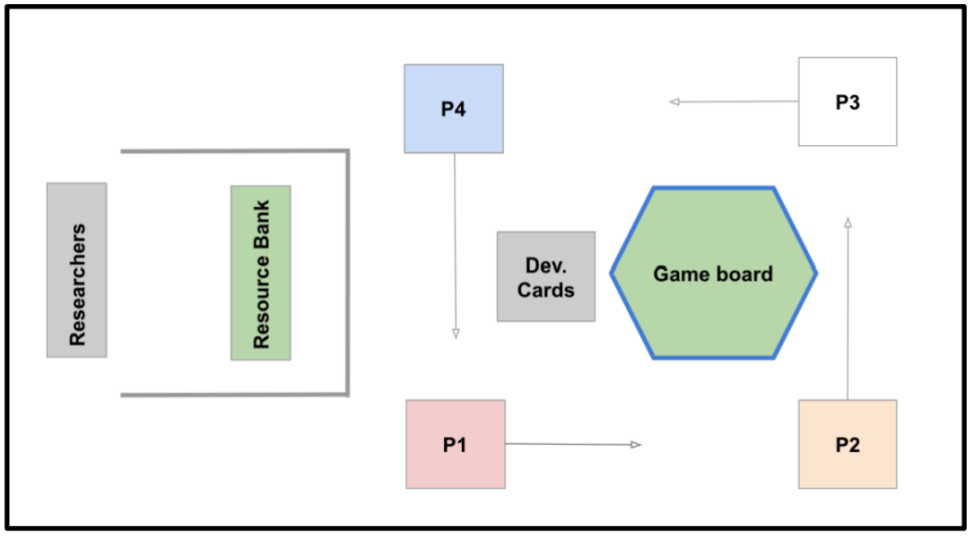
This study's twelve adult participants were 7 students, enrolled at the University of North Texas, and 5 non-students. The participants' ages ranged from 21 to 36. Prior to the study, each individual provided informed consent to participate. The University of North Texas Internal Review Board has approved all procedures, documented here, used in this study (IRB #22-470).

Setting

Each session was conducted in a 20 ft. x 10 ft. conference room that included a large table and chairs. Participants sat across from and next to each other at the end of the conference table nearest the wall-mounted television, in a square configuration.

Figure 1

Diagram of Experimental Setting



Source: Smith & Becker (2023).

Between the participants, on one end of the table, sat the game board and the development cards. The resource pool cards were placed further down the table from the game board, obstructed

from the participants' view by a cardboard partition. One to two data collectors sat at the far end of the table from the players (nearest the white board) and did not interact with the players during experimental sessions except to clarify the events of the previous turn when asked by the experimenter. When the need for clarification arose, questions from the participants and/or clarifications from data collected were directed at the experimenter, who then spoke directly to the participants. The experimenter stood for the duration of each session, moving around the table as needed to adjust the resource pool and to manage other tasks pertaining to the experimental procedures and data collection.

Materials and Game Rules

The board game Catan was used as the apparatus for the study. The game materials included a game board, playing cards, figurine pieces, two dice, and tokens. The board represents an island, and the different hexes represent regions on that island that produce resources (in the form of resource cards). In the class game of Catan, players compete to earn "victory points" by building roads, towns, and cities on the island using the resources provided by these hexes. To get resources, players must have cities or towns bordering the hexes in question (everyone starts with one city and one road) when the number associated with that hex is rolled on the dice.

The board game pieces used in this experiment included six border pieces, 19 hexagonal tiles depicting a terrain type (e.g., mountains) that corresponded with one of six categories of resources (e.g., ore). A circular token with a number ranging from 2-12 was placed on top of each terrain hex with the exception of the hex at the very center of the game board (i.e., the "desert"). Tokens with numbers of a low probability of being the combined roll of two six-sided dice were printed in black ink with 1-3 dots below the number, indicating the probability of that number being rolled. The remaining tokens were printed in red ink, with 4-6 red dots below the

number, indicating a higher probability of being rolled. This study omitted some of the pieces that are used in the original Catan game design in order to simplify and streamline the game. The omitted pieces included the Robber piece, Knight cards, and the Largest Army token. Participants were provided with booklets detailing the rules for all conditions of the experiment. Additionally, 60 trading tokens, copies of individual consent forms, a pen or pencil and scratch paper were provided to each participant.

Figure 2

Catan Board and Materials

The total count of all resource cards used across all four players was 190, compiled from decks combined from two Catan game sets. The 22 development cards used were also compiled from two game sets. Each player received a building cost card showing what resources would be needed to build cities, towns, etc., as well as four wooden “city” tokens, five “settlement” tokens, and fifteen “road” tokens, each with a designated color (e.g., Participant 1 has a red building card

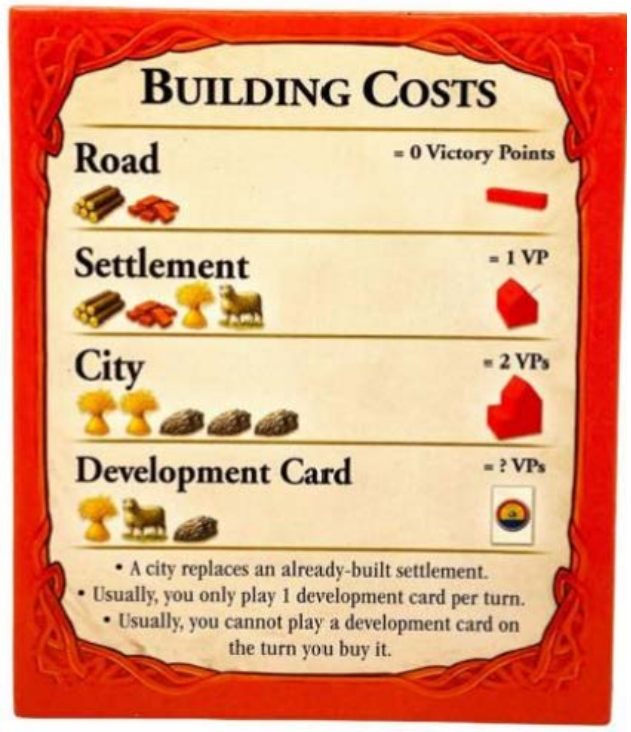
and all red tokens). The colors for each player were used to distinguish each player's pieces as they developed on the board over the course of the session, as well as verbally designating the resources each participant chose to take from the common pool on their turn, when applicable (e.g., "Blue would like two sheep").

Baseline Rules

Instead of having players compete to get the most victory points, we modified the goal of the game, telling the players that their task was to acquire a minimum of 8 victory points to "survive" the game. This was to render the game into a non-zero-sum task to better model a typical CPR. Victory points were awarded contingent on using resources acquired on player rolls to later build infrastructure across the game board in the form of roads, settlements, and cities (see Figure 3).

Figure 3

Building Costs Card



Each player began the game with two settlements, each attached to two roads corresponding to the color designated by the pieces in front of them when they chose a seat at the table. The placement of beginning roads and settlements as well as the location of terrain hexes and the numbered discs atop them were determined by the Catan rulebook, provided in the box set. This was done to ensure that no advantage would be provided to any player due to deviations in terrain hex placement. This starting configuration was arranged prior to the arrival of participants in all sessions, and each session used the same starting configuration throughout the study.

Both the baseline phase and the experimental phase were based on a simplified version of the rules-as-written Catan game provided with the game materials. The major deviations from the rules-as-written version included an alternate win condition in which any player earning more than eight victory points would "survive" the game, deviating from the designed rules determining a sole winner (i.e., the first to reach 10 victory points). This modification was made to remove the zero-sum win condition and to make the modified game rules more analogous to the context of managing resources in a common pool. The experimenter read aloud these amended rules to all participants prior to the beginning of the game, when they were also provided with a packet including a written version of the modified game rules (see Appendix A).

The other major deviation from the commercial game was that the resource cards in the "bank" were limited and increased in each round proportionally to their remaining quantity, again to simulate a typical natural CPR. When each session began, the resource pool was stocked with six of each of the five resources, totaling 30 resource cards in the common pool. At the end of each round, another 1 resource card was added to the bank for every 3 that remained there.

The first player to act was Red (i.e., P1), then Orange, White, and Blue. On each player's move, they can take four actions: 1) Roll, 2) Trade, 3) Build, and/or 4) Buy a development card.

The only compulsory action a player was required to take on their turn was to roll the dice. The additional three actions were or were not to be taken due to either the player having the appropriate number of resources required to take the action, or based on the individual player's strategy. Additionally, in the rules-as-written version of the game, players are allowed to offer trades with any other player on their turn, and to define their own terms of the trade. Both phases of the modified game rules used for this study have omitted inter-player trade.

Procedure

At the start of each session, participants were allowed to choose the chairs in which they would remain for the duration of the experimental session. The color of the game materials in front of their chosen chair designated them with a "player" color to be referred to throughout the game (e.g., P1 is Red, P2 is Orange, etc.). The rules for each game phase (i.e., baseline phase, experimental phase) were read aloud to all participants prior to the onset of the experimental session. This study included three groups of four participants each (i.e., 12 total participants). The researcher informed the participants that the game phase would change at certain points during the session, but did not disclose prior to the start of the game at what point these changes would be implemented. Participants were told, however, that when the change would occur, there would be a break in gameplay when the researcher would inform them of the new condition rules.

Once all the rules for the starting condition of the game were read aloud, the participants were allowed to ask clarifying questions, which were then addressed by the experimenter. When all clarifications had been made, the experimenter led the participants in a practice round of the condition wherein each participant played a full "move" - again being allowed to ask the experimenter for clarifications as needed until each player's practice turn was completed, ending

the practice round. Prior to the beginning of each new condition, or the return to a previously played condition, players were read the rules in full and led through a practice session. For reversal conditions (i.e., those returning to a previously played phase), players often waived the opportunity to have the rule re-read and to play another practice round.

While the participants were informed during recruitment of the approximate duration of the entire session (i.e., three hours), they were not informed of how many rounds were to be completed to fulfill any phase of any condition within the experimental session. The full game consisted of 19 rounds, or 76 individual player turns. Prior to beginning the first condition, and during breaks between conditions, participants were allowed to interact freely with each other, the experimenter, and/or data collectors. Prior to each condition of play, players were instructed to refrain from speaking to one another about the game, but that they could talk normally with one another otherwise. In the event that a player began to talk about the game with another player, the experimenter reminded them that this was not allowed. Participants were allowed to ask for a break at any point during the experimental session, and were informed that two 10-minute intermissions will be given over the course of each experimental session. Snacks and refreshments were freely available to all participants during the full experimental session. The criteria for completing this experiment were met when three groups of four participants completed the full, 19-round game.

Dependent and Independent Variables

The dependent variable in this study was the turn-by-turn quantification of the common pool resource as measured by the number of cards for each resource in the "bank" after each individual player's turn and at the end of each round. The pool consisted of five stores of resources: lumber (sourced from forest terrain tiles), ore (sourced from mountain tiles), brick

(sourced from clay tiles), wheat (sourced from plains tiles), and wool (sourced from sheep tiles). At the beginning of each session, the experimenter set the "bank" for each resource at six cards, stacked vertically behind the cardboard partition. When an individual player would take from the resource pool during their turn, data collectors recorded how many cards were taken and from which pool. Additionally, the number of resources requested by the player were recorded in addition to how many resources were actually awarded by the player. For example, if a player ordered three units of a certain resource on their turn, but only two of that resource were left in the common pool, the data collectors would record that the player had ordered three but only received two. This strategy allowed for the separate analysis of resource utilization attempts as well as resource depletion. By tracking resource levels during individual turns in addition to after whole rounds of play, researchers could later analyze both individual and summed group influences on the quantity of the common pool.

This study's independent variable was the manipulation of the game rules in each phase of the experimental session. The baseline condition of the game, included only the modification of the Catan rules-as-written (as already described). The second, experimental condition implemented the eight rules for self-governance developed by Ostrom (1990/2015) as described below under the "Experimental Rules" section. This condition was identical to that of Smith & Becker (2023) except that the use of positive rule-generation replaced graduated sanctions.

Experimental Rules

Prior to the beginning of the experimental phase of the game, the experimenter would pause play and describe additional rules implemented in the experimental phase. The experimenter read the new rules in full, offered any clarifications requested from the participants, and led the group in a practice round of four individual player turns. Three major rule changes

comprised the experimental phase: the appointment of a "monitor," adding an option to "call a town meeting," and "positive rule generation," which took place while a town meeting was in session. These three rules are designed to implement each of Ostrom's (1990/2015) design principles for the management of resources in a common pool. Game play proceeds in the same manner as in baseline phases, except for two changes. First, one player - the "Monitor" - can deliver consequences to players during any turn based on their use of the common pool. Second, an additional optional action is added to each turn: during any turn a player may "call a town meeting" to discuss and/or propose new rules regarding rewards for individual play that affect the resource bank. The four players would then vote to approve the rule change, a majority vote confirming the new rule. During the town meeting the Monitor may also give information as to the general levels of each resource in the bank (e.g., "Wheat is scarce, Ore is depleted, all other resources are good for now.")

The Monitor

The player entering the experimental phase of the game with the largest sum of victory points was automatically appointed monitor. If two players had the same sum of victory points, the group voted for one of either candidate to be monitor. The monitor was allowed to view the common pool at any point of play during the experimental phase, but was still not allowed to communicate with the other players. However, the monitor was instructed to immediately deliver consequences dictated by the positive rules generated by the group immediately upon the player fulfilling the positive rule contingency.

Call a Town Meeting

When the experimental rules were in play, each player had the option at the end of their turn to call a town meeting. Town meetings could involve either the whole group or only those players

with infrastructure on the same terrain hex (i.e., a resource-specific town meeting). During town meetings, players were allowed to discuss strategy and rules concerning that resource and/or agree to change the consequences for resource use that the monitor implemented. During all-player town meetings, players could also "sue the monitor". A player would simply state that they are suing the monitor and give their reasoning for proposing this action. The monitor was also allowed to give reasons that may justify their actions. When all parties had delivered the arguments, the whole group voted. A majority vote decided whether or not the monitor was sued. If there was a tie or if the vote did not pass, no consequences were delivered to the monitor. If the vote passed and the monitor was sued, they gave three of the resource cards from their hand back to the common pool. This was the only point during either phase of this study when players were allowed to strategize with one another, or to discuss another player's strategy at all.

The rules of the experimental phase put each of Ostrom's eight design principles into practice. These principles, their compatibility with their operationalized definitions, and the moves corresponding to each principle are listed in Table 1.

Table 1

Principles, Behavioral Definitions, and Game Moves

Principle	Behavioral Definition	Game Move
Clearly Defined Boundaries	Participants of the CPR are well defined via contingencies clearly signaled and imposed on individuals.	Whole group and Resource group defined by game piece adjacency. Contingencies for provision of resources defined by participant game piece locations.
Environmental Congruence	Participants of the CPR set rules (i.e. verbal stimuli and associated contingencies) for appropriation (withdrawal from the CPR) and provision (contribution to the CPR).The contingencies must adapt to the environment and CPR condition.	Initial rules provided by the experimenter in line with CPR, rules can be changed by participants in correspondence to CPR changes observed by monitor.

(table continues)

Principle	Behavioral Definition	Game Move
Collective Choice Arrangements	Participants governed by a set of rules (i.e. verbal stimuli and associated contingencies) that apply to the CPR can systematically redefine or remove existing rules to best fit current conditions of CPR and the group. Participants engage in interlocking behavior that results in the creation of new or altered contingencies and/or rules as cues for contingencies.	Participants can hold “Town Meetings” to discuss and/or change any sanction or reward rules currently in effect.
Monitoring	Participants observe, report and/or consequate the individual responses of other participants and changes of CPR's condition (amount of resources currently available in the CPR). Monitors can be selected participants within the group or the entire group.	One player becomes “The Monitor” and can track resource utilization.
Graduated Sanctions/Rewards	Participants set reinforcement contingencies in place that affect those who follow rules (i.e., verbal stimuli and associated contingencies) and/or defect.	Participants can receive rewards via the monitor contingent on behavior during their move or another player’s move.
Conflict Resolution Mechanisms	Participants can counter-control by calling a meeting with the group and verbally defending their defection against the rules (i.e., verbal stimuli and associated contingencies).	Participants can “Sue the Monitor” and thereby discuss grievances.
Right to Organize	External authorities, or those who do not participate but oversee any rules (i.e., verbal stimuli and associated contingencies) created by participants, do not deliver consequences to participants or modify contingencies set up by participants.	Experimenters cannot interfere with reward modifications made by participants.
Nested Enterprises	Contingent consequences relevant to local conditions exist amongst cumulative groups of individual participants.	Players can call a town meeting for particular resource group or for the whole group

Adapted from Smith & Becker (2023).

Experimental Design

Each session of this study used a reversal experimental design (i.e., ABA). Each group’s data were analyzed as an independent experiment. Each player was given a table depicting the

available actions they may take on their turn, a description of how to take each action with examples, and the order in which these actions are to be taken.

Table 2

Moves per Turn and Rounds per Condition

Condition	Moves per Turn	Rounds
Baseline (A)	• Base Moves: • Roll • Trade • Build • Play a Development Card	• Study 1 (ABA): • Rounds 1-6; 12-16 • Studies 2 & 3 (ABA): • Rounds 1-5; 11-15
Experimental (B)	• Base Moves plus: • Call a Town Meeting: • Sue the Monitor • Modify Rewards • Monitor: • Rewards • Access to resource level	• Study 1: • Rounds 7-11 • Studies 2 & 3: • Rounds 6-10

Roll

The Roll action began when the player rolled the two six-sided dice. The combined value of the two dice rolled determined which resources were available to be taken from the common pool by any player with a settlement or a city on the relevant terrain hex. This could include multiple terrain hexes. After the player rolled, the experimenter announced the value of the roll and which players may order which resources from the common pool. The order in which players may order from the pool began with the player who made the roll, then followed in the order of Red, Orange, White, Blue. Players with a single settlement on a terrain hex whose value matches that of the dice roll could order up to three resources associated with that terrain hex from the common pool. Players with a single city could order up to six of that resource. These values are additive, giving players the opportunity to order more resources per turn, based on their infrastructure and the resource's availability in the common pool.

The common pool of resources, obstructed from the player's view by a cardboard partition, contained a finite number of resources each round - beginning with six of each resource when the game begins. At the end of every round (i.e., four individual player turns), the experimenter would add one resource card to the bank for every 3 cards that remained in the bank. If a resource category was reduced to no cards at all, it would "replenish" after a set time; 6 more cards would be added after 12 rounds of play. For example: If at the end of a round, there were three Wheat cards remaining in the bank and six Ore cards - with all other resources at levels of two or fewer cards - the experimenter would add one Wheat card and two Ore cards to the bank. Players could request as many resources as they liked, depending on what infrastructure they had built on the designated terrain hex, however they could only receive up the number of cards in the pool. Since players could not see the resource bank, their only feedback regarding the levels of resources in the common pool came from their ability to order a number of resource cards and either receive them in full, receive a portion of the cards requested, or receive no cards and be told by the experimenter, "[Resource] is temporarily depleted." Players were also instructed to not talk about the game, so one could not say to the other "Don't take that many!" or give nonverbal signals such as a head shake or hand signal to indicate to the player ordering from the pool that their move might result in the crashing of a resource in the common pool.

An example Roll action: P3 (White) rolls two 6-sided dice on their turn - one 5 and one 3. White has no settlements or cities on any terrain hex with a value of 8, but Blue and Orange do. The experimenter would then say, "Okay White, you can't order any resources this turn. We will let the other players order before completing your other actions for your turn. Blue, you have a settlement on this clay tile that has an 8 on it, and another settlement on this mountain tile that is

also an 8. You can order up to three of each from the common pool." Blue replies, "Blue would like two clay and two ore." The experimenter then takes the requested cards from the resource bank and hands them to P4. Then the experimenter would say, "Alright, Red it looks like you are unable to order resources this time too. Orange, it looks like you also have a settlement on this same clay tile, and a city on the mountain tile. You can order up to three brick and up to six ore." P2 then says, "Orange would like three clay and six ore." The experimenter then checks the resource pool, but clay was depleted after Blue's order, and there are only three ore left in the resource bank. The experimenter then says "Clay is temporarily depleted. Here are three ore." Now that each player has either been notified that they cannot order any resources this turn, or has been delivered as many resources ordered as the resource bank will allow, the experimenter then returns their attention to P3 and says, "Okay, White. What other actions would you like to take on your turn?" White then takes any remaining moves on their turn (e.g., trade, build, play a development card; see below)

Trade

When all applicable players had ordered their resources, the player who rolled the dice was given an opportunity to trade resources with the bank at a ratio of 4:1; for example they could trade 4 ore for 1 wool. If the player had a settlement build near a "port" - a part of the game board on the edge of the map depicting a boat and a dock - they could trade with the common pool at a lower ratio as indicated on that port: either 2:1 or 3:1. If the player did not have a settlement on a tile containing a port, or did not have four of the same resource, they were unable to trade with the bank and they took no Trade action. Players were not allowed to trade resource cards with one another during any phase of the game.

Build/Buy Development Card(s)

After any applicable trade had ended, the player was then allowed to build and/or buy development cards. They could build any or all of the following infrastructures: roads, settlements, or cities. Any roads built were required to connect to an already existing road of the player's color. Settlements were required to be placed a minimum of two roads from one another. A player could build a settlement that connects to the road of another player as long as it also connects to a road of the player's color. Cities could only be upgraded from settlements already built prior to the current turn's Build action.

Development cards may be purchased with the appropriate resources indicated by the Building Costs card (see Figure 3). These cards may give the player a free victory point or another type of advantage (See Play a Development Card).

Play a Development Card

Development cards could be played as the last action of a player's turn. Two types of victory cards from the original game were used in this study: Victory Point cards and Progress Cards. A Victory Point card gave the player a free victory point with no other advantage. Victory Point cards did not give any more than one free victory point. Progress cards included advantages that were specific to the resources available within the progress of the game (e.g., All players must give all their ore cards to you). If a player did not have the resources required from the Progress card played, they gave the player who played the card nothing. Development cards could be purchased when the player took the Build action and could be played in the same round as the round in which it was purchased, should the player choose to do so. The player was not compelled to play a Development card at any point in the game, and could reach the end of the game with unplayed Development cards.

Call a Town Meeting

During experimental phases, a player could call a town meeting (as described above) as their final optional action.

Data Collection

One to three data collectors were present for each experimental session, in addition to the experimenter. The experimenter did not collect data during experimental sessions. Data collectors were present for the duration of the entire game, and recorded each player's resource order (request) from the common pool as well as which resources were actually delivered. Data was recorded on an Excel spreadsheet on a laptop computer used by the data collector during each experimental session. Formulas within the spreadsheet gave live updates to the resource pool in digital form, tracked when resources were to be replenished, when resources crashed and how many turns remained before the resource again became available in the common pool. At the end of each round, data collectors corroborated their spreadsheet data with the physical cards in the common pool to ensure the Excel data matched the actual cards and resources used. Data corresponding to individual play was identified by the player's name and color (e.g., P1 - Red) and the cells corresponding to player turns were shaded the same color as the color designated to that player. No personal identifiable information about players' identities were recorded on any data collection tool.

Interobserver Agreement

One of this study's three experimental sessions included more than one observer. When more than one data collector was present, a trial-by-trial Interobserver Agreement (IOA) score was calculated. Only Study 1 included multiple observers, with an IOA score of 89%.

Graphs and Analysis

When all data was compiled after the end of an experimental session, those data would then be converted into a series of graphs for analysis. Total turns until all resources simultaneously crashed were displayed in scatterplots. Total turn-by-turn resources levels were displayed in a line graph format, and the number of total turns until each resource crashed were visualized using violin plots.

RESULTS

Figure 4 depicts the number of turns until all five resources in the bank crashed to zero. The only condition in which this occurred was during A2 of Study 3, where all resources in the bank were depleted to zero on turn 11.

Figure 4

Turns Until All Resources Simultaneously Crash

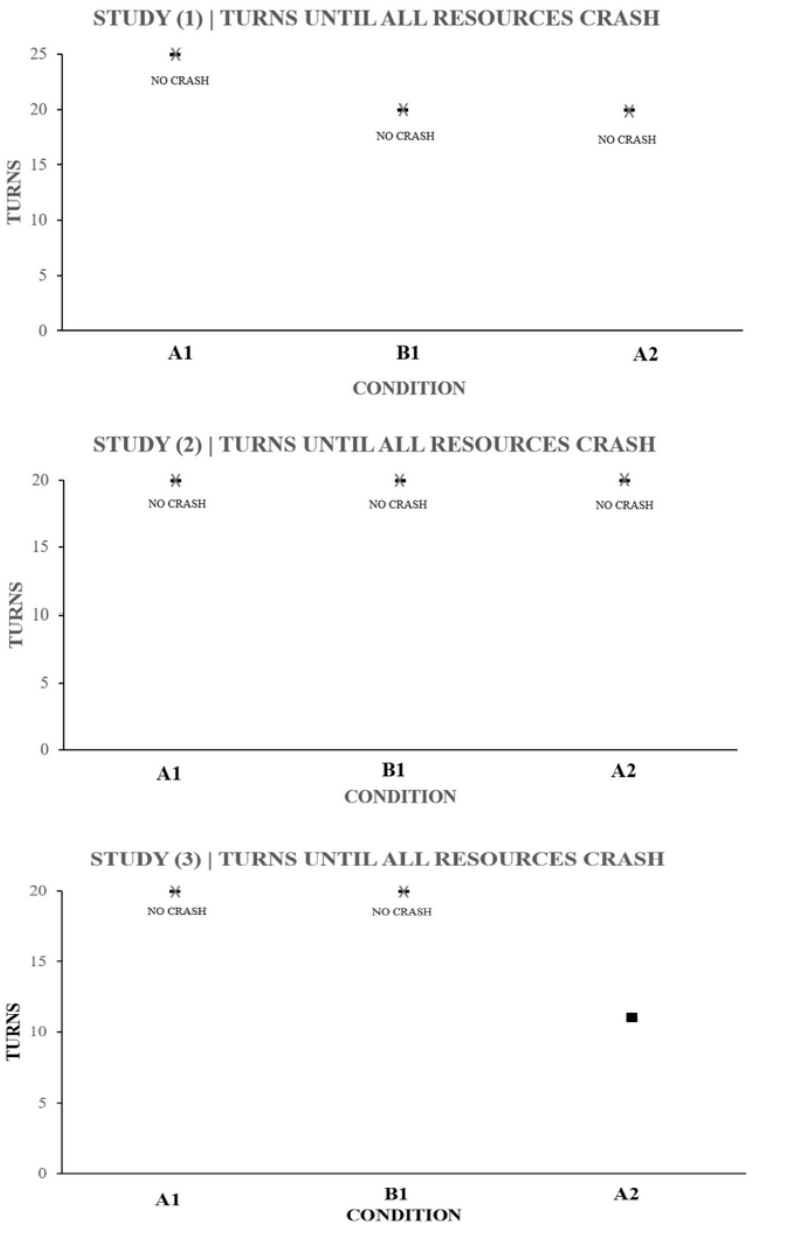
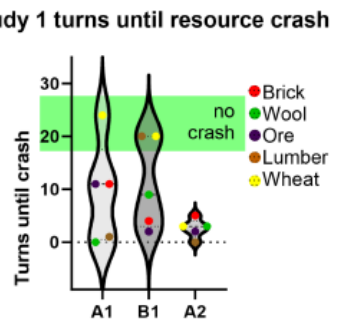


Figure 5 depicts the number of player turns until all resources in the bank crashed (i.e., depleted to zero cards). On the left, the data are presented in a table, on the right in a violin plot. Several resources had not crashed at all at the end of the phase; these are marked as 24 in the first baseline phase in study 1 and 20 in subsequent phases (each phase after the first baseline consisted of 20 rounds). Resources that never crashed are included in the green strip of the violin plots

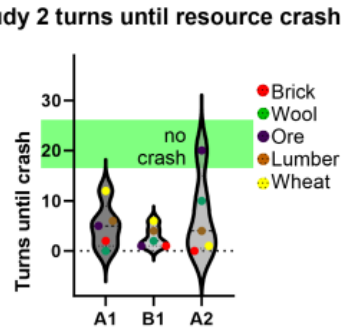
Figure 5

Number of Turns Until Each Resource Crashed

STUDY 1: # OF TURNS UNTIL RESOURCE CRASH			
	Condition		
	Condition A1	Condition B1	Condition A2
Resource	25 Turns	20 Turns	20 Turns
Brick	11	4	5
Lumber	1	20	0
Wheat	24	20	3
Wool	0	9	3
Ore	11	2	2
ALL COMBINED	47	55	13



STUDY 2: # OF TURNS UNTIL RESOURCE CRASH			
	Condition		
	Condition A1	Condition B1	Condition A2
Resource	20 Turns	20 Turns	20 Turns
Brick	2	1	0
Lumber	6	4	4
Wheat	12	6	1
Wool	0	2	10
Ore	5	1	20
ALL COMBINED	25	14	35



STUDY 3: # OF TURNS UNTIL RESOURCE CRASH			
	Condition		
	Condition A1	Condition B1	Condition A2
Resource	20 Turns	20 Turns	20 Turns
Brick	15	20	4
Lumber	20	5	5
Wheat	0	20	5
Wool	3	20	2
Ore	20	20	11
ALL COMBINED	58	85	27

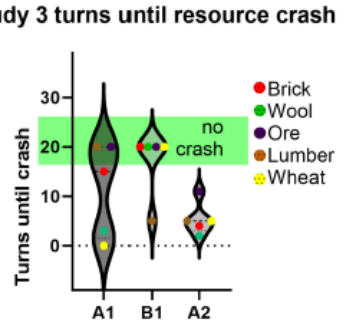
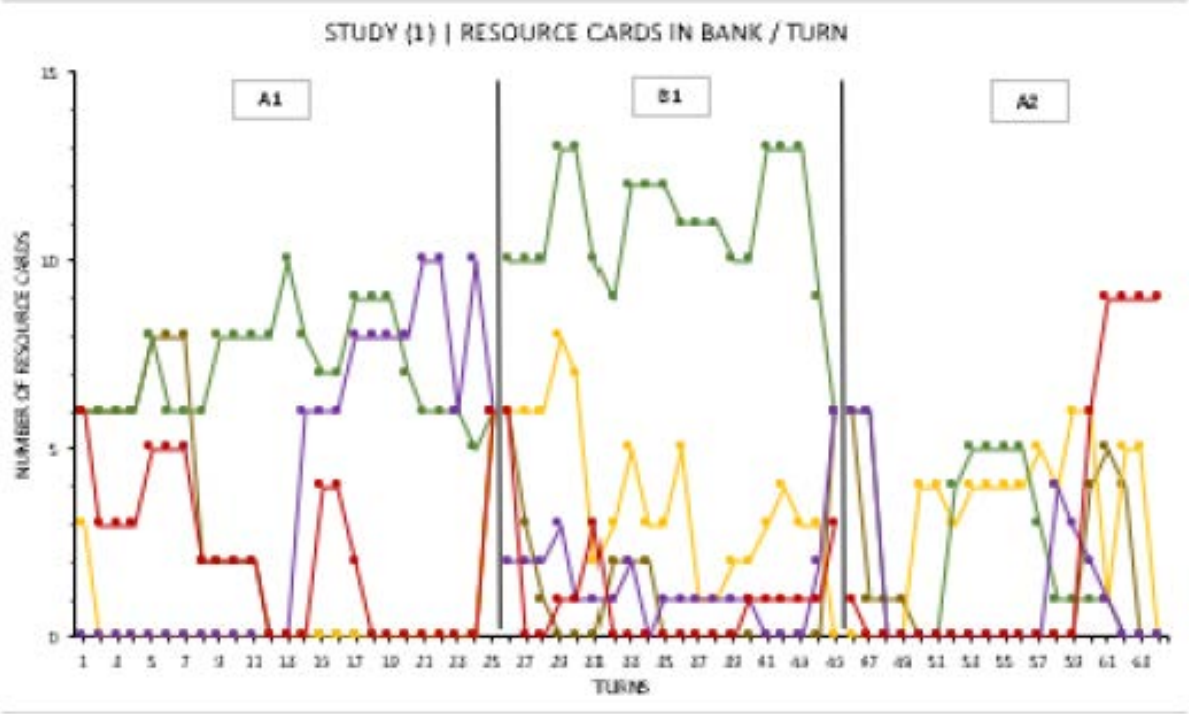


Figure 6 displays the total number of each type of resource card in the bank on sequential player turns for all three experimental groups. In Study 1, there were a total of 64 player turns: 24 in the A1 condition, then 20 each in the B1 and A2 conditions. Studies 2 and 3 totaled 60 player turns (i.e., 20 rounds per condition). While some resources crashed immediately (e.g., Ore in Study 1, condition A1), others did not crash at all for the whole condition (e.g., Wool in Study 1, condition A1). No condition demonstrated a simultaneous total depletion of every resource except for the A2 condition in Study 3. In all experimental conditions for each study, at least one resource exceeded the initial level of 6 due to the appreciation rules in which the experimenter would add one resource card to the bank for any three of that card remaining in the bank at the end of the round. Resources were also given to the bank by the players when they performed the trade action (see Methods).

Figure 6

Total Resource Cards in Bank per Turn



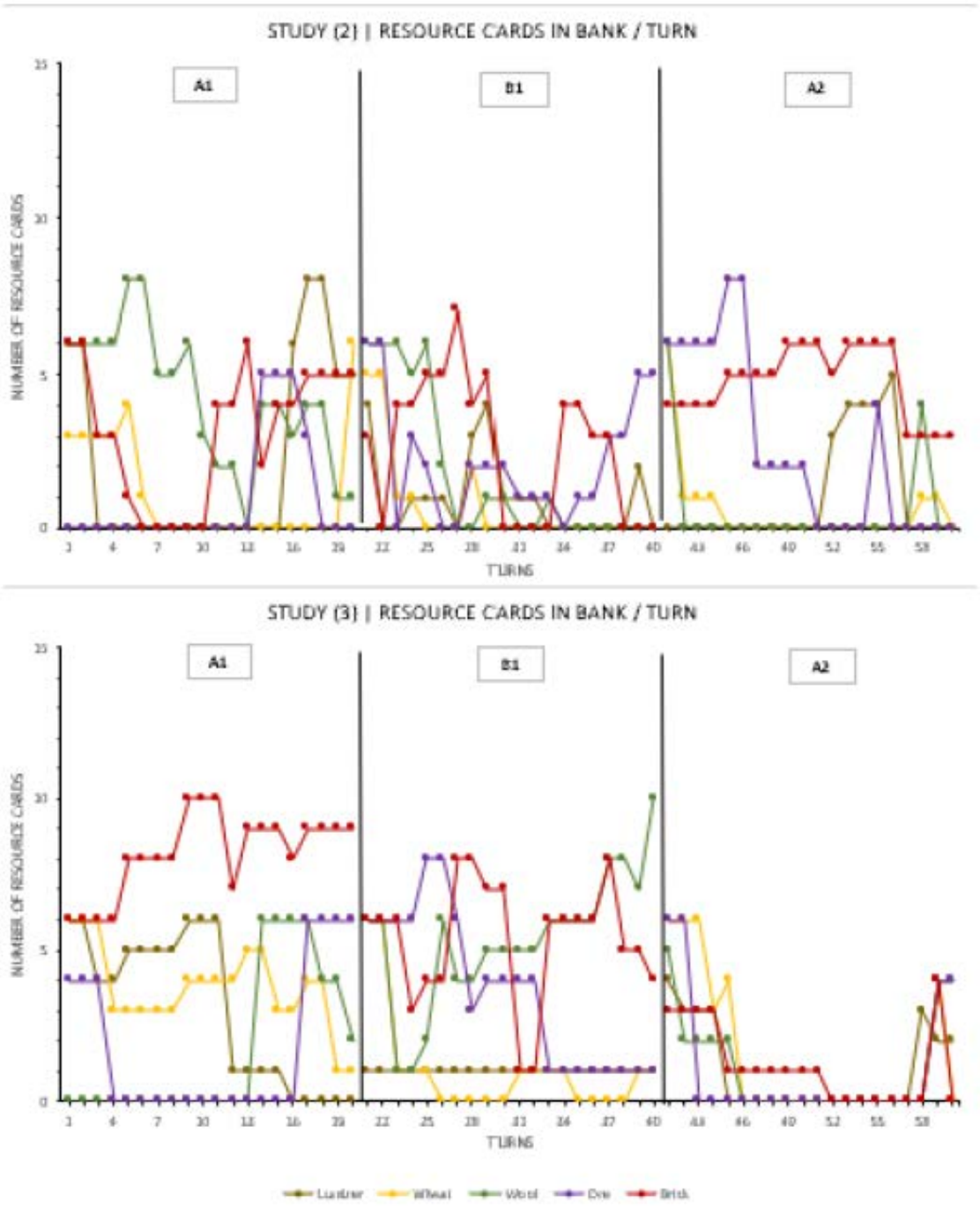


Figure 7 depicts the average resource levels and resource requests per round for each condition across all three studies. During Study 1, the average resource level and total requests were relatively consistent throughout conditions A1 and B1, with high variability in B2. During Study 2, resource requests surpassed the average resource level during each round except for

Round 5 of A1. The participants in Study 3 ordered below the average resource level for all of A1 and B1, with the exception of Round 1. For all groups, total orders far surpassed the average resource level in A2, wherein player orders reached their highest levels of the entire experimental session.

Figure 7

Average Resource Level and Resource Requests per Round

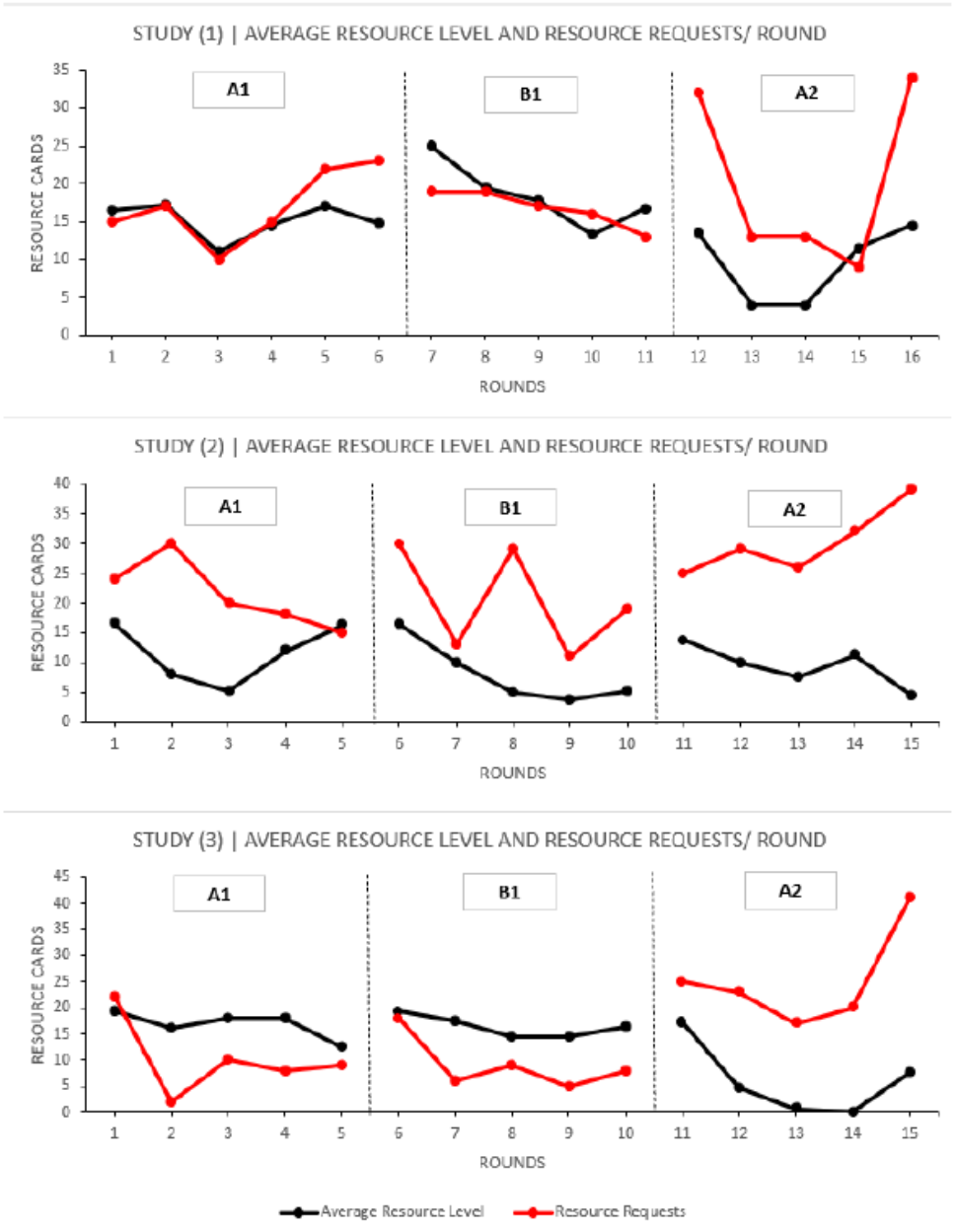
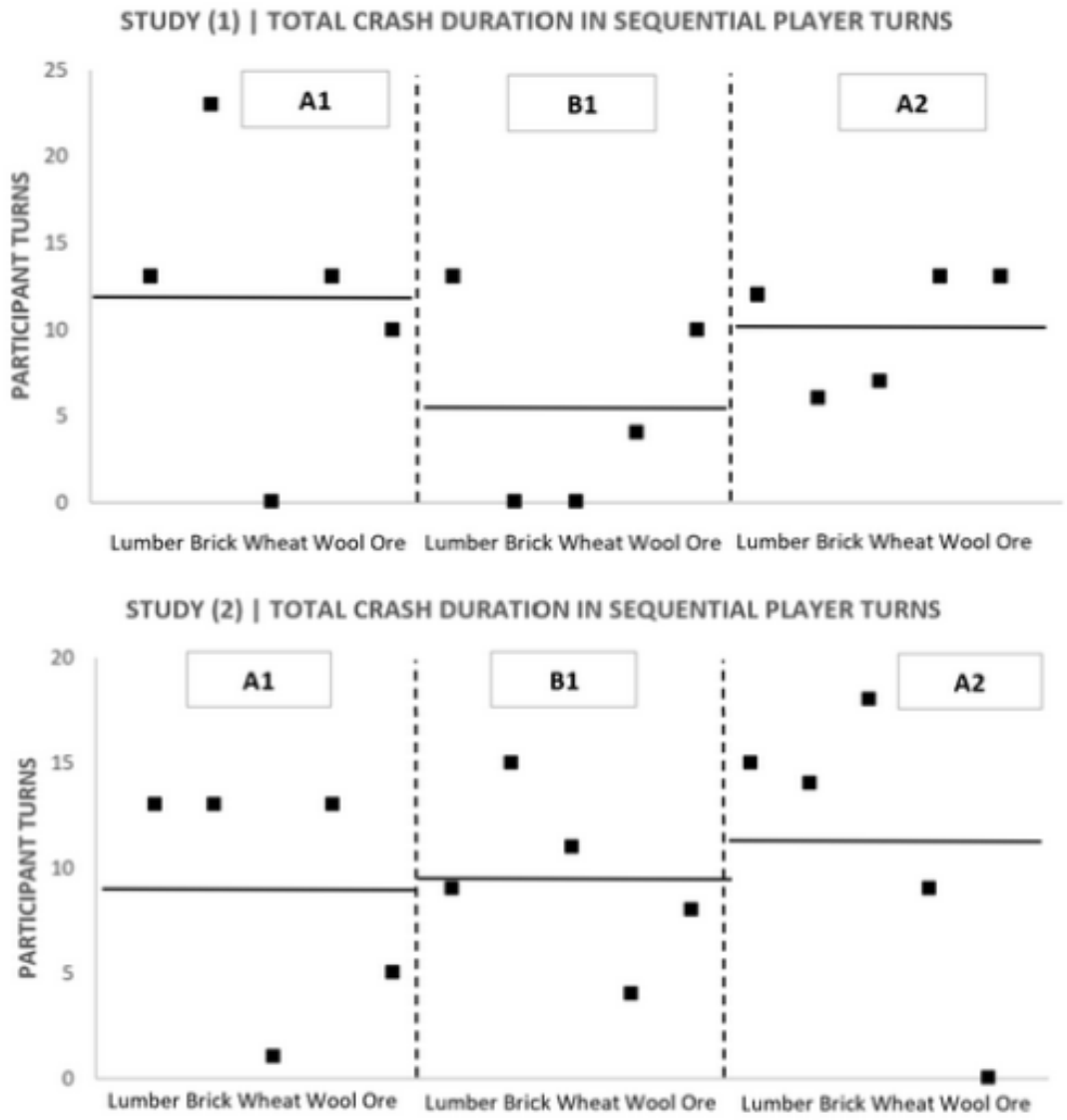


Figure 8 depicts the total crash duration across participant turns for all three experimental sessions. The solid, horizontal line for each phase depicts the average duration of crash across all five resources. In all conditions, crash duration was relatively near the average for all resources, with some exceptions: in A1 of Study 1, Brick was crashed for almost all player turns (i.e., 23 of 25 turns); in A2 of Study 2, Wheat was crashed for 18 of 20 player turns and Ore did not crash at all; in B1 of Study 3, the only resource to crash to zero was Brick for 9 of 20 player turns.

Figure 8

Total Crash Duration in Sequential Player Turns



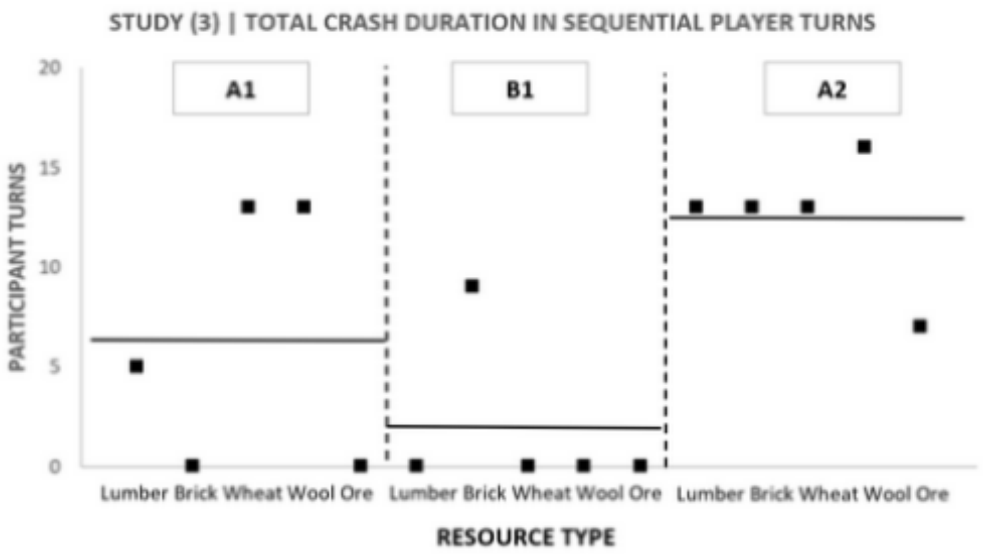
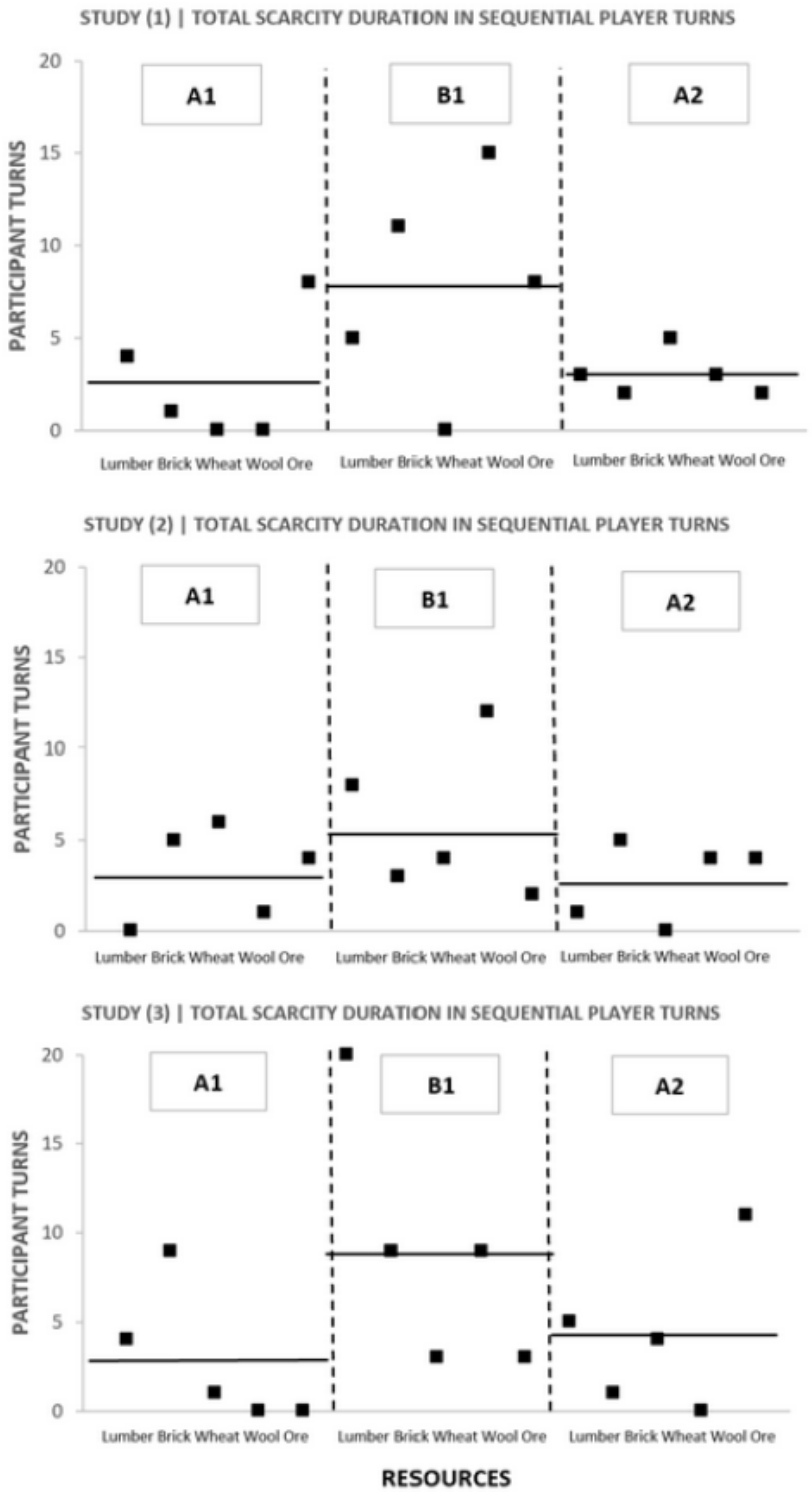


Figure 9 depicts the total duration for which a resource was scarce (i.e., 3 or fewer cards) across participant turns. The horizontal solid line represents the average duration of scarcity across all resources. During Study 1, all resources in A1 and A2 were relatively near the average, with the exception of Ore in A1 displaying a scarcity duration well above the average for that condition. In B1, Wheat was never scarce while Wool was scarce for 16 of the 20 player turns. During Study 2, Lumber (during A1) and Wheat (during A2) were never scarce. In B1, Wool was scarce for 12 of the 20 player turns. All other resources were near the average level of scarcity across all three experimental conditions. In Study 3, Wool and Ore were never scarce in A1, and neither was Wheat in A2. During B1, Lumber was scarce for all 20 of the player turns. Across all three studies, average scarcity duration was higher during B1 than either A1 or A2 conditions.

Figure 9

Total Scarcity Duration in Sequential Player Turns



DISCUSSION

Conclusions

While Ostrom's principles have previously shown to have a strong effect on self-management in a CPR game (Smith, 2023), this study failed to show the same effect. Specifically in the number of turns to reach a total depletion of all resources, data from Smith & Becker (2023) showed a reliable and replicable crash in conditions where Ostrom's principles were not in effect that did not occur not when they were. The data presented in this study only observed a total crash in a single condition, and few to no differences due to the IV (see Figures 4 and 5). Other measures also showed weak, inconsistent, or no results of the IV manipulation including resource level and resource requests (no effect), crash duration (inconsistent effect), and resource scarcity (weak effect). This could be because the positive-rules-only version of Ostrom's principles are not as effective as the rules that incorporated sanctions in Smith & Becker (2023). However, these groups differed from those of Smith & Becker in more than just the effect of the IV; CPR levels in baseline conditions (which should have been implemented identically) were far less unstable in these groups. This leads me to suspect that my methods may have failed to replicate a key component of those of Smith & Becker (2023). Because the baseline CPR in these groups was not as unstable, any effect of my IV on that instability could have encountered a ceiling effect.

Because of this baseline difference, broad observations were noted by the experimenter and data takers in order to discover what methods may have been dissimilar between studies during baseline conditions. Many potential reasons were uncovered as to why my baselines could have differed from Smith & Becker (2023), of which I will describe those that seemed most likely and that we plan subsequently to test.

While procedures used in both studies included a verbatim reading of both the baseline and experimenter rules, Smith & Becker (2023) emphasized victory points more than the experimenter in the current study. Each time an individual player would build a settlement or city, the experimenter in Smith & Becker (2023) would include a verbal stimulus (e.g., “That’s another victory point for you. You have 4 victory points now.”). The experimenter in the current study only told participants their victory point totals when asked, and at the end of an experimental condition. Smith & Becker (2023) also verbally encouraged participants to track their own victory points on their scratch paper, whereas in the present study the experimenter encouraged participants to track feedback from the monitor regarding the state of the resources in the bank, and only during B1 conditions. This could have been a critical factor in the individual players’ behavior as consequated by victory points. The differential experimenter behavior could have established (or failed to establish) victory points as effective individual consequences. For a CPR to encounter the tragedy of the commons, resource provision needs to outstrip resource capacity, which probably would not happen if some outcome of that provision were not programmed as an individual reinforcer. The behavior of the experimenter may have been important for that potentiation of resources in this game-based CPR.

Supporting this idea, some participants in the Smith & Becker (2023) studies achieved 8 or more victory points and were dubbed “successful survivors” while none of the 12 participants in this study achieved 8 victory points. This difference also could have affected how the players ordered from and/or traded with the resource bank. For example, during Study 3, P3 (Orange) rarely ordered from the bank, and did not build a single road or settlement for the entire game. Anecdotally, the players in these groups also asked more questions about how to play the game itself, and occasionally made verbal statements indicating a lack of understanding about the

contingencies required to “survive” the game (e.g., “I have so many cards, I don’t know what to do with them).

Another potentially important difference between these studies was that the experimenter in Smith & Becker (2023) emphasized the importance of trading tokens more. The experimenter would periodically emphasize the value of trading tokens when received (e.g., “You got a trading token! Now you trade more easily with the bank. You only need to trade two cards in for one in return instead of four cards.”) When players receive reinforcement for acquiring trading tokens, and when they would exchange them for a more favorable 2:1 trade with the resource bank than the initial 4:1, players traded with the bank more and in ways that may have produced a more robust collection of resources within the bank.

Future Directions

While some DVs showed weak or inconsistent positive results across these three studies, none of these three groups replicated either the baseline or the IV effect that showed so strongly in the Smith & Becker (2023) groups. The lack of CPR instability in baseline phases may account for the weak or inconsistent effect of the IV that we saw in this study if they essentially imposed a ceiling effect on possible improvements from baseline. We therefore plan to run further replications, this time implementing more precisely delineated baseline procedures (i.e., including the original experiment’s procedures with regard to victory points) as well as original experimental procedures (including both rewards and sanctions). Once both baseline instability and IV effects can be replicated, new replications will then be needed before the effect of the independent variable in this study (i.e., rewards only) can be fully evaluated.

In order to decipher whether the explanations stated above account for the differences between these studies and those of Smith & Becker (2023), they will be formalized for these

replications. More explicit descriptions of the contingency for "successful survival" will be given at the start of the game. Before beginning the verbatim reading of the rules, we will add a scripted emphasis on victory points. For example, the experimenter will begin the session with "Your goal is to survive Catan. To be a successful survivor, your job is to earn at least 8 victory points. To earn victory points, you need to build settlements, cities, and play development cards." Verbal reinforcement will be delivered by the experimenter each time a player takes an action that increases their victory point total (e.g., "You just built a settlement. That brings your victory point total to 3, only 5 more to successfully survive the game."). In addition to verbal reinforcement, tangible tokens representing victory points will be provided, and victory points for each player throughout each condition of the experimental session will be displayed. We will display each player's victory point totals either on a dry erase board or on a digital screen throughout all conditions during future iterations or extensions of this study.

Future studies should also include an analysis of the verbal behavior amongst participants - both during the game and during a formal debriefing. Across the three groups, participants asked if trading between them was allowed, and expressed disappointment when the experimenter responded that it would not be, and disallowed them amending the rules to do so during town meetings. Allowing players to trade among each other, as is allowed in the unmodified Catan game, is an experimental manipulation that may be valuable for future investigators. While trade between individuals may not directly affect the self-management of CPRs, it more closely models the nonbinary approach to interactions present in community systems (i.e., helping only one or two individuals does not necessarily mean those interactions do not also help the whole group).

The verbal behavior of players during town meetings was anecdotally recorded by data

collectors, who commented on the Excel data collection document the turn and round when the meeting was called, the rules proposed, and the results of voting on new rules. However, these data were not further analyzed or reported. Future studies that perform analyses of the verbal behavior of the participants - both in town meetings and throughout the whole game - may uncover additional, previously unnoticed variables that could be critical to producing the desired effects of Ostrom's eight design principles as an intervention package.

Additionally, while not allowed to strategize about the game, participants would often change their verbal behavior with respect to each other based on in-game events. For example, if a player chose to request the same resource the preceding player received, only to be told the resource was now temporarily depleted, they might joke with the other player "wow, I can't believe you did that!" Even expressed as a joke, a more detailed analysis of these types of statements might uncover new experimental questions as to the role of verbal behavior in rule-governed behavior, community ethics, and the intricacies of countercontrol. While the participants informally expressed they enjoyed playing the game after sessions had completed, a formal debriefing and analysis of their verbal behavior might enlighten future investigators about procedural nuances that might not be apparent in the initial analysis (e.g., the baseline effects of this study uncovered the behavior of the experimenter as a critical variable when Smith & Becker (2023) did not find that in their initial investigation).

Certain limitations to this study can be attributed to restrictions imposed by the procedures approved by the IRB (e.g., limited number of rounds to comply with the three-hour maximum time allotment made repeated reversals impossible) and the design of the Catan game itself (e.g., limiting the participants and game materials to a maximum of four players may not model real-world CPR conditions and poses procedural issues in democratically electing a

monitor when votes may result in a tie). Effects of these limitations can be inferred from the higher numbers of requests for resources from the bank in B2 conditions relative to the average level of resource cards in the bank than in either preceding condition in all three groups (see Figure 6). It is possible that players - with the knowledge that the study lasts three hours but not knowing which round would be the last in the game - adjusted their in-game responding that produced a “lame duck” effect of ordering the maximum resources allowed regardless of their previous strategies. Additionally, these limitations may have produced the stronger effect of players managing scarcity within the pool (see Figure 8) rather than working to produce victory points for themselves. For example, in Study 3, players called a town meeting wherein they made a rule that they would all show their own resource cards face-up on the table so that everyone had access to monitoring each other’s hands at all times. This rule modeled a more bureaucratic design for CPR management than the procedures of the study were hypothesized to produce, as opposed to Ostrom’s model for self-governance. It could be that organizing behavior via strict rules produces this effect rather than more general ethical guidelines present in real-world CPR self-governance. Future studies might take a more free-operant approach to the procedures described in this study, starting with the measuring CPR self-governance using the rules-as-written Catan game, then amending the rules inductively as effects are uncovered during data analysis.

While this study failed to replicate the baseline effects shown in Smith & Becker (2023), the inductive process that it spurred provides opportunity to continue the work of empirically assessing critical elements in Ostrom’s eight design principles, and the CPR conditions in which they operate. It illuminated a key part of our successful tabletop CPR model, which was not sufficiently noted in the previous study. Through my planned replications and through future

work in this field, I hope that this work can help to build a foundation for meaningful work on how to prevent the tragedy of the commons; a problem that impacts human communities worldwide.

The longevity of the human species, the environments we inhabit, and the habitability of our planet rely on the assumptions that problems caused by human behavior can be solved by the principles of a science of behavior and collaboration with other disciplines (Cihon & Mattaini, 2020; Skinner, 1987). An “ideal” world is likely unachievable in practice, but behavior analysis should continue empirically evaluating methods of organizing behavior that produces more favorable outcomes than those that, if left unaddressed, contribute to the suffering of humans and the organisms with which we share our world.

APPENDIX A

MODIFIED GAME RULES

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Catan Updated Rules

Introductory Note:

- This game is a modified version of the game Catan. Many of the rules are the same, while others vary greatly from the original rules. The purpose of this sheet is to provide you with a comprehensive list of the rules for this experimental version of the game.
- You will play two rounds as practice with the group and an experimenter before beginning the game. Feel free to ask any clarifying questions at this time.

Participant Communication:

- **You may not speak with or coordinate with other participants about the game except where specified by the rules below.**

Goal of the Game:

- The individual(s) with a minimum of 8 victory points at the end of the game are the winners and receive the title of "Most Successful Survivors".

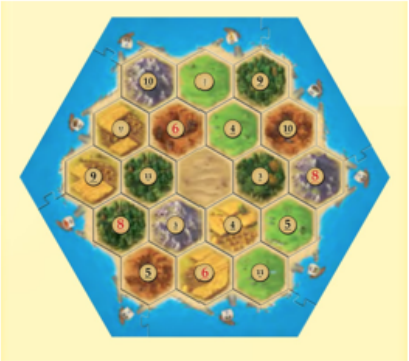
Setting Up the Game

Game Components:

1.	19 terrain hexes (tiles)	**7.**	16 cities (4 of each color)
2.	6 sea frame pictures	**8.**	20 settlements (5 of each color)
3.	18 circular number tokens	**9.**	60 roads (15 of each color)
4.	95 resource cards (brick, grain, lumber, ore, wool)	**10.**	Rule Booklet
5.	11 development cards (6 progress cards and 5 victory point cards)	**11.**	Trading Tokens
6.	4 "Building Costs" cards	**12.**	Paper & Pen

Constructing the Island

- The researchers will have the game board constructed like so:



Resources

Resource Bank

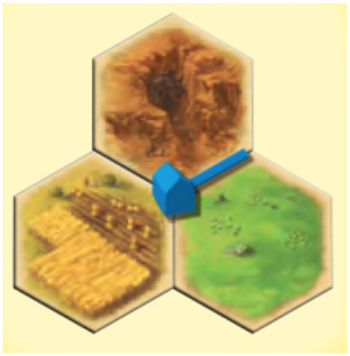
- The resource bank will be kept next to the game board on the table.
- You can only take cards from the resource bank.
- Any trade with the resource bank goes back into the resource bank.
- Any resources spent to build go to the researcher's stack.
- At the start of the game, the resource bank will consist of 6 of each resource card.
- The experimenter will be adding to the bank with the remaining resource cards.
  - **Note: For every 3 resource cards in the bank, 1 extra is added each round until the deck is at maximum capacity.**
- **If a resource gets depleted from the resource bank (to a quantity of 0), you must all wait 12 turns before 6 new cards are added to the bank.**

Finish Setting Up

- In front of you will be a bag of game materials and a build card that you will utilize throughout the game.
- **2 roads and 2 settlements will be placed onto the board for you by the researcher. Keep the other materials in front of you.**

- Settlements and cities may only be placed at the corners of the terrain hexes, never along the edges.
- Roads may only be placed at the edges of the terrain hexes (1 road per edge).

➢ Your road + settlement placed onto the board will look like the figure below (in this example, the player can take 1 brick card, 1 wool card, and 1 wheat card for this placement):



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How to Take Your Turn:

- Player 1 (red) will go first.
- On your turn, you can do the following in the order listed:

Roll	You must roll for resource production. ➢ If desired, you can choose to not take the resource card from the bank.
Trade	You may trade resource cards with the resource bank. ➢ You do not have to trade/may not be able to trade that round.
Build	You may build roads, settlements, or cities and/or buy development cards. ➢ You may play one development card at any time during your turn. ➢ You do not have to build.
Buy a Development Card	See "(4) Play a Development Card," below.

- Keep track of your victory points using the pen and paper provided.

(1) Roll

- **Roll** for resource production.
  - You begin your turn by rolling both dice. The sum of the dice determines which terrain hex(es) produce resources.
  - Each player who has a settlement on an intersection that borders a terrain hex marked with the number rolled can take up to 3 resource cards of the hex's type from the resource bank.
    - This means you can take anywhere between 0 to 3 resource cards if your hex number is rolled.
    - If you have multiple settlements on a terrain hex then you still take up to 3 resource cards.
  - If you have a city or cities on a terrain hex, you can take up to 6 resource cards.

➢ **If you roll a 7, no one receives resources.**
- A seven represents the desert hex. No resources are produced from the desert hex.
- Continue on with your turn.

(2) Trade

➢ **Trade** resource cards.
- You can trade at a 4:1 ratio by putting 4 identical resource cards back in their stack in exchange for any 1 resource card of your choice.
- If you have a settlement or city on a harbor, you can trade with the resource bank more favorably (at either 3:1 ratio or 2:1 ratio, depending on the harbor). ■ You must trade the resource type shown on the harbor.

(3) Build

➢ **Build roads, settlements, or cities.**
- Through building, you can increase your victory points, expand your road network, improve your resource production, and/or buy useful development cards.
- To build, you must pay specific combinations of resource cards to the "spent" pile next to the researcher.
- Take the appropriate number of roads, settlements, and/or cities from your supply and place them on the board when you are able to build (if you choose to do so).

➢ **Building Cost Cards**
- These cards tell you what resource cards are required to buy development cards and build roads, settlements, and cities.
- They also tell you how many victory points you earn for building each.

➢ **Build Roads**

- A new road must always connect to 1 of your existing roads, settlements, or cities.
- Only 1 road can be built on any given path/side of the terrain hex.

➢ **Build Settlements**

- **Distance Rule:** You may only build a settlement on an unoccupied intersection and if none of the 3 adjacent intersections contains a settlement or a city (you must have 2 roads in between cities/settlements). The two roads must be built before a city/settlement is built.
- Each of your settlements must connect to at least 1 of your own roads.
- Regardless of whose turn it is (i.e., during any production phase), you can receive up to 3 (between 0 to 3 cards) if a hex number is rolled where you have a city placed.

- **Build Cities**
  - You may only establish a city by upgrading one of your settlements.
  - When you upgrade a settlement to a city, put the settlement piece back in your supply and replace it with a city piece on the board.
  - Cities produce twice as many resources as settlements. You can receive up to 6 resource cards if a hex number is rolled where you have a city placed.

- **Buy a Development Card**
  - When you buy a development card, draw the top card from the deck.
  - Development cards never go back into the supply, and you cannot buy development cards if the supply is empty. Once they run out, they do not come back.

(4) Play a Development Card

- **Play a Development Card**
  - You may play 1 development card by placing it face up on the table.

- **Play a Progress Card**
  - If you play a progress card, follow its instructions.
  - Remove the card from the game area once it has been used.

- **Play a Victory Point Card**
  - Remove the card from the game area once it has been used.

Alternate Rule Activation

- At two points during the game, alternate rules will be activated by the experimenter.
- Players will not know when this will occur until the experimenter says "We are activating the alternate rules starting this round."
- Players will also not know how long this phase will last until the experimenter says "We are taking out activation of alternate rules starting this round".
- During these phases of the game, all previous rules still apply.
  - However, there will be new rules added, including a player called **"The Monitor"**, **Rewards**, **Sanctions**, and the move **"Call a Town Meeting".** The alternate rules will be added to each player's turn every round until notified to stop.

The Monitor

- **The Mo**
  - The monitor will be the player with the most victory points at the first round of the alternate rule activation.
    - If there is a tie for victory points, the group will vote for the monitor.
  - The monitor tracks the resource bank, resource use by each player, and implements sanctions and rewards.
  - If a player engages in a play that deems a necessary reward or sanction, immediately implement that reward or sanction before they have the opportunity to hold a town meeting.

Rewards and Sanctions

- **Rewards and Sanctions**
  - All players will be affected by the rewards and sanctions.
  - Rewards and Sanctions will be implemented by monitor.
  - Participants can call a town meeting to make changes to rewards or sanctions during their turn.

- **Note:** The experimenters cannot interfere with minor participant reward and sanction modifications so long as these modifications correspond to the current game rules and utilize the game materials given to them.
  - Example: Each time you donate to the mountain resource bank then you receive two trading tokens.
  - Non-example: If you donate to the mountain resource bank then I will buy you a coffee tomorrow.

➢ **Initial Rewards:**

- If you donate a resource card to a depleted resource, then you receive one trading token (2:1 trade).
- If you donate a resource card to a scarce resource in the bank two turns in a row, then you receive two trading tokens.

➢ **Initial Sanctions:**

- If you take the final resource card from the bank, then you lose a turn the next round.
- If you take the final resource card from the bank two turns in a row, then you must give up half of your hand to the resource bank.

How to Take Your Turn:

➢ **When alternate rules are in effect, turns will consist of the following steps:**

- Roll, Trade, Build, and Play development cards as usual during your turn. ○ **NEW: Call a Town Meeting**
  - This occurs last during your turn.
  - You do not have to call a town meeting.

5) Call a Town Meeting

➢ This occurs last during your turn.

➢ You can call a town meeting for your resource community (i.e., players that also have a settlement or city on a mountain, field, etc.) or for the whole group.

Town Hall for Resource Community

➢ **Town Hall for Resource Community:**

- If you and another player have a settlement or city on the same resource (does not have to be the exact same hex), then you can call a town meeting to meet with them.
- To hold a town hall for the resource community say, "I'd like to hold a town hall for _____ resource."

- In these town hall meetings you can:
  - Discuss / change sanction, rewards, or monitoring rules for that particular resource group.
    - Simple majority vote to change a rule; if tied then it does not pass.

Town Hall for Whole Group

➢ **Town Hall for Whole Group:**

- If you call a town hall meeting for the whole group, all players participate in the town hall.
- To hold a town hall for the resource community say, "I'd like to hold a town hall for the whole group."
- In these town hall meetings you can:
  - Discuss / change sanction and reward rules that affect the whole group.
    - Simple majority vote to change a rule; if tied then it does not pass.
  - **Sue the Monitor:** players can sue the monitor and defend why.
    - All players vote on whether the monitor gets sued.
    - If the vote is tied, the monitor does not get sued.
    - The monitor must put 3 resource cards back into the resource bank if the group agrees to sue the monitor.
    - **Reasons to sue the monitor:** the monitor unfairly sanctions someone, the monitor refuses to sanction themself, the monitor unfairly rewards someone, etc.

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Ending the Game

- The game is over after **60** rounds.
- The experimenter will let you know what round number we are on after every 5 rounds.
- At any time, you can ask the experimenter for the current round number.

Winners

- **Most Successful Survivors**
  - The players that have at least 15 victory points by the end of the game are the most Successful Survivors of the game! Congratulations!

Final Note:
Thank you for your participation in this research study.
Please reach out to the experimenters Ian Paterson and Dr. April Becker for any further questions or concerns.

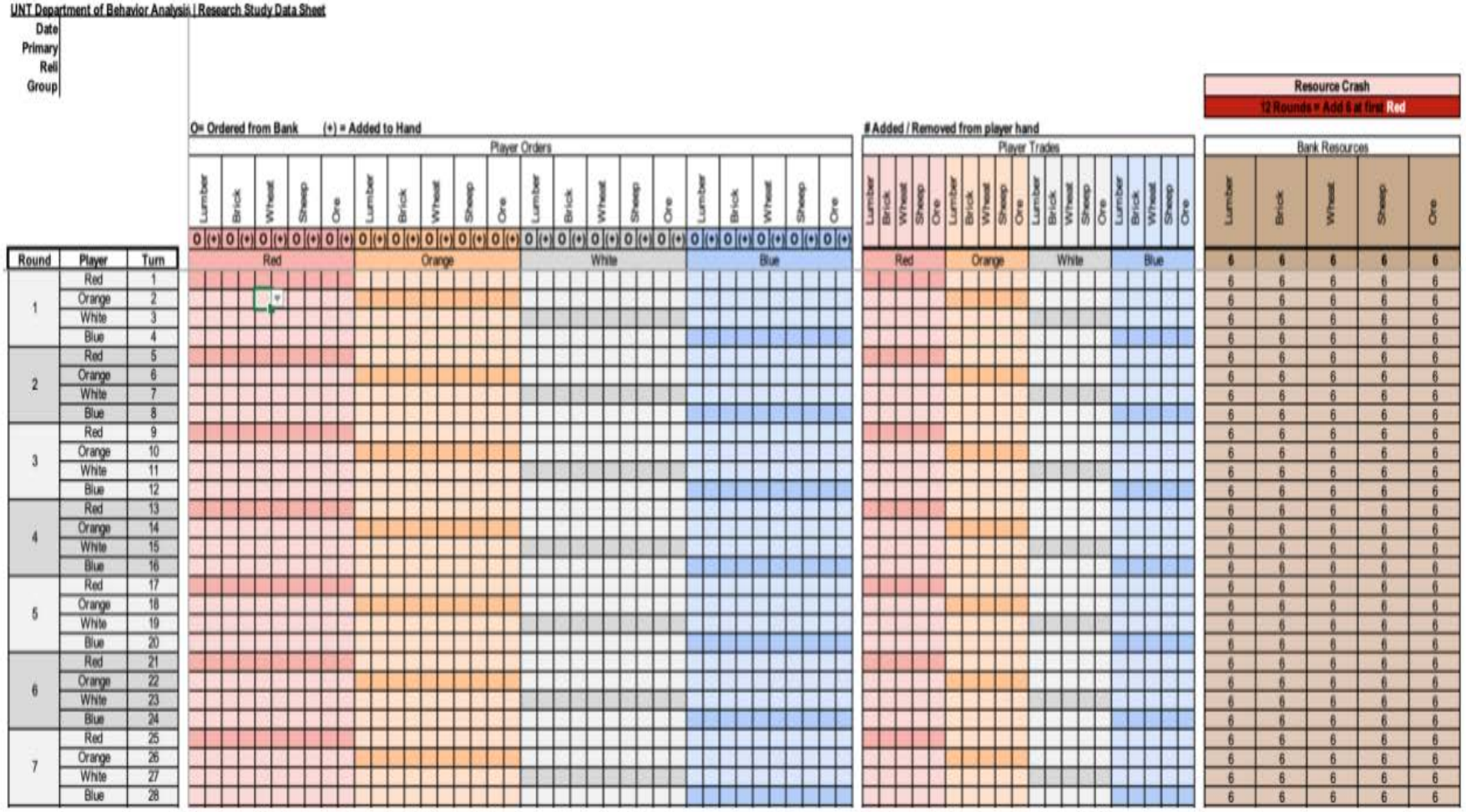
APPENDIX B

RED ACTIVATED RULES

PLAYER 1 : RED ACTIVATED RULES	
Roll	**Roll the dice for resource production.** ➢ See Rolling Rules
Trade	**"RED is going to trade ____ for ____."** **You may trade resource cards with the resource bank.** ➢ 4:1 trade ➢ See Trading Rules
Build	**"RED is going to build/buy _____."** **You may build roads, settlements, or cities and/or buy development cards.** ➢ You may play one development card at any time during your turn. ➢ See Building Rules
Play a Development Card	**"RED is going to play a development card."** **You may play 1 development card by placing it face up on the table.** ➢ If you play a progress card, follow its instructions. ➢ Remove the card from the game area once it has been used.
Call a Town Meeting	**"RED is going to call a town meeting for _____."** ➢ You can call a town meeting for your resource community or for the whole group. ➢ See Call a Town Meeting Rules

APPENDIX C

DATA SHEET


UNT Department of Behavior Analysis | Research Study Data Sheet
Date
Primary
Reli
Group
O= Ordered from Bank
(+) = Added to Hand
Player Orders
Added / Removed from player hand
Player Trades
Bank Resources
Resource Crash
12 Rounds = Add 6 at first Red
Lumber
Brick
Wheat
Sheep
Ore
Red
Orange
White
Blue
Round
Player
Turn

APPENDIX D

GAME PRIVACY SCREEN

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