SELF-GOVERNANCE IN A CPR GAME: AN EMPIRICAL ASSESSMENT OF ELINOR OSTROM'S EIGHT DESIGN PRINCIPLES

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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

Radical behaviorist B. F. Skinner proposed a question in 1987 that altered the way in which behavior analysts engage in research and applied services by asking why people are not currently acting to save the world. Of course, Skinner was discussing big picture issues focused on the destruction of human existence and depletion of natural resources due to nuclear war, but he acknowledged that problems of both greater and lesser intensity are connected to the processes by which communities of people behave in such a way that will either lead to the selection of sustainable or destructive cultural practices over time. Throughout history, individuals have assembled to collaborate on community practice-related problems such as sustainability, particularly as applied to resources shared and consumed by many. Behaviorists have yet to uncover the critical sets of variables leading to the preservation or conservation of shared resources, recurrently termed common pool resources.

A common pool resource (CPR) is defined as "a natural or man-made resource system that is sufficiently large as to make it costly, [but not impossible], to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom, 1990/2015, p. 30). Examples of common pool resources include fishing stocks, river water, irrigation canals, forests, and other shared land. Any resource that does not belong to or is not controlled by a sole individual is essentially considered a common pool resource, since the current definition for CPR is broad enough to capture a wide range of resources. The definition may need further modification in the future, since there are specific types of CPRs that hold more value to a community than others. Those who withdraw resources from the pool are labeled "appropriators," and those

who contribute to, manage, or take care of the resource are categorized as “providers” of the CPR (Ostrom, 1990/2015). These terms will be used throughout the paper accordingly.

Ecologist Garrett Hardin coined the phrase “tragedy of the commons” in 1968, referring to the disastrous effect human behavior tends to inevitably have on a CPR. Hardin first described the tragedy of the commons as a population issue, and then added that this is an individual multi-resource maximization issue as well, meaning there will continuously be too many people and those people will be interested in benefiting their own individual needs (Hardin, 1968), leading to depletion of common resources. Resource depletion is understood to be directly influenced by physical environmental factors, weak governance systems, individual overuse of the resource, and overpopulation in communities where the common pool resource is being used by too many individuals (Ostrom, 1994; Ostrom, 1990/2015; Atkins et al., 2019; Borba, 2019). Common pool resource depletion is more common than the average individual is likely aware of; world-Renowned political scientist, economist, and Nobel laureate Elinor Ostrom extensively studied CPRs throughout her career, and anecdotally stated that “hardly a week goes by without a major news story about the threatened destruction of a valuable natural resource” (1990/2015, p. 13). Though Ostrom’s statement may come across as exaggerated to some, the significance is that the tragedy of the commons is reasonably familiar to many individuals due to the amount of nonrenewable, slow to renew, and scarce resources shared by communities all over the world. In 2019, behaviorist Aecio Borba asserted that the tragedies can range in magnitude, from a small inconvenience to a catastrophic, complete societal collapse (Borba, 2019, p. 230). For example, a minor inconvenience would be an unproductive individual fishing trip whereas a catastrophic event might include a community

having to relocate or take control of population growth due to the fishing area being entirely destroyed from overfishing. Regardless of the magnitude of the issue, there are behaviors selected and reinforced over time that continue to cause these tragedies, and it should be the goal of a behaviorist interested in this phenomenon to analyze those selected behavioral processes, both individually and in terms of their interconnected functions on the cultural level.

Conservation of the commons is not just a behaviorist's problem to solve; in fact, it has been addressed more often by other fields including economics, ecology, anthropology, psychology, sociology, and biology. Behaviorists are just beginning to crack open the tip of the iceberg that is culture, and are doing so with caution because of the largely complicated and dynamic structure of cultural systems that are in place. Other fields have typically found little success in developing appropriate interventions because that is often not their primary aim, and because there is often a "preoccupation with 'inner man,' autonomous or mediational, [that] has interfered with the development of a functionally analytic approach that would specify the laws according to which environmental contingencies select, modulate, and maintain behavior" (Malagodi, 1986, p. 2) or according to which interventions may be designed. In order to develop interventions that can allow scientists to better "save the world," behavior analysis must attempt to understand these sustainability practices and self-governance systems through the lens of material observation and single subject/single-group experimental analyses of interconnected behavior. Within the field, there have been several researchers interested in resource distribution and self-government systems, including B.F. Skinner, E.F. Malagodi, S. Glenn, A. Borba, and others.

Despite these limitations, some important work and behaviorally compatible research

has arisen from cultural economists such as Elinor Ostrom, who devoted decades of research to common pool resources and self-governance systems built around those resources. These home-grown self-governance systems have proven to be, in some cases, either destructive enough to the resource that the system leads to societal collapse or so productive and sustainable that the resource and community has flourished for centuries. Accumulated research findings discovered by Ostrom and colleagues through retrospective assessment and empirical evaluations have identified common characteristics of successful CPR systems that may foster conservation of a common pool resource (Ostrom, 1992; Ostrom, 1994; Ostrom, 1999; Ostrom, 2006; Ostrom 1990/2015). Although not expressed in precise behavioral terms, these characteristics suggest interlocking behavioral contingencies (IBCs) between individuals that could constitute and/or maintain the behavioral contingencies that often lead to either sustainability or to the tragedy of the commons. Though Ostrom did not particularly define participant behavior in these scenarios as IBCs, it is clear that there are "interlocking contingencies of reinforcement in which the local behavior of participants is directly reinforced" (Glenn et al., 2016, p.13). and that can be measured by their aggregate product (i.e. the critical outcome of the interconnected behavior). Though one individual may be engaging in operant responses to receive a reinforcer independent of the aggregate product, the completion of their task or engagement in that operant response is critical to produce the aggregate product of CPR sustainability that produces selective continuation of the cultural pattern.

In 2019, behaviorists Lemos and colleagues analyzed the role of Elinor Ostrom's eight design principles within a self-governance system through case studies of the extractive reserves, or RESEXs, located in Brazil. The authors also developed a behavioral interpretation of

each of the eight principles and how they operate particularly within the context of the RESEXs. In an attempt to uncover the existing behavioral procedures and processes rooted in the self-governance principles, Lemos et al. (2019) dissected each principle in the context of Glenn's conceptualization of the culturant. The authors describe how interlocking behavioral contingencies between community members and government officials define two major aggregate products of the culturant in the RESEX context: the defined geographic and social boundaries of the CPR. Ultimately, Lemos et al. (2019) imply that these eight principles can be explored effectively through Glenn's framework, and Ostrom's principles in real word scenarios can be discussed and diagrammed behaviorally. Behaviorists must continue to conceptualize these principles further, and investigate how contingencies within these principles can be discussed within the field.

Also in 2019, Borba and colleagues discussed how a selectionist view of cultural practices and a behavioral understanding of ethical self-control may assist in answering societal questions about the overuse of resources by analyzing these behaviors within a metacontingency context in the Caboclos community (residing in the Brazilian Amazon) that values production and sustainability of açaí berries. While evaluating individual and group activities surrounding the common pool resource of açaí berries in the Brazilian Amazon, Borba found that it was useful to ask two questions, including (1) "Why does someone choose to behave in such a way that produces deleterious environmental effects for the group?" and (2) "Why are these [individual] contingencies in place?" (2019, p. 244). To answer the first, Borba suggests that current non-social and social contingencies of reinforcement decrease ethical self-control, and this can be analyzed at the ontogenetic level. To answer the second question,

Borba argues that the pressure to deliver an aggregate product of these resource units nationally or internationally can leave room for central governance systems to intervene on the self-governance system, and this should be analyzed at a cultural level. Borba (2019) looked at these exact features on a cultural level by examining acai berry distribution practices within a meta- and macrocontingency context in the Brazilian Amazon, and how crucial they are to the economy of these communities.

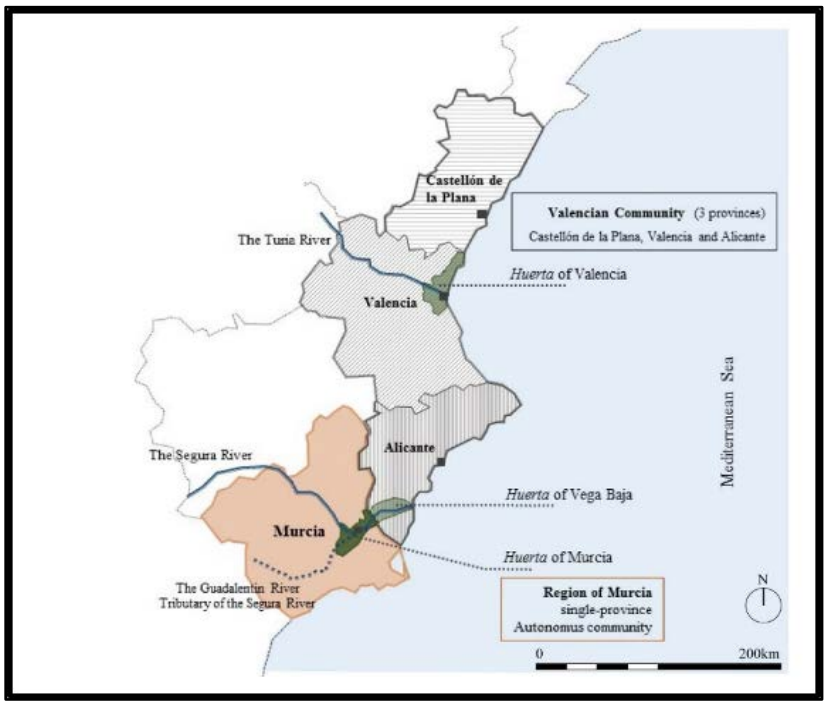
In 2016, behaviorists Camargo and Haydu investigated the behavioral dynamics of common pool resource appropriator self-management by empirically testing the effect of visual prompts and verbal feedback on the average consumption, available resources, resources extracted, and accuracy of instructions given from experienced players to newcomer participants within the context of an online common pool resource game called "Fish Market." The authors found that when visual supports were given to participants, their resource consumption remained high, but the CPR took much longer to crash completely at Round 54. When verbal feedback was given to participants, average consumption remained consistently low, and in this condition the CPR did not crash until the final round of the game (Round 63) compared to the control group that crashed the CPR at Round 30. Results from this study indicated that self-monitoring and feedback can support resource sustainability over time.

While these early studies are encouraging, none of the behavioral treatments of CPR management to date directly test Ostrom's eight principles, which are far more complex than the variables that have been investigated, and which suggest specific interactive structures in groups as particularly powerful for CPR self-governance. However, a great deal of work on the topic of CPRs generally and the eight principles in particular have come from Ostrom herself

and from researchers in economics and associated fields (e.g. Cox & Villamayor-Tomas, 2010; Ferraro & Agrawal, 2021; Ostrom et al., 1992; Ostrom, 1994; Ostrom, 1999; Ostrom, 2006; Ostrom, 1990/2015). An example of a well-studied CPR involves the irrigation systems located and shared among the Spanish cities of Valencia, Murica, Orihuela, Alicante, and Glick: one of the longest enduring common pool self-governance systems (Marti & Garcia-Mayor, 2020). Since this region notoriously receives very limited rainfall throughout each year, water is not an abundant resource in these communities. It is critical that each city receives water through artificial irrigation systems, called Huertas, in order to meet their basic survival needs, as well as for each city's "highly developed agriculture [that] would not have been possible without irrigation works bringing water to the farmer's fields" (Ostrom, 1990/2015, p. 51).

Figure 1

Regional Map of Spanish Huertas



The Turia and Segura rivers, which run through Valencia and Murica, are divided into 8 major canals which make up 16,000-hectare Huertas (see Figure 1). As irrigation systems were created to distribute water throughout these areas, resource distribution rules were established and modified over time. The self-governance system created in this region has lasted at least 550 years and Ostrom predicts this system has likely lasted closer to over a thousand years (Ostrom, 1990/2015, p.51).

In the beginning, these communities conceivably engaged in successfully interlocking behavioral contingencies (IBCs) that led to more predictability and stability of water in the region. Over time, Ostrom notes that more conflicts arose, leading to more widespread self-governing practices. When IBCs in one community failed to harmonize with IBCs in another, preventing effective communication or collaboration about local practices, conflict would have been likely since these communities shared the resource. Upstream communities had far different practices than downstream communities, causing the majority of the issues between communities, and eventually leading to an official meeting between eighty-four irrigators across the region to formulate regulations in 1435 (Ostrom, 1990/2015, pp. 50-51). Marti and Garcia-Mayor discussed how several intangible components have contributed to how the initial IBCs may have initially come to be, stating that "intangible components are an integrated part of the landscape configuration and management involving the following specific norms based on ancestral by-laws and regulations derived from Islamic law and traditions" (2020, p. 6). These intangible components also include overt behaviors within each community that tend to promote community trust, social cohesion, property structure, cooperation, and coordination. One community's intangible components may greatly vary from another, and Marti and Garcia-

Mayor describe how geographical terrain conditions can also keep communities in isolation from one another which has contributed to variances in both intangible and tangible components (2020, p. 17).

Farmers and irrigators in these regions, designated as common pool resource officials, have continued to consistently meet face-to-face to discuss resource levels across the region, including water allocation, to revise rules that have been in use when necessary, to select new officials as others step down from their position, to decide on assessments to conduct, and to determine appropriate sanctions for those who defect from the stated rules. The Spanish Huertas continue to be one of the most successful self-governance systems due to long-lasting organization of rules and commitment of officials to communicate and resolve conflicts face to face annually. As stated, rules are created and modified over time; the allocation of water ensures predictability of resources to downstream communities as an antecedent strategy to reduce conflict in the future.

Not all communities have created flourishing self-governance systems like the irrigators residing in the Spanish Huertas. Carrying capacity is a persistent issue within many communities, resulting in systems without clear regulations that still attempt to control population growth in unconventional ways. One example, according to the analysis of anthropologist Marvin Harris, is the cultural practices of the Maring tribe residing in New Guinea. Harris described the Maring as tribes of individuals that specialize in farming, as well as raising and capturing pigs (1974). The Maring have battled with the issue of carrying capacity for decades, which led to a phenomenon of engagement in systematic warfare to regulate population growth across Maring communities. Harris states that “as a result of warfare, local

groups are forced to abandon their prime garden areas at a point below carrying capacity" (1974, p. 70). The same selecting consequence that maintains this warfare could, under other conditions, maintain a CPR system that prevent the tragedy of their commons proactively and without violence. However, the Maring's development of reactive rather than antecedent-based cultural systems to fix their problem is not atypical. Cultural communities deeply embed their customs or practices over time, and these practices may be hard to change organically once adopted into the system.

In short, the field both inside and outside behavior analysis has established that communities of individuals will independently create systems that control for individual and group needs in regards to a common pool resource. These studies suggest that behavioral principles reside within Ostrom's principles, though the complexity of the subject matter has possibly halted progress of exploration of these design principles within an empirical and behavioral framework. With all of these compiled research findings and many others further advancing the world's knowledge of prosperous self-governance systems, it is critical that these design principles be empirically tested as a multi-faceted framework within a simulated common pool resource game context. A behavior analytic approach to assessing the effectiveness of Ostrom's principles could be used to uncover sets of variables critical to establishing and maintaining successful self-governing practices, as well as promoting enduring and sustainable common pool resources. Testing these principles on an experimental level may expose variables that may be valuable in the prevention of the tragedy of the commons scenario. It is the primary goal of the present study to operationally define participant behaviors that correspond with each design principle using behavior analytic terminology, and

then to directly measure the effect that the implementation of design principles, as game rules, has on resource levels and participant responses within the context of a simulated common pool resource game. The present study enters uncharted territory in the realm of CPR behavior analysis since the design principles have yet to be tested as a package in an experimental setting in any field of study to this point. In the pursuit to capture relevant data from a simulated common pool resource context, the present study will utilize a single subject/single-group reversal experimental design as well as an experimental adaptation of the board game Catan with a relatively "crashable" resource bank. The purpose of this paper is to empirically investigate individual and group responses as well as resource distribution when Ostrom's eight proposed principles are placed in and taken out of a common pool resource game. In the following section, the experimental procedures used to gather this data, as well as rationale for including the selected experimental conditions are further described.

CONVERTING OSTROM'S EIGHT PRINCIPLES INTO TESTABLE, BEHAVIORALLY SPECIFIC DEFINITIONS

In order to experimentally test these principles within an empirical and behavioral framework, they must first be operationally defined. It is the objective of the present study to convert Ostrom's principles into precise, testable, and behaviorally specific definitions and then to test and analyze the eight principles as a package in a simulated CPR game.

Ostrom organized collaborative group behaviors into eight different design principles in an attempt to create operational self-governing rules across settings, and these design principles ultimately offer the reader suggestions of broadly stated practices that could be utilized anywhere and with anyone (Atkins et al., 2019; Cox & Villamayor-Tomas, 2010). Though there are many distinct differences between various successful CPR-governing systems, there are also fundamental similarities. Ostrom derived these principles by analyzing similarities among enduring self-governing common pool resource institutions created by various communities, tribes, or other cultural systems around the world. They are described in Governing the Commons as "essential elements or conditions that help to account for the success of these institutions in sustaining the CPRs and gaining the compliance of generation after generation of appropriators to the rules in use" (Ostrom, 1990/2015, p. 90). The eight design principles are: clearly defined boundaries, environmental congruence of appropriation and provision rules, collective-choice arrangements, monitoring, graduated sanctions, conflict-resolution mechanisms, rights to organize (without governmental authorities restricting the self-governing system), and nested enterprises. Though there are eight explicitly listed, Ostrom argues that the first seven principles should be utilized across the board while the eighth

(nested enterprises) is reserved for resources that are a part of larger and more complex organization systems (1990/2015). The development of these principles was a step in the right direction, since many organizations that have historically failed to halt resource depletion have sought simply to punish or threaten appropriators directly rather than implementing short-term and long-term reinforcement for appropriators and providers to participate in sustained interactive practices that result in stability of the common pool (Skinner, 1987, p. 13).

In unpredictable environments, it is critical that a sense of certainty is fostered through a history of a consistently sustained CPR. These principles set up a system of participant interlocking behavioral contingencies and corresponding consequences that provide an organizational consistency that in turn leads to flexible adaptation in the face of changes. Ostrom discusses how these contingencies and the rationale behind them can keep discounting rates low for most individuals (1990/2015, p. 89). If individuals can communicate with one another and see the impact that their individual behaviors or interlocking behaviors have on the resource, whether that be through maintaining the baseline level of resource units available within the common pool or increasing that level, then individuals might be reinforced by this natural consequence. Over time, these principles tend to "affect incentives in such a way that appropriators will be willing to commit themselves to conform to operational rules devised in such systems, to monitor each other's conformance, and replicate the [common pool resource] institutions across generational boundaries" (Ostrom, 1990/2015, p. 89). In other words, these principles often set up or simply explicitly tact successful contingencies that offer short-term and long-term reinforcement to individuals that may change their behavior to sustain a common pool resource in their community. Ostrom is alluding to behavioral principles and

processes that can be put into place at any point in time to preserve these resources, but stresses that these eight principles are currently only derived from correlational data, so much empirical and theoretical research is yet to be done for them to be considered sufficient or necessary conditions to sustain a common pool resource.

Ostrom sequenced the order of principles in a seemingly strategic manner. The principles are arranged from broad to narrow, and each principle builds upon the last. There is not an eighth principle without the seven previous.

Principle (1): Clearly Defined Boundaries

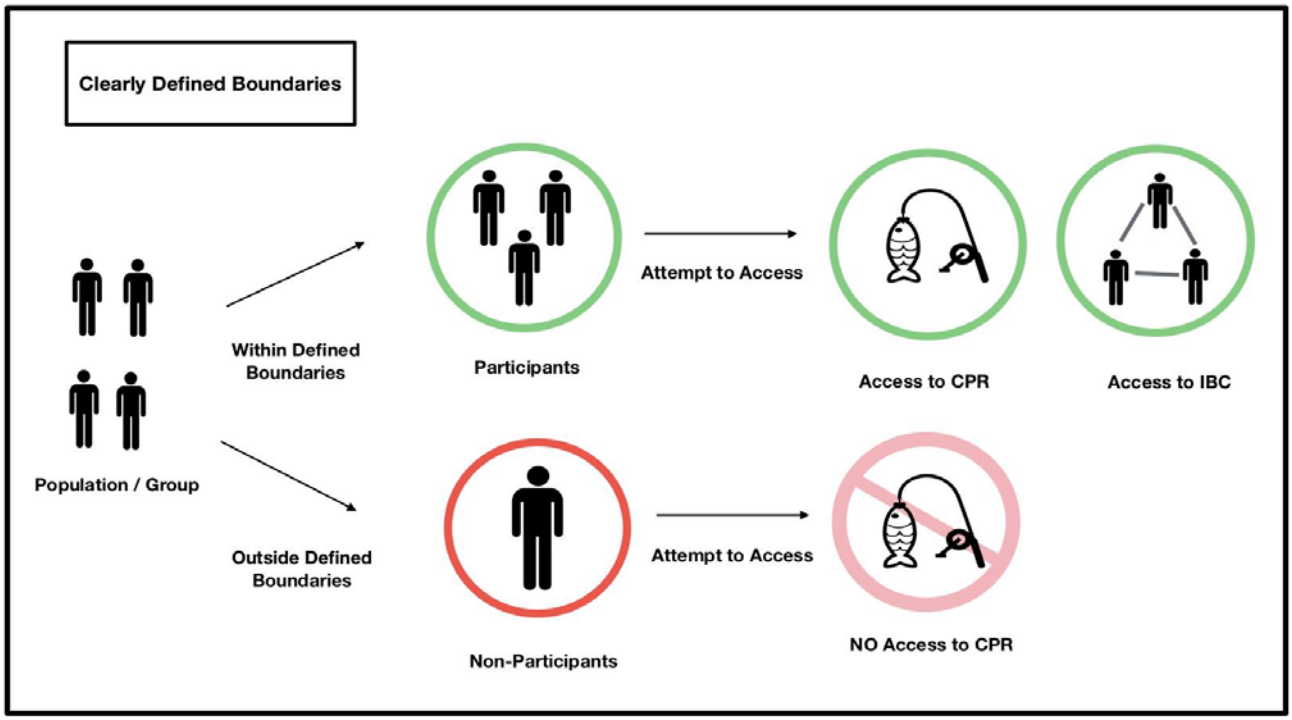
Ostrom established the first principle as clearly defined boundaries. If a population is to set up any system of rules regarding a common pool resource, they first must know who may participate in the resource provision and appropriation. This introductory step to a self-governance system delineates participants from non-participants of a CPR within a given population (Atkins et al., 2019, p. 32). In Ostrom's terms, engagement in clearly defined boundaries means that "individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself" (1990/2015, p. 64). Participants of the CPR set rules for appropriation and provision. From a behavior analytic perspective, categories such as these must be described in terms of the behavioral relationships that may define them. Ostrom's appropriation and provision rules establish contingencies, including discriminative stimuli and consequences for participant behavior.

In day-to-day life, individuals may see this in various examples such as applying for a hunting license or permits for land use/ownership in a given community. These behaviors in turn avoid punitive consequences for hunting or building behavior, which were contingencies

specified in the rule stimuli. Clearly defined boundaries could therefore be characterized behaviorally as a scenario in which differential contingencies apply across individuals such that appropriators, but not non-appropriators, access the resource via prescribed response patterns, and that effective stimuli exist signaling what individuals are included in these contingencies. Contingencies on non-appropriators may actively discourage access.

Figure 2

Diagram of Clearly Defined Boundaries



Principle (2): Environmental Congruence

Once a population's contingencies are differentiated for appropriators and non-appropriators, the participants of the CPR can begin to formulate more specific rules that pertain to the shared resource. As users of the CPR and often "locals" within the community, participants learn the boundaries of CPR in relation to the surrounding environment over time.

These boundaries might include how many people can withdraw from the CPR, how much can be withdrawn in consideration of the local environmental conditions, what time of year the resource is best harvested (if applicable), or how the local climate and setting factors should affect CPR access.

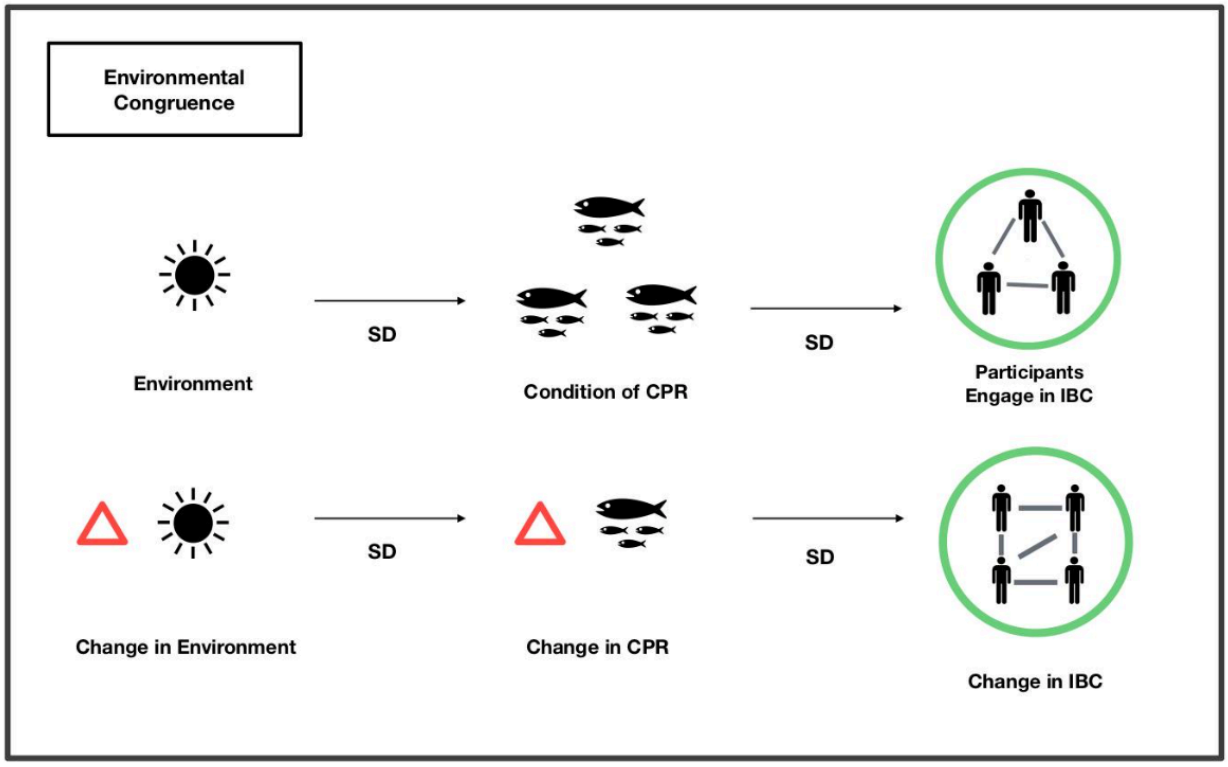
With Principle 2, environmental congruence of appropriation and provision rules, Ostrom emphasizes the need for community rules (contingencies) to fall in line with the natural, non-social demands of the resource, and to adapt with the resource to maintain such congruence if/when the CPR changes. More specifically, Ostrom states that the "appropriation rules restricting time, place, technology, and/or quantity or resource units are related to local conditions and to provision rules requiring labor, materials, and/or money" (Ostrom, 1990/2015, p. 65). The average behaviorist would agree with Ostrom; appropriation behavior (and the contingencies that control it) must adapt to match the CPR's environmental demands in order to produce sustainable outcomes; the environment should not have to (and probably can't) adapt to match contingencies put in place by individuals. Participant rules must adapt to dynamics of the environment, including resource variation and variation in participation or chains of behavior. Without this congruence, CPR rules (contingencies) will likely be detrimental to the CPR unless the participants change them. With congruence, the resource should sustain until/unless a new environmental change occurs.

Ostrom highlights the strengths of local systems via this principle; central governance systems – or any entity removed from close dealings with the CPR – may be less aware of the congruence of rules with the CPR environment. Individuals will likely see this principle on a day-

to-day basis in their local communities. The figure below illustrates the contingencies participants of the CPR must follow when abiding by this principle.

Figure 3

Diagram of Environmental Congruence



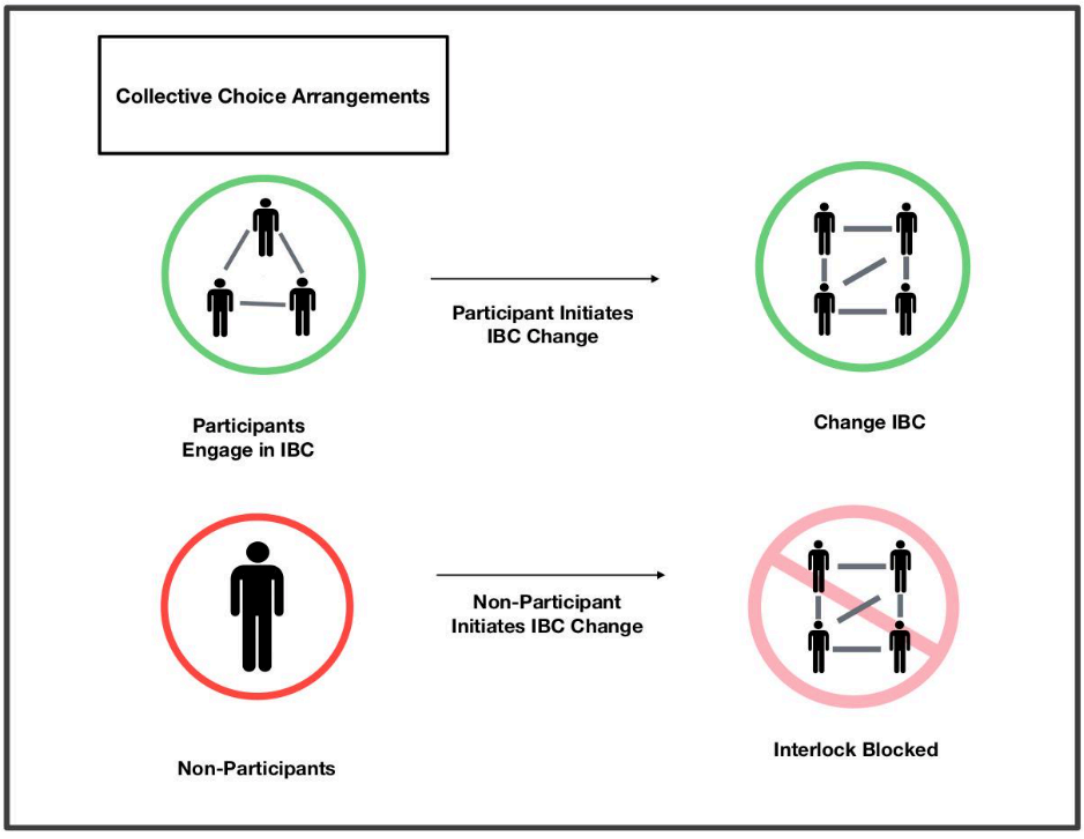
Principle (3): Collective Choice Arrangements

Once the groundwork has been set, the population has been split into participants and non-participants, and participants have created rules that align with environmental conditions, principle 3 can come into play. Now that there are established rules, and there is an understanding that these rules must be changed from time to time, it raises the question, who gets to change the rules? Ostrom's third principle is fulfilled if "most individuals affected by the operational rules can participate in modifying the operational rules" (Ostrom, 1990/2015, p.

65). Broadly, if a participant's behavioral environment is affected by the rules (contingencies) put in place, then that same participant can submit a request to change the rules. Behaviorally, participants whose appropriation behavior is governed by a set of rules (contingencies) that apply to the CPR can interact with other appropriators and/or providers, which can lead to re-defining or removing 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.

Figure 4

Diagram of Collective-Choice Arrangements



This principle permits all participants to gain control of rule modifications to some extent, creating widespread feedback from appropriators (2015, p. 65). Ultimately, there must

be an attempt to secure “fair and inclusive decision making” between all participants involved with the CPR (Atkins et al., 2019, p. 32). For example, this may look like hunters in a local community meeting to revise hunting rules.

Principle (4): Monitoring

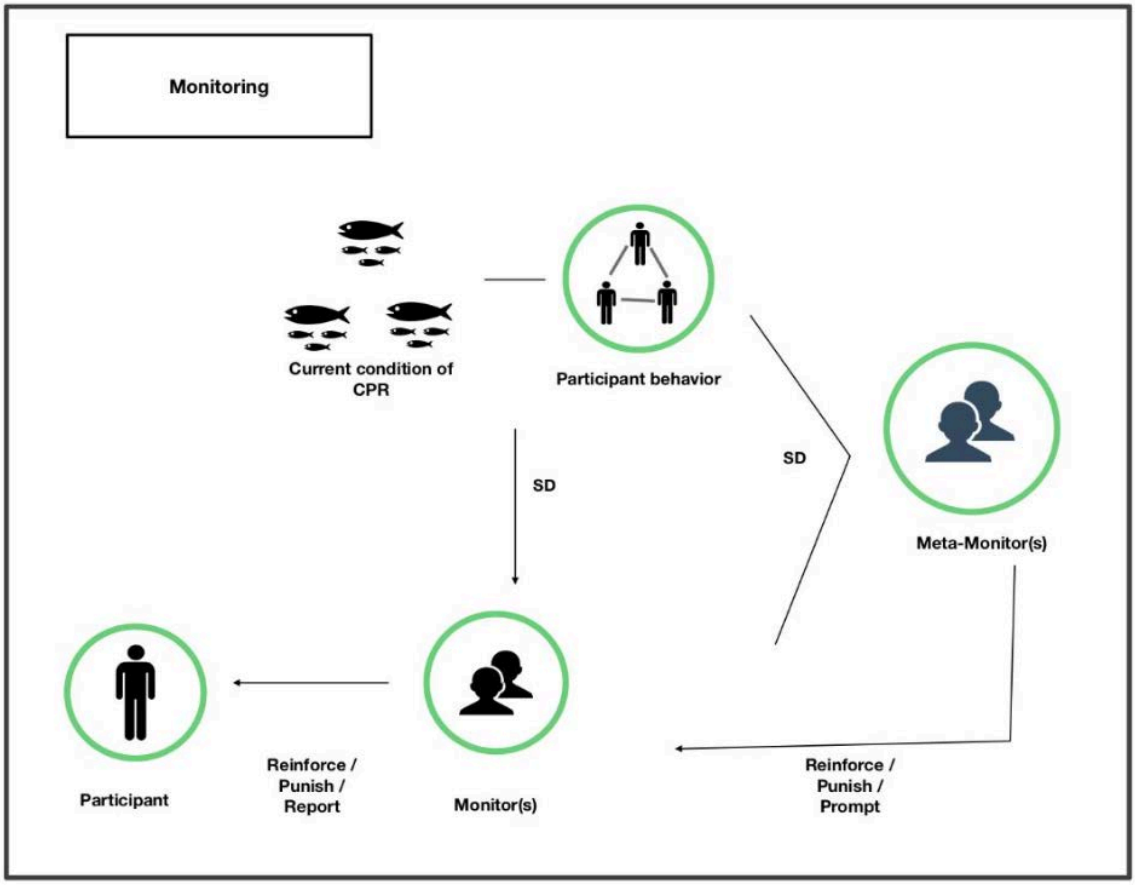
Ostrom next introduces the role of monitors, and explains that the “monitors, who actively audit CPR conditions and appropriator behavior, are accountable to the appropriators or are the appropriators” (Ostrom, 1990/2015, p. 66). Though Ostrom does not expand on this principle in Governing the Commons other than to provide a simple definition, it is clear that the role of the monitor and possibly any other meta-monitors are left fairly open-ended for each community to define further. The only established standards for this role specified by Ostrom are that the monitor observes the condition of the CPR and are often the appropriators themselves and liable for the way in which appropriators behave.

In behavioral terms, the monitor could be defined as participants that observe, report and/or consequate the individual responses of other participants and changes in the CPR’s condition (amount of resources currently available in the CPR). The monitors can be selected participants within the group or the entire group. If the CPR is large enough, observation is verified by at least one independent observer. In some cases, participants that choose to observe and report other participant’s behavior during each cycle can choose to submit an anonymous written verbal report to the group. In both real-world scenarios and experimental scenarios, observing and reporting can look like vigilante monitoring, third party monitoring, punch-in/punch-out cards, or verbal reports.

In forest CPRs where communities hunt, monitors may have various titles like “park rangers” or “game wardens.” Monitors are often rewarded for their duties that protect the CPR, and can just as easily be punished for not completing their duties. The monitor may be the “glue” that holds the whole system together, but not if these individuals engage in rule defections or observer drift. The diagram below illustrates the contingencies in places between the environment, participant behavior, monitor and meta-monitor behavior, and individual sanctions or rewards.

Figure 5

Diagram of Monitoring



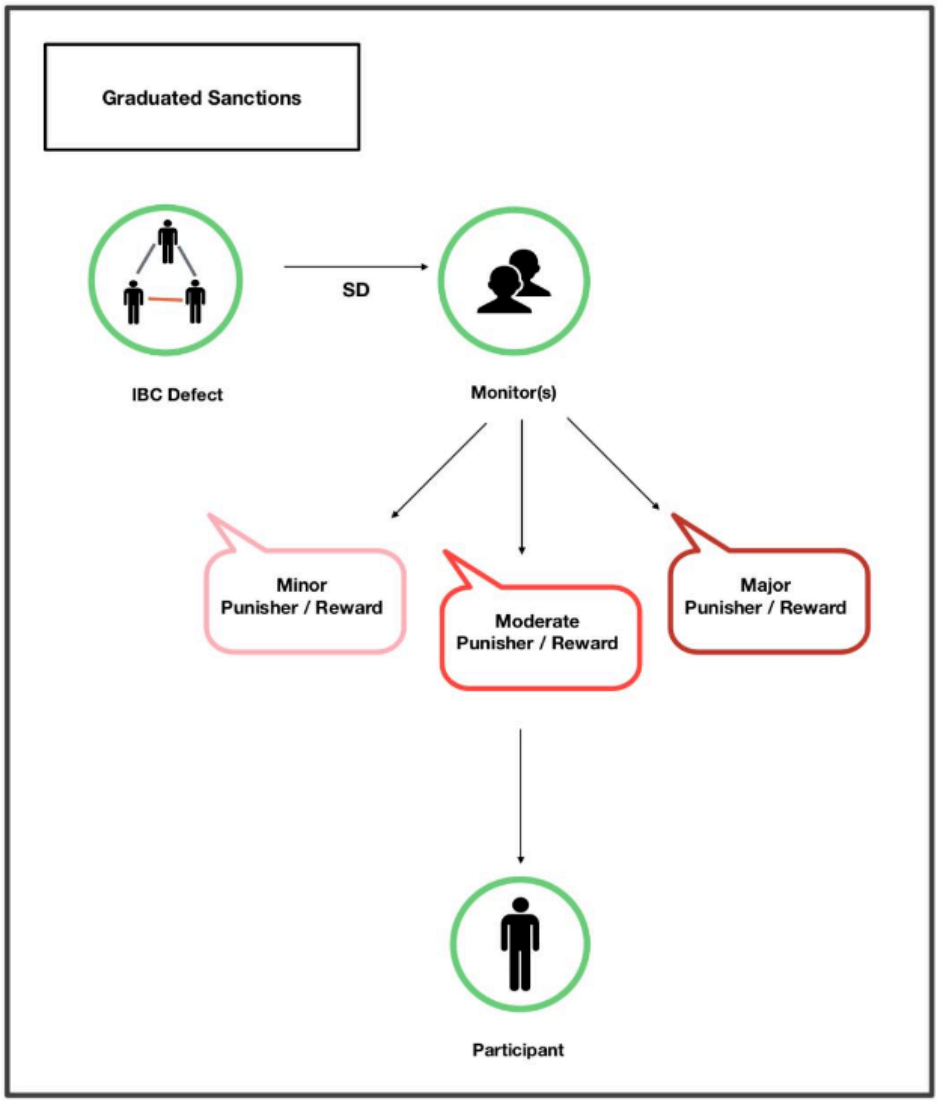
Principle (5): Graduated Sanctions

Once there is a monitor who can respond to IBC or rule defections made by participants, Principle 5 comes into play: a system of sanctions must be created to fairly match each defection. Ostrom states that with Principle (5), "appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both" (Ostrom, 1990/2015, p. 66). Furthermore, Ostrom specifies that graduated rewards can also be established with the system in order for the monitor to differentially reinforce participant behavior.

This principle can be behaviorally defined as the provision by participants of reinforcement and punishment contingencies for following rules and/or defecting. Participants who defect receive an appropriate level of punishment. These levels are decided by the group and each level of punishment or reinforcement is progressively severe. For hunters, it may be common for those that defect from rules or typical interlocks to face consequences that amplify in severity. For example, a first time minor offense could lead to paying a fine or having a suspended license. However, as defections intensify or multiply by a single individual, the offense could lead to a permanent loss of license or imprisonment. In the real-world example of land ownership, graduated sanctions might look like an individual first getting a violation notice, then paying a fine if it occurs again, and lastly losing land. In laboratory settings, players in a CPR game will often use verbal chastisement and other costly sanctions related to the game, such as giving up simulated money or tokens as a fine or penalty (Ostrom, 1999; Cox & Villamayor-Tomas, 2010).

Figure 6

Diagram of Graduated Sanctions



Principle (6): Conflict Resolution Mechanisms

Behaviorists are no stranger to the concept that any system that relies on punishment and other coercion is not likely to endure or benefit participants long-term and is likely to produce countercontrol (Sidman, 2001). If a system does not build in a way for its participants

to systematically engage in counter-control mechanisms, the participants will find ways to do so unsystematically and in a manner that may undermine the system.

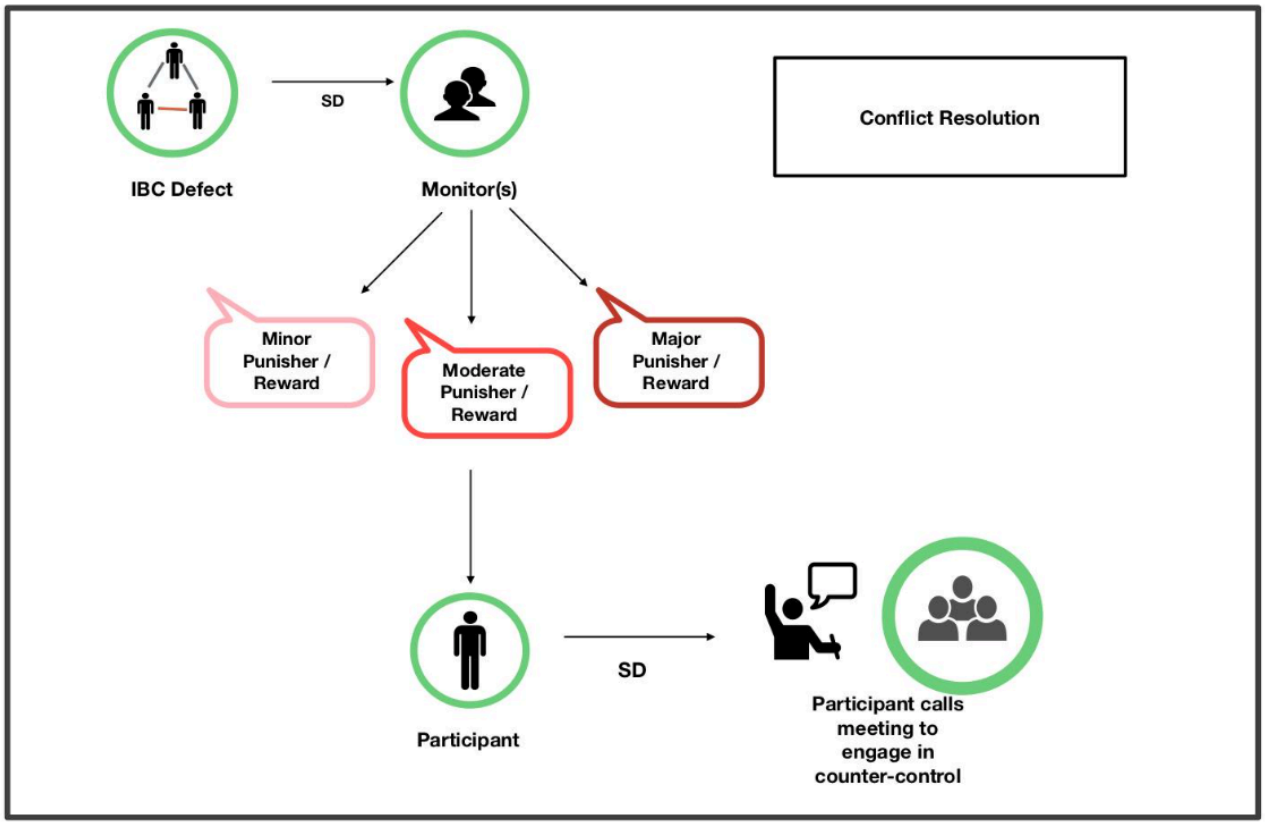
Ostrom agreed with this notion, as she included conflict resolution mechanisms as principle six, stating that "appropriators and their officials [must] have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials" (Ostrom, 1990/2015, p. 69). Embedding these countercontrol mechanisms within the system allows the participants to independently defend any of their behaviors within limits; this is a practical solution to include when punishers are likely to be in regular physical contact with participants, which provides many opportunities for undesired forms of countercontrol. Defined in behavioral terminology, this principle specifies that participants can counter-control by calling a meeting with the group and verbally defending their alleged defection against the rules; counter-control in this setting may look like a participant pausing the experiment to vocally explain why they defected or bargaining for less or no punishment. Participants can also error-correct (e.g., return excess resources or otherwise make up for the offense) to avoid sanctions by way of these meetings.

In many real-world common pool resource scenarios, including forest CPRs that allow hunting, conflict resolution mechanisms often look like an individual attending court, submitting evidence, or stating an alibi. Individuals with a history of consistent rule following may have greater sway in these circumstances. Individuals may also utilize these structures to protest if they regard a rule as unjust for their current circumstances. This is seen in laboratory settings as well, where the participant within a group communicates to all other available participants about their rationale behind the interlock defection, and the individual may or may

not error correct in those situations if allowed by the group (Ostrom, 1999). The group may agree with the individual and dismiss the sanction, or the group may disagree and hold the sanction in place for that individual to contact.

Figure 7

Diagram of Conflict Resolution Mechanisms



Principle (7): Right to Organize

The world as people currently know it is split into territories and nations that possess a group of authorized participants to govern the defined area. Many common pools reside in or are dispersed throughout smaller communities within these nations or territories. Ostrom has spent much of her time in research studying central versus polycentric governance systems and warning people of the first type due to the often coercive nature of central governance systems

(Ostrom, 1994). The authorities of the governance system external to that of the common pool are not appropriators or provisionaries of the CPR. These external authorities may oversee participant interlocks and resource levels across several CPRs in a given region. However, Ostrom warns that effective self-governance seems to require that external authorities not interfere with the CPR self-governance system, as those who do not participate on a day-to-day basis will not always make the best decisions that benefit the CPR as well as the communities that participate in its appropriation. Ultimately, implementers of rules and rule changes being local rather than by a central governance system is a major advantage for CPR sustainment. Local implementers may know the limits and boundaries of the CPR more than a central governance authority might, due to the local implementer's proximity and history of appropriation from the CPR. Rules and controlling agencies can govern and organize human behavior by explicitly stating clear contingencies for individuals within a group to follow, but too many controlling agencies can create coercive control over human behavior (Skinner, 1953, p. 334; Sidman, 2001).

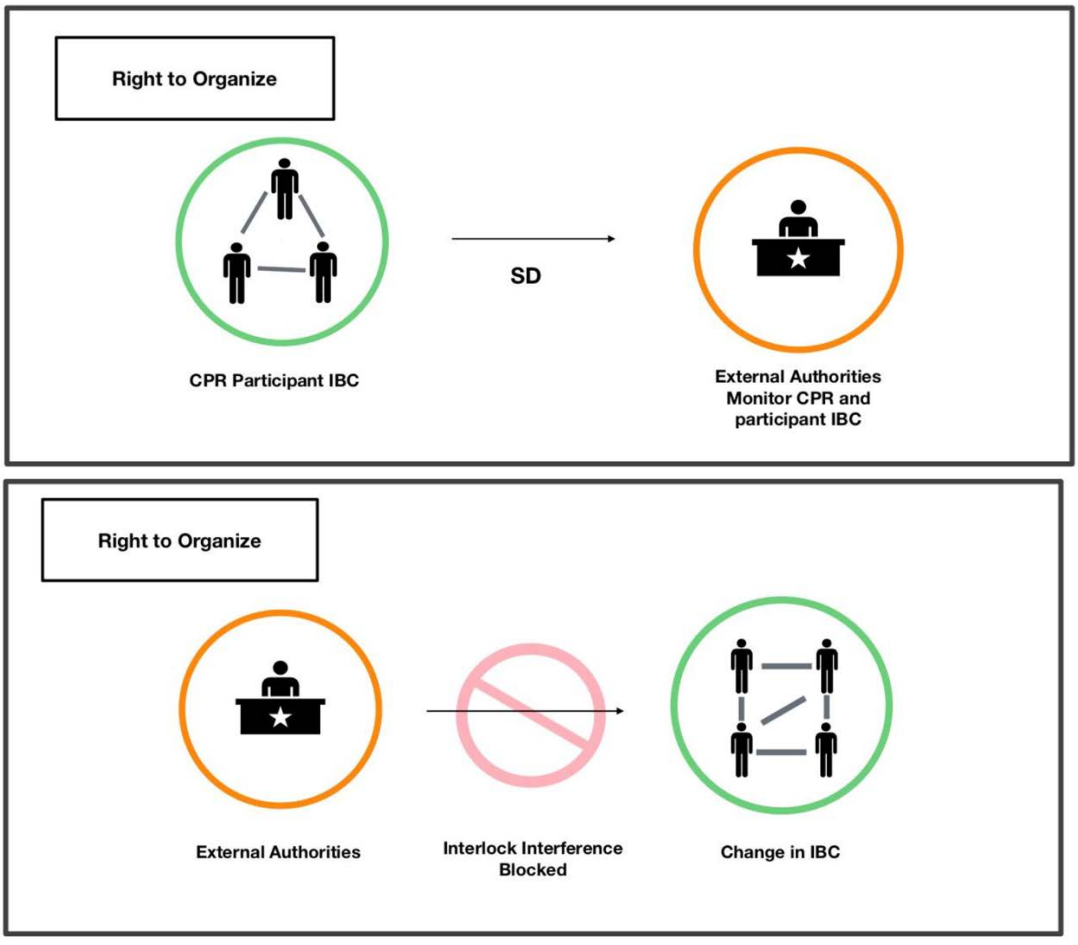
Principle seven was introduced to specify the role of the external authority in the self-governance system. Ostrom keeps this definition simple by stating "the rights of appropriators to devise their own institutions are not challenged by external governmental authorities" (Ostrom, 1990/2015, p. 69). The behaviorist might define this operationally as external authorities, or those who do not participate but oversee and/or set contingencies other aspects of participant behavior (unrelated to the CPR), do not deliver CPR-related consequences to participants or modify contingencies set up by participants. This principle essentially blocks all interference with self-governance rules and locally successful interlocks, as interference by non-

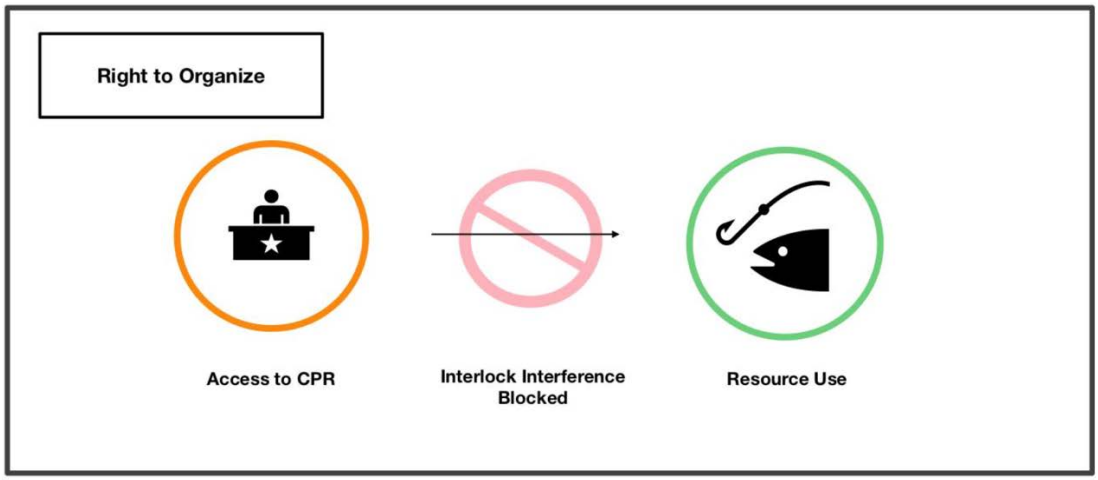
participants can be detrimental to the long-term sustainability of the self-governed CPR.

This is seen in the real world where local authorities meet with external authorities to define their restrictions. In many cases, these meetings set up scenarios where the central Government cannot suddenly step in with any new restrictions, because if they do this can offset the balance of CPR. In laboratory CPR games, the experimenters are often the "external authorities," and are allowed to oversee participants changing rules but are unable to modify participant rules so long as these modifications correspond to the general game rules and utilize the game materials given to them (Ostrom, 1999).

Figure 8

Diagram of Right to Organize





Principle (8): Nested Enterprises

Common pool resources come in all shapes and sizes, which includes resources as expansive as an ocean, shared amongst several continents. The Indian Ocean, for example, lies between Australia, Asia, and Africa, and houses resources that billions of individuals surrounding it must share. Such a CPR may be shared amongst multiple territories that rarely get a chance to communicate with one another but must depend on each other for future survival. For common pools that have outgrown independent community systems, Ostrom suggests the construction of meta-systems, or what she describes as "appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities [that] are organized in multiple layers of nested enterprises" (Ostrom, 1990/2015, p. 69). Since this principle only applies to CPRs that are a part of larger and/or more complex systems, nested enterprises may not be included in as many self-governance systems as the other seven. However, systems that may require deeply rooted nested enterprises allow for a considerably more effective balance of control and ultimately a more successfully sustained CPR (Ostrom, 1994).

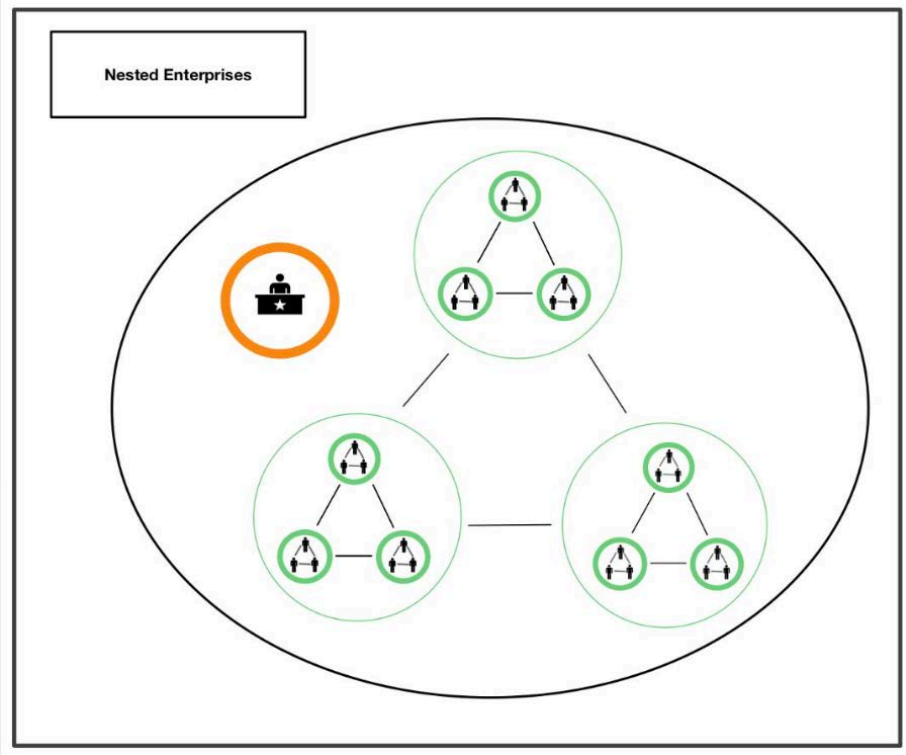
Behaviorists may define nested enterprises as several conditionally contingent

consequences for IBC's relevant to local conditions that exist amongst cumulative groups of individual participants. In other words, at least some members of nested CPR systems must interact across CPR systems, coordinating in a manner similar to individual appropriators within a single CPR.

An example of this principle in hunting communities is the inclusion of local, regional, and national levels of protection for the forest as well as the animals and other organisms residing in that forest CPR. In laboratory experiments, nested enterprises might look like multiple groups of participants using the same CPR, and those groups are allowed to set up a system of organized layers to communicate amongst groups between group members (Ostrom, 1999).

Figure 9

Diagram of Nested Enterprises



Principle (9): A Hidden Principle?

Behavior analysts can recognize that Ostrom has carefully assembled a skeleton of self-governance principles that correlate with common interlocks of prosperous CPR communities, however her description relies heavily on the structure of rules. Once we suggest behavioral definitions for the principles, their reliance on a backbone of embedded behavioral contingencies – whether or not these contingencies are stated or signaled as rules - seems apparent. Even without explicit rules, unspoken but clearly signaled contingencies could still function effectively to instantiate the principles. I therefore suggest that Ostrom's paradigm contains a hidden ninth principle: rules of a community, whether officially stated or not, reflect real contingencies followed by the community. This is important since any stated rule could potentially fail to reflect (or even to contradict) real practice, in which case they cannot fulfill the principles.

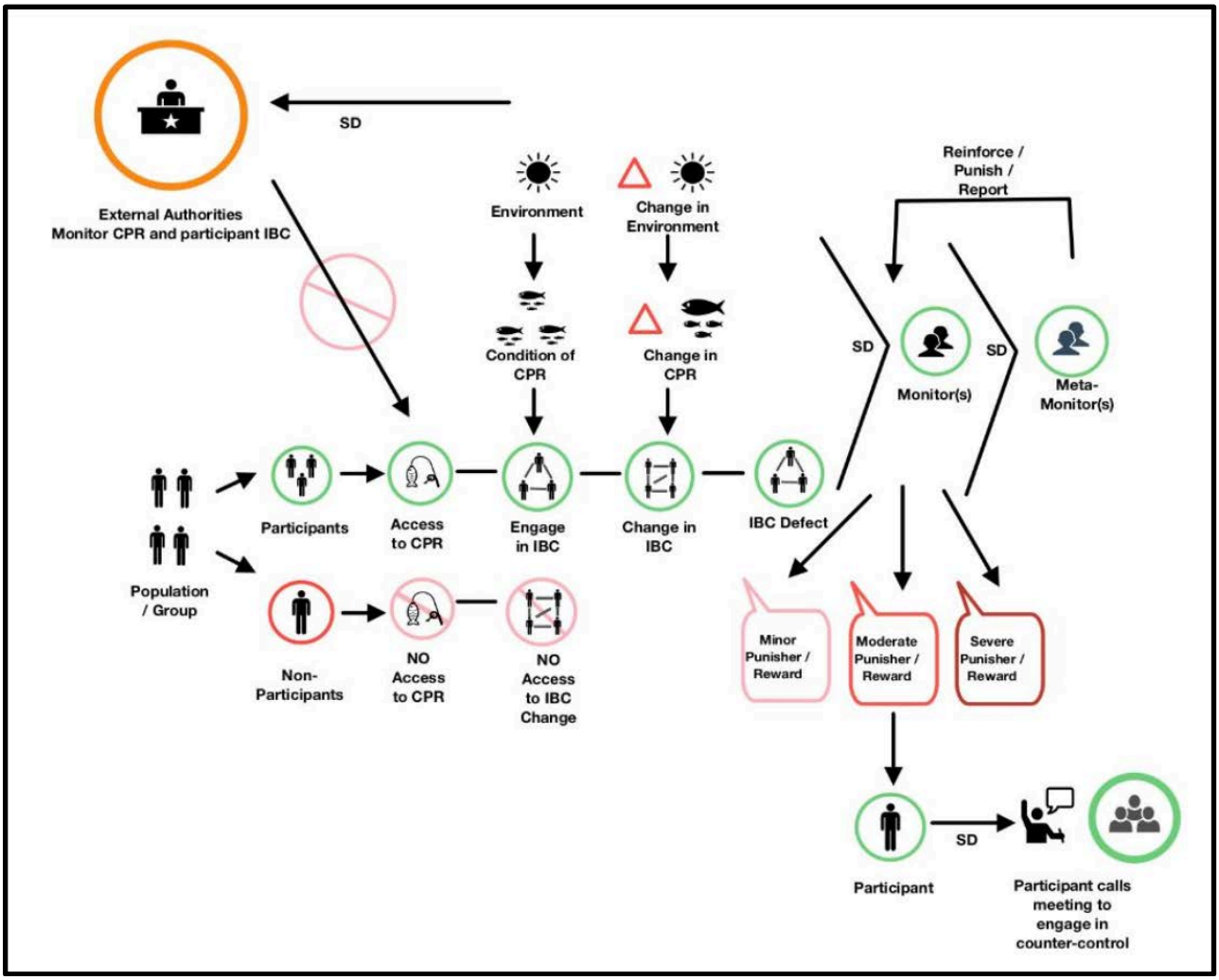
This concept aligns with what Andronis has explored through his research with rule-governed behavior. Andronis stated that "in most instances where rules are said to govern specified classes of behavior, those behaviors may nevertheless occur and be reinforced without the rules' having been given in the first place – this is certainly true of the various experiments on rule-governance reviewed by Chase and Danforth, and it is probably generally true of all situations in which rules are said in some way to 'describe' existing contingency relations" (1991, p. 2). While rules and defined principles allow for individuals to be held accountable for sustainability practices, it is often the case that most individuals are behaving in a particular way to protect the CPR before explicit rules are even tacted by the community.

Altogether, seven of the eight principles can be combined within a single diagram to

visualize these interlocking behavioral contingencies working in conjunction within the same system as a skeleton might. If a principle were to be removed or interfered with, the IBCs and ultimately the sustainability of the CPR will inevitably be affected.

Figure 10

Diagram of the Hidden Ninth Principle



These interpreted behavioral specifications of Ostrom's 8 principles provide a testable independent variable that can be arranged according to their defining properties across both natural and model social contexts. A thorough test of the principles should include multiple

experiments that vary the context and non-defining properties across which the principles may or may not show efficacy. We begin by translating these principles in the context of a tabletop board game that models a CPR social context.

METHOD

Participants

Participants for the present study were 12 adults, including 4 students of the University of North Texas in Denton and 8 non-students, ranging in age from 24 to 32 years old. All participants had no reported formal intellectual or developmental diagnosis, all exhibited clear verbal proficiency, and all demonstrated the ability to follow complex game instructions. Each of the participants individually and independently agreed to read through a consent form given by the researcher before the experiment began, and were allowed to withdraw involvement at any time. All procedures utilized in the present study were approved by the University of North Texas Institutional Review Board (IRB #22-470).

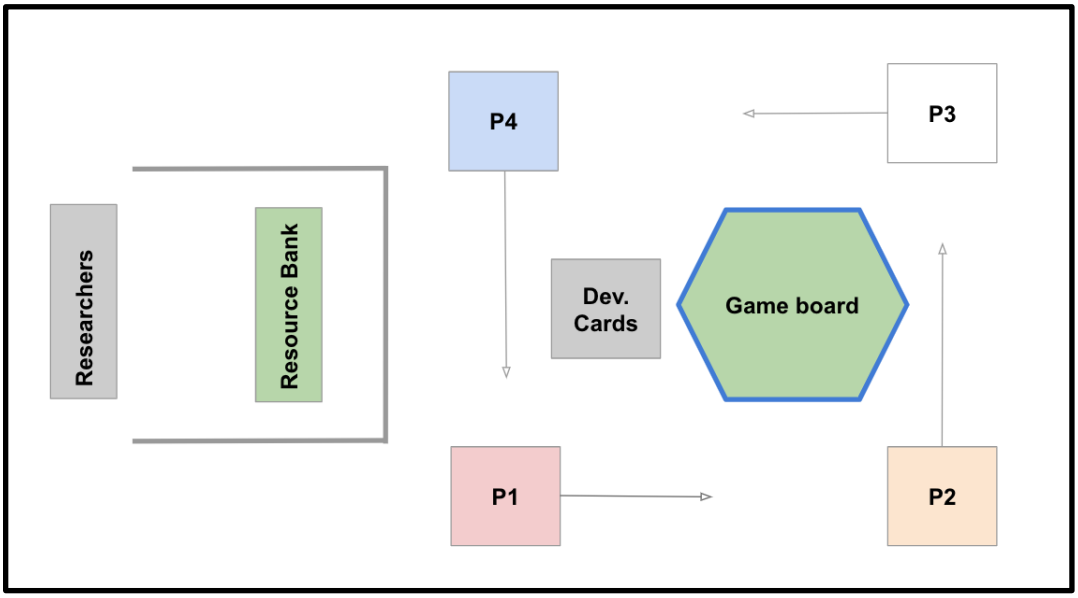
Subjects for the present study were recruited through laboratory and classroom announcements, flyers (on free public use posting locations), social media announcements (via UNT-affiliated social media entities), word of mouth, and SONA (a system utilized at UNT that enables research participation for class credit). Students were not recruited from classes taught by members of the research team. If recruiting via SONA, students received one SONA credit for every 30 minutes of participation in this study. Recruitment of subjects largely took place at the University of North Texas within classrooms approved by professors, department billboards on campus, and through university online presence. All individuals that are not undergraduate or graduate student participants as well as students that are not offered SONA credit were notified that no compensation will be given to participants for participating in this study.

Setting

All experimental sessions were conducted in the conference room within the Department of Behavior Analysis at The University of North Texas in Denton, Texas. The conference room was set up with a large rectangular table, several adjustable desk chairs, a "data collector booth" where two research assistants comfortably collected data throughout the entire session, and game materials set up as in Figure 11. Light snacks and refreshments were also provided to participants within the conference room near the game materials.

Figure 11

Diagram of Setting and Experimental Arrangement



Materials

The experimental materials consisted of game pieces from the commercial board game "Catan," individual rule booklets with control and experimental rule cards, sixty trading tokens, a cardboard resource bank barrier (providing a visual block so that participants could not see the bank), individual consent forms, and a pencil and paper for each participant. The Catan

game pieces used were the 6 terrain hex border pieces, 19 terrain hex tiles, 18 circular number tokens, 190 total resource cards (two decks from two full game sets), 22 development cards (progress cards and victory cards decks from two full game sets), 4 building "cost cards," 16 cities (four of each color), 20 settlements (five of each color), and 60 roads (fifteen of each color). There are four total colors (red, orange, blue, and white), one for each participant; the participants used these colors as self-labels when ordering or trading during their turn in order to protect individual privacy (e.g., "Red would like three ore").

Figure 12

Image of Catan Complete Game Board and Game Pieces

Procedure

The experiment begins by four participants meeting the researchers as well as the rest of the group of participants at the University of North Texas. The researchers then asked all four participants to sit at the table and walked the group through the rules of the modified

version of the game Catan. Since there are two sets of rules for baseline and experimental phases, each group only learned the rules of the condition they were beginning with. For Groups 1 and 3, this was the control condition rules, and for Groups 2 and 4, this was the experimental condition rules. The participants were also informed that a rule switch would occur a few times during the game and that the researchers would let them know the new rules when the condition switch was made.

The experimental version of the board game Catan simplified the overall standard game and modified it to simulate a common pool resource context within a board game setting. Unlike normal Catan, the experimental version allows anyone who earns more than eight victory points to personally win, removing the zero-sum competitive aspect of the game. All rules were handed to participants on a rule sheet and read to the participants (see Appendix). Each participant was first informed of all game rules before it began as a group. The researchers then offered practice rounds before the game started so that each participant was fully informed of the rules and engaged in correct game moves without consistent prompts from the researcher. Participants were expected to play the game for roughly three hours, or 19 total game rounds, at which time the researchers ended the game. Participants were explicitly told how long they would play the game for, but were not informed of the amount of rounds that were going to be played total or for each condition. Participants were instructed of all condition changes throughout the game as they were occurring, with an extra practice round added when the condition switched. All practice rounds were ignored by data collectors and the game was reset to the original board, resource bank, and individual hands for the initial round of that condition after practice rounds were held.

Participants each engaged in one session which lasted up to three hours in total duration. A single game was played over the course of the single session, with a total of 19 rounds or 76 turns. Participants interacted with the researchers upon entering and only interacted with other participants when instructed to by the rules given to them. The researchers notified participants of any changes or breaks throughout the study. Each participant was allowed to request a break at any time during the study and was provided with two scheduled 10-minute breaks, snacks, and refreshments throughout the study visit; all participants are informed of this in their consent forms. This research experiment was considered completed after four different 4-person groups of participants have undergone the present study.

Independent and Dependent Variables

The independent variable that was manipulated in this experiment was the game condition. Two game conditions were played within a single game: control game rules and experimental game rules. The experimental game rules added extra game rules onto the control game rules. These new rules implemented Ostrom's eight design principles for sustainable self-governance of a CPR. For Groups 1 and 3, the order of conditions was control-experimental-control. For Groups 2 and 4, it was experimental-control-experimental. Game rules for each condition are described in more detail below [see Experimental Design and Appendix].

The dependent variable in the present study was the endurance of the common pool measured by resource levels each turn and each round. The resource bank initially consisted of six of each of the five resources (lumber, ore, brick, wheat, wool,). On each turn, data collectors

recorded the number of resource cards in each stack as well as the individual number traded to and ordered (requested) from the resource bank. These dependent variables were chosen so that experimenters could analyze whole-group resource consumption and exchange as well as individual participant appropriation and provision responses. Participant orders were tracked in addition to the number of resources the participant actually took (the former could have been larger than the latter) because participant orders captured attempts to overfish from the resource bank once it had been depleted.

Experimental Design

This study utilized three counterbalanced reversal replications in ABA and BAB reversal single-subject designs (see Table 1).

Table 1

Experimental Design Groups

Condition	Moves per Turn	Rounds
Control (A)	Base Moves: • Roll • Trade • Build • Buy Development Card	Study 1: ABA: Round 1-6; 14-19 Study 2: BAB: Round 7-13 Study 3: ABA: Round 1-6; 14-19
Experimental (B)	Base Moves Call a Town Meeting • Sue the Monitor • Modify Reward/Sanctions Monitor • Rewards/Sanctions • Access to resource level	Study 1: ABA: Round 7-13 Study 2: BAB: Round 1-6; 14-19 Study 3: ABA: Round 7-13

These designs were applied to the single interacting group, which is the "individual" in our analysis. Two groups completed an ABA design and one group completed a BAB design. There

were two conditions during the study: baseline condition and experimental condition. In the baseline condition, participants played the modified base game of Catan as instructed. In the experimental condition, participants were given additional game rules that tie back to Elinor Ostrom's eight design principles; these additional game rules implemented a resource/rule monitor, game related rewards and sanctions, and the opportunity to communicate by "holding a town meeting" with certain participants. Four total groups completed the study. The BAB and ABA groups each switched conditions on the same round of the game.

Baseline Rules

The baseline game rules are as follows. The object of the game is to gather a minimum victory points, which can be earned by building settlements or cities on the board or playing victory point development cards. Both building and earning development cards requires resources. The game begins with the resource bank set to 30 resource cards total, six of each of the five different resources (lumber, brick, wheat, wool, and ore). The participants randomly select a seat that is assigned a game color (red, orange, white, or blue). The game board is set up with two settlements and two roads for each player, set initially in the same spot for all 4 groups (e.g., "red" in Group 1 has two settlements with a road connected to it on the same place as "red" in Groups 2, 3, and 4). The board and resource bank are set up exactly the same at the beginning of each session. Red will start the game by completing their turn first, then orange will go next, followed by white and blue. Each participant will be offered the same four moves each turn they get. Each participant gets one turn in a single round, so a round consists of four turns total. In a single turn, participants may follow 4 moves (the last 3 are each optional) in order: (1) Roll the dice, (2) Trade resource cards with the resource bank, (3)

Build/put a game piece on the game board, and (4) Play a Development Card. The players must roll the dice each round but get to decide if they can or will make the other three moves.

Roll

Once a player rolls the dice, the number rolled corresponds to a number on one or two terrain hexes on the game board. Any participant with a settlement placed on the corresponding terrain hex can request up to three resource cards from the bank that are produced by that terrain hex (e.g., If two threes are rolled, the players will look for a six on the board. Six corresponds with a Hills terrain hex towards the bottom of the board, which produces the resource of wheat. Since Orange has a settlement on that particular terrain hex, they can request anywhere between zero to three wheat resource cards from the resource bank, regardless of whose turn it is.) Any participant with a city (worth double the victory points as a settlement) placed on the corresponding terrain hex can request up to six resource cards from the bank that are produced by that terrain hex. If a player rolls a seven, nobody will receive resource cards during that turn since a seven corresponds to the desert terrain hex, which produces no resources in the game.

The resource bank, or the common pool resource within the game, is hidden from participant view throughout the entire game. The participants are unable to see when a resource runs out within the bank. Since the bank starts with thirty cards total, or six of each kind, a resource will be considered “crashed” once it is depleted to 0 cards. Ultimately, if players choose to overfish cards from any of the resources, the resource can crash within a single turn. Once a resource is crashed, it remains at 0 for twelve player turns at which time it is replenished back to six resource cards. At the end of each round, experimenters grew the

resource by adding resource cards to each resource at a 3:1 ratio. For every three resource cards of each of the five resources in the bank, one is added. The higher the amount of resource cards, the larger the resource growth is by the end of the round. The players are unable to communicate about the game during the baseline game rules, so any verbal interlocks that may form are not through emitted vocal verbal behavior of the participants.

Trade

After the player rolls the dice, they can choose to trade any four of the same resource cards in their hand with one resource card of another kind in the resource bank (e.g., Red has four brick resource cards and decides to trade them to the resource bank for one ore resource card.) If the player's settlement or city is on a port (toward the edge of the board), that player may engage in a more favorable trade, at a possible 3:1 or 2:1 ratio, depending on the port. Players cannot trade with each other during the game. If the player does not have four resource cards to trade, or chooses not to trade, then they will move onto the next move.

Build

The player can then build roads, settlements, or cities by discarding resource cards from their hand and placing the game piece on a terrain hex that extends their game pieces already on the game board. The player must refer to their Building Cost Cards (see Figuer 13) in order to know which resource cards to discard in order to build or buy a development card. The player must also follow building rules, which includes the distance rule. The distance rule specifies that the player must place at least two roads in between settlements and/or cities, and those roads must be built before the next settlement is built by that particular player.

Figure 13

Image of Catan Building Cost Card

Play a Development Card

The final move a player can make during their turn is to play a development card. Development cards used in this experimental version were the victory point cards, or cards that give the player an additional victory point, and progress cards, or cards that give the player another kind of resource-specific advantage in the game. If the player does not have a development card or chooses not to play one in their hand, they must skip this move and move to the next player's turn. If the player chooses to play a development card, they must turn over the card face up onto the table and follow the instructions listed on the card. All four game moves were visible on a card (see Figure 14) so that players could continually see the game play order.

Figure 14

Individual Player Visual Aid

PLAYER 1 : RED	
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.

Experimental Rules

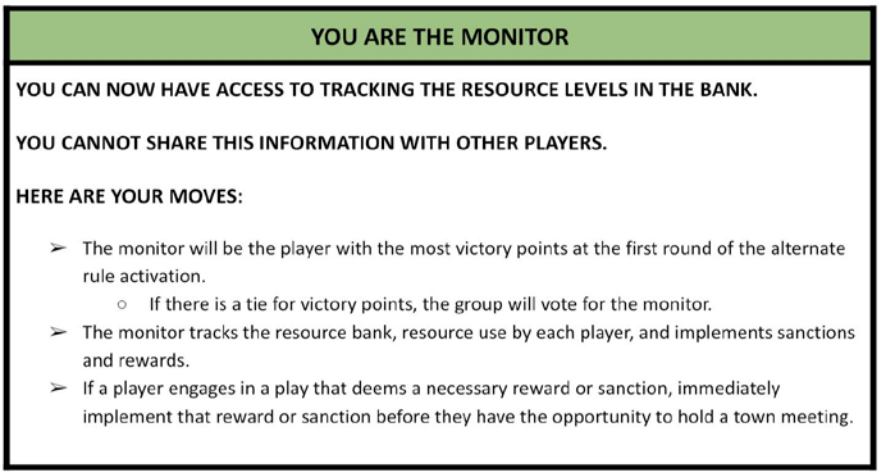
The rules for the experimental part of the game are as follows. During the game, the researchers will tell the group of four participants that new rules will be in place, and they will be instructed on how to play these new rules. These new rules will allow participants to regulate their resource card pool using graduated sanctions and rewards, "the monitor" and "town meeting" game play options that implement all eight of Ostrom's design principles. Sanctions administered were limited to game-related actions such as points, cards, and skipped turns. Participants will be instructed when to return back to the original way of playing by the researchers as well. Each turn, the players will continue to engage in the same base game moves, which include (1) Roll, (2) Trade, (3) Build, and (4) Play a development card.

The Monitor

The monitor is elected automatically as the player with the most victory points at the beginning of the first experimental condition round. If there is a tie for this position or if the group is beginning with this condition, the group will vote for their preferred 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 the monitor judges as deserving of a necessary reward or sanction, the player is instructed to immediately implement that reward or sanction before the other player has the opportunity to hold a town meeting. This added rule refers to Ostrom's fourth design principle, "Monitoring."

Figure 15

Monitor Visual Aid



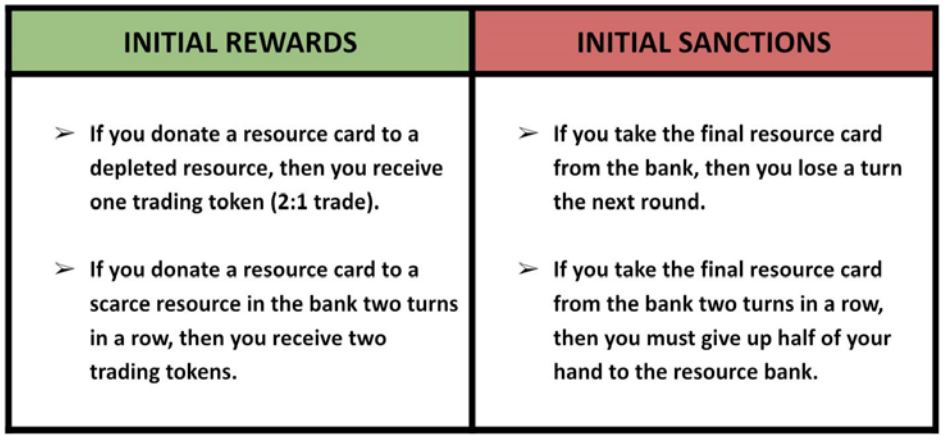
Graduated Sanctions and Rewards

This added rule refers to Ostrom's Fifth Principle, "Graduated Sanctions and Rewards." The experimental game rounds began with predetermined reward and sanction rules set by the researchers [see Figure 16]. If a player engages in any of the listed reward or sanction

behaviors, the monitor (at their discretion) could implement a sanction or reward. The player must then accept the reward or sanction given to them by the monitor. In the "call a town meeting" sections of the game, players could choose to alter, add, or remove rules for sanctions or rewards, but at least two rewards and sanctions had to be stated by the rules at any given point. Rewards and sanction following and rule alterations were also recorded by the experimenters, however, experimenters were unable to interfere with rules or modifications as long as they aligned with the general rules of the game and only utilized game pieces and moves (no rules implementing consequences outside of the game were allowed). Players could communicate with each other and vote on the sanction and reward modifications only if an individual player chose a game move called "Call a town meeting." After this move was finished, communication was once again not allowed and rules/sanctions were fixed.

Figure 16

Reward and Sanction Visual Aid



Call a Town Meeting

The last move a player can make during their turn while experimental rules are in play is called "Call a town meeting." The players are now given the opportunity to discuss the game

with one another in an organized fashion. At the end of their individual turns, they can decide to call the whole group together or call a particular resource group together.

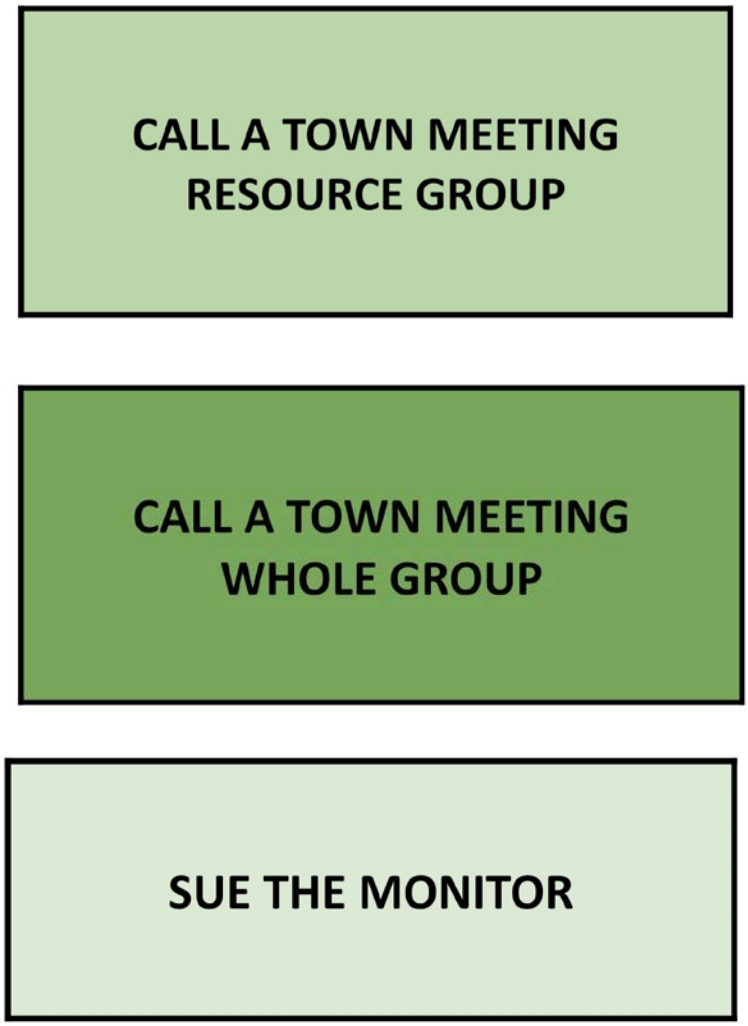
If two or more players have a settlement or city on the same resource type (does not have to be the exact same terrain hex), then those players can call a town meeting to meet with each other. The rest of the group will listen into this meeting, but cannot participate in voting or discussing the game with those players. To hold a town hall for a particular resource community (i.e., lumber, brick, wheat, etc.) they will say, "I'd like to hold a town hall for _____ resource." In these resource community town hall meetings, the players can modify sanction, rewards, or monitoring rules for that particular resource group. This required a simple majority vote to change a rule; if the vote was tied then the change did not pass.

If a player calls a town meeting for the entire group, all players participate in the town hall. The player will say, "I'd like to hold a town hall for the whole group." In these whole group town hall meetings, the players can modify sanction and reward rules that affect the whole group using the same voting rules outlined above. The player holding the town meeting can also choose to "sue the monitor." Players can sue the monitor and defend why. All players vote on whether the monitor gets sued, and 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. An individual player may choose to sue the monitor for several reasons, for example, the monitor unfairly sanctions someone, the monitor refuses to sanction themself, or the monitor unfairly rewards someone. If a player chooses to engage in any of these moves, they must place the game card by their hand until they are finished calling a town meeting. Once the

town meeting is complete, the player will place the game card back towards the center of the table near the game board.

Figure 17

Town Meeting Visual Aids



The experimental condition captures all eight of Ostrom's design principles within the additional rules given to participants. They can be seen in the game moves that coordinate with the behaviorally defined principles listed in Table 2.

Table 2

Correspondence between Ostrom's Principles and Experimental Game Rules

Principle	Behavioral Definition	Game Move
Clearly Defined Boundaries	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).	Whole group and Resource group defined by game piece adjacency
Environmental Congruence	The contingencies must adapt to the environment, the environment should not have to adapt to the contingencies.	Initial rules in line with CPR, rules can be changed by participants particularly in correspondence to CPR changes observed by monitor
Collective Choice Arrangements	Participants governed by a set of rules (i.e. verbal stimuli and associated contingencies) that apply to the CPR can systematically re-define 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 and punishment contingencies in place that affect those who follow rules (i.e., verbal stimuli and associated contingencies) and/or defect. Participants who defect receive appropriate levels of punishment (levels decided by group and each level of punishment is progressively severe).	Participants can receive rewards or sanctions 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/sanction modifications made by participants
Nested Enterprises	Conditionally contingent consequences for IBC's 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

Data Collection

In-person observation occurred during the study by multiple observers. Observers were in the room with the participants in order to collect data throughout the entirety of the game. The observers collected data specifically on the total number of resource cards in each stack within the resource bank after each turn as well as each round of participant turns during the game in order to assess the gains and losses in each stack throughout the game. The collected data was inputted onto an online excel data sheet. No identifying information were collected from participants. Data on player's behaviors will be collected according to numbered players and colors (player 1 - player 4 / red - blue) without any reference to the identity of any player. Since no players participated in more than one game, there was no need to track player identities.

Interobserver Agreement

An interobserver agreement (IOA) was completed for each experiment within the present study in order to account for any errors in data collection. Two data collectors were present for data collection during Study 1, Study 2, and Study 3. Trial-by-trial IOA was conducted for each study in order to determine the accuracy of reports across each turn of the game. For Study 1, data for 58 of 76 turns were identical, receiving an IOA of 76% across each dataset. For Study 2, data for 54 of 72 turns were identical, receiving an IOA of 75% across each dataset. For Study 3, data for 54 of 72 turns were identical, receiving an IOA of 75% across each dataset.

Graphs and Analysis

After the experimentation phase was complete, all collected data were graphed and visually analyzed across all three studies. All cumulative resource levels by condition were inputted into individual line graphs, and then total participant turns to each individual resource crash were inputted into scatterplot graphs to further examine resource crashes across all five resources, conditions within each study, as well as across studies. Average resource level and total orders per round line graphs were also created and analyzed across studies in order to assess participant responding in relation to the resource level in the bank each round.

RESULTS

Results from the initial pilot study as well as the three subsequent official study datasets are included in this section. Results below show the distinct difference across experimental conditions and effective sustainment of the game CPR within and across B conditions, or conditions where Ostrom's principles are applied as game rules.

Pilot 1

Figure 18 shows all data from Pilot 1, including a table and scatterplot graphs depicting total participant turns until each of the five resources crashed individually and altogether, as well as a line graph illustrating total participant orders placed and average resource levels per round. Other dependent variables were graphed as well onto scatterplot graphs, including amount participant turns spent crashed/depleted as well as turns spent scarce. Resources were not counted scarce if crashed, so scarce resources were resource types with 1-3 cards in the bank during a participant turn. The sequence order of conditions were set to A-B for Pilot 1, meaning the participants in this group were only instructed of baseline rules at the start of the game. Ostrom's rules were introduced at the start of Round 9 and remained in the game until the game ended at Round 18.

During the A condition participants crashed all resources to 0 cards in the resource bank by Turn 31 of the 32 total turns in the condition. Ore and wheat were the only resources to sustain within the first five turns, or two rounds, of the game, not crashing until Turns 10 (ore) and 23 (wheat). Total participant orders during each round of the game in Condition A were considerably greater than the average resource level in the bank for 6 of the 8 total rounds. Of the 32 turns in Condition A, four of the five resource types spent over 10 turns

crashed/depleted, ranging from 5-27 turns crashed during the condition. All resource types spent under 10 turns scarce, ranging from 1-8 turns scarce during the condition. Resources spent less time scarce due to spending more time crashed.

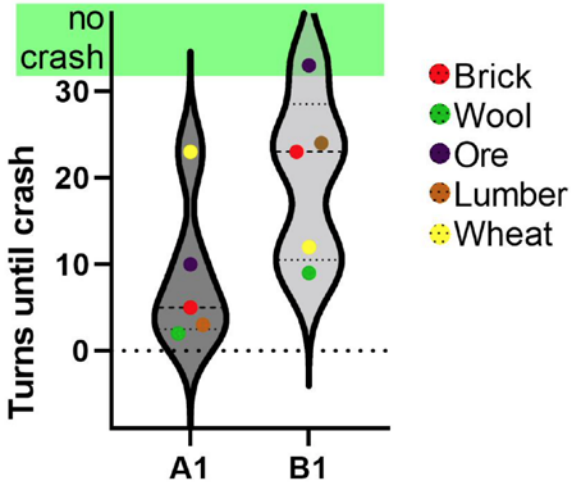
Once the condition switched over to B and Ostrom's rules were presented to the group, participants staggered crashes enough to prevent the five resources combined from ever depleting simultaneously within the 10 total rounds of the B1 condition. One of the five resources, ore, was sustained until the final round of the condition (Round 13); the others crashed earlier. Total participant orders during each round of the game in Condition B were significantly lower than the average resource level in the bank throughout the condition. For all ten rounds in B, participant orders remained below the average resource level line. Of the 40 turns in Condition B, ore spent 0 turns crashed and wool spent 7 turns crashed, while all other resource types spent more than 10 turns crashed, ranging from 0-16 turns crashed. All resource types spent a wide range of participant turns scarce, ranging from 1-26 turns scarce during the condition. Resources spent more time scarce due to spending less time crashed.

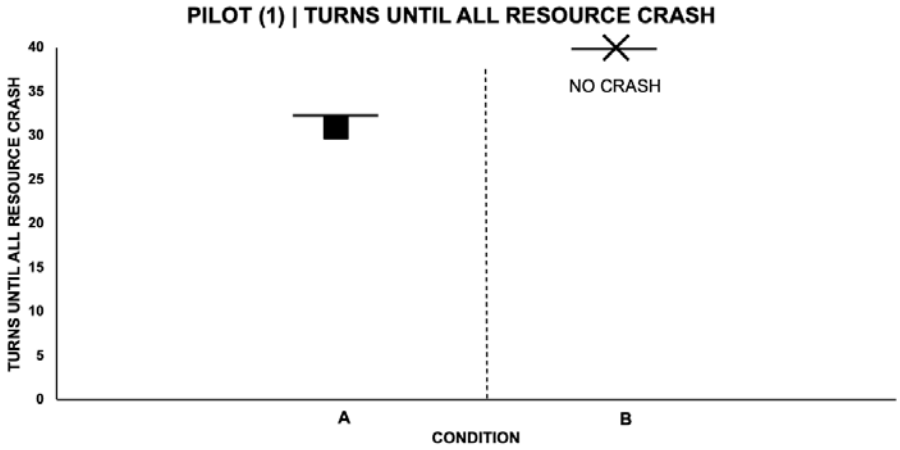
Figure 18

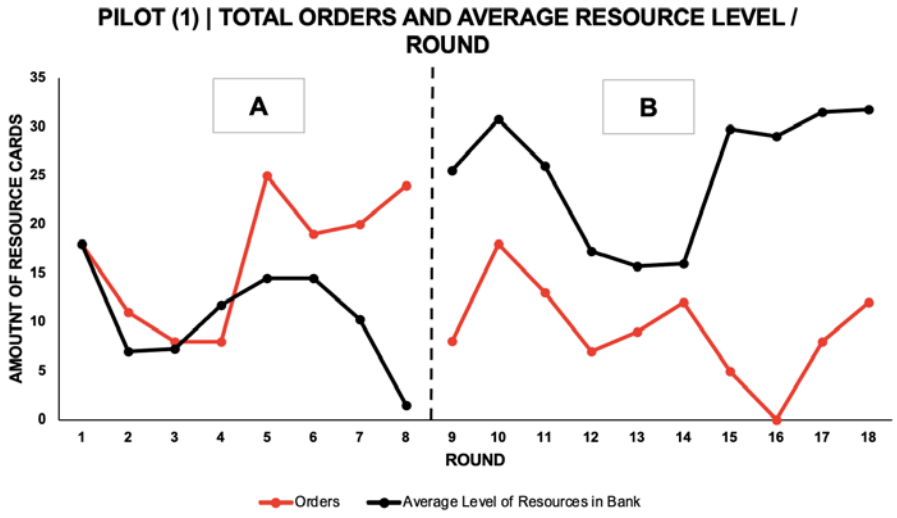
Pilot 1 Graphs

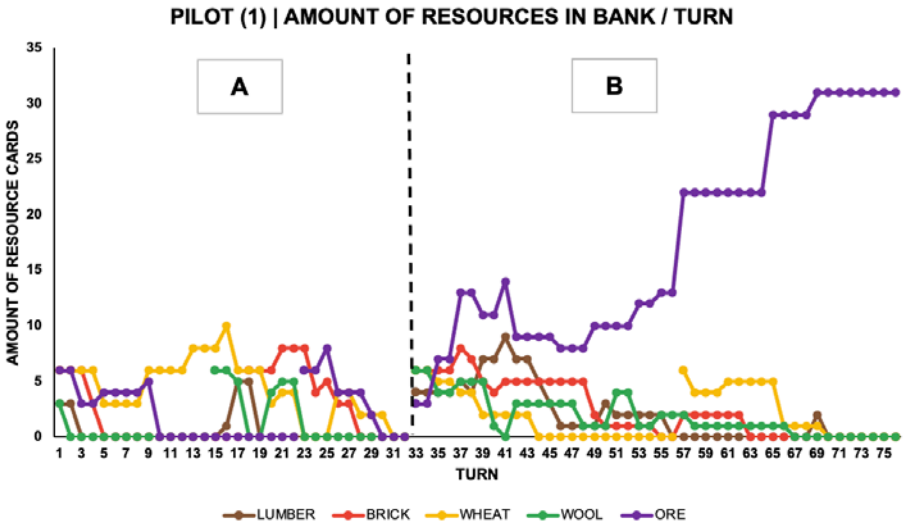
PILOT (1): # OF TURNS UNTIL RESOURCE CRASH		
	Condition	
	Condition A	Condition B
Resource	32 turns	40 turns
Brick	5	23
Lumber	3	24
Wheat	23	12
Wool	2	9
Ore	10	> 40
ALL COMBINED	31	> 40

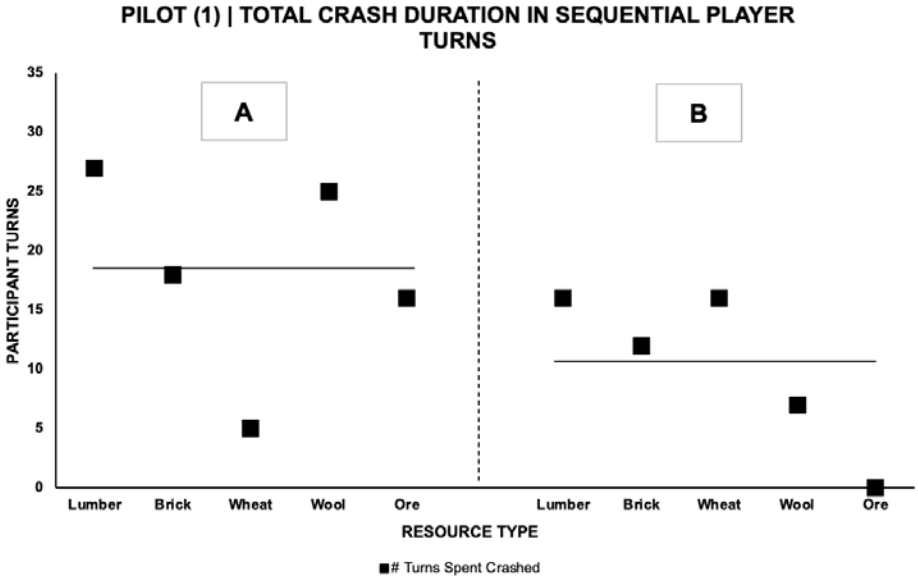
Pilot turns until resource crash

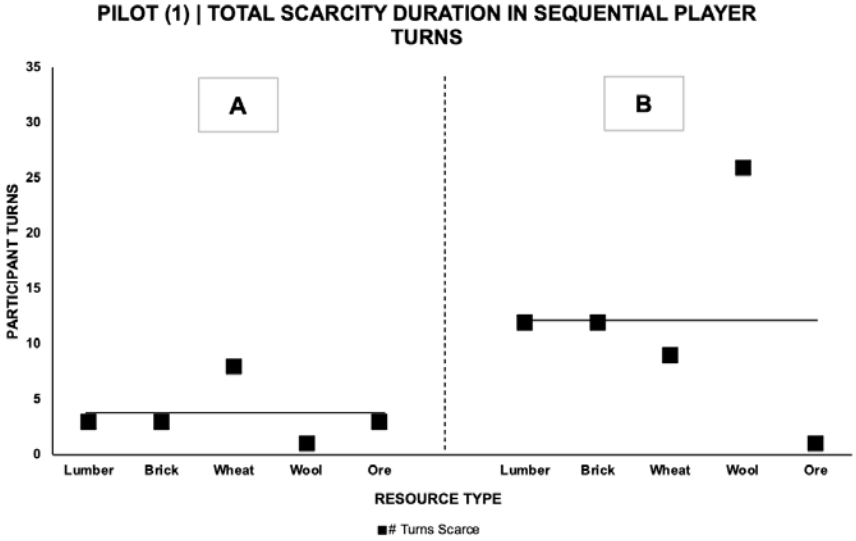







PILOT (1) | AMOUNT OF RESOURCES IN BANK / TURN
A
B
AMOUNT OF RESOURCE CARDS
TURN
LUMBER
BRICK
WHEAT
WOOL
ORE


PILOT (1) | TOTAL CRASH DURATION IN SEQUENTIAL PLAYER TURNS
A
B
PARTICIPANT TURNS
Lumber
Brick
Wheat
Wool
Ore
RESOURCE TYPE
Turns Spent Crashed


PILOT (1) | TOTAL SCARCITY DURATION IN SEQUENTIAL PLAYER TURNS
A
B
PARTICIPANT TURNS
Lumber
Brick
Wheat
Wool
Ore
RESOURCE TYPE
Turns Scarce

Study 1

Figure 19 shows all data from Study 1, including all of the same measures included in Pilot 1. The sequence order of conditions was set to A1-B1-A2 for Study 1, meaning the participants in this group were only instructed of baseline rules at the start of the game. Ostrom's rules were introduced at the start of Round 7 and then removed from the game by the start of Round 14.

During the first A condition, or A1, participants crashed all resources to 0 cards in the resource bank by Turn 14 of the 24 total turns in the condition. Brick was the only resource to sustain within the first five turns, or two rounds, of the game, not crashing until Turn 14. Total participant orders during each round of the game in Condition A1 were considerably greater than the average resource level in the bank for 4 of the 6 total rounds. Several crashed resources were replenished automatically by Round 5, leading to an abrupt shift between total orders and average resource levels for Rounds 5 and 6 of the game. Of the 24 turns in Condition A1, all resource types spent over 10 turns crashed/depleted, ranging from 11-15 turns crashed during the condition. All resource types spent under 10 turns scarce, ranging from 0-7 turns scarce during the condition. Resources spent less time scarce due to spending more time crashed. Four of the five resource types took 13 turns to recover, while brick was not renewed at any point once crashed due to the condition ending before recovery could occur.

Once the condition switched over to B1 and Ostrom's rules were presented to the group, participants staggered crashes enough to prevent the five resources combined from ever depleting simultaneously within the 7 total rounds of the B1 condition. Two of the five resources, wool and ore, were sustained until the final round of the condition (Round 13); the

others crashed earlier. Only one of the resources, brick, crashed within the first round of B2. Total participant orders during each round of the game in Condition B1 were slightly greater than the average resource level in the bank for 2 of the 7 total rounds. In the majority of rounds in B1, participant orders remained below the average resource level line. Of the 28 turns in Condition B1, brick and wheat spent 13 turns crashed, while all other resource types spent less than 10 turns crashed, ranging from 2-6 turns crashed. All resource types spent a wide range of participant turns scarce, ranging from 2-20 turns scarce during the condition. Resources spent more time scarce due to spending less time crashed. Two of the five resource types took 13 turns to recover, while wool and ore were not renewed at any point once crashed due to the condition ending before recovery could occur. Lumber recovered quickly in Condition B1 due to a participant trade with the bank.

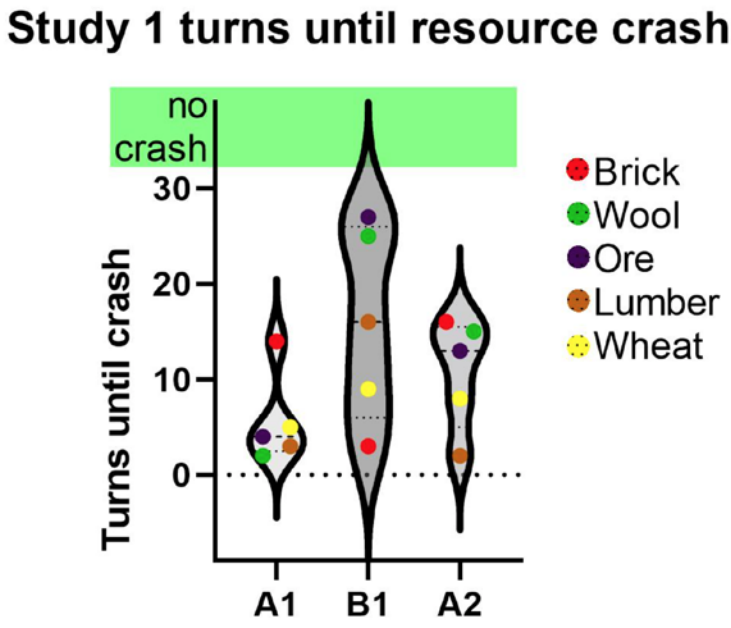
The condition changed back to A2 once Round 13 was completed, and all resources in the bank crashed simultaneously by Turn 14 of the 24 total turns in the condition. Brick and Wool sustained the longest of the five resources in the bank, not crashing until Round 4 and 6, respectively, in this condition. Though participants staggered resource crashing more in Condition A2 than A1, resources were unable to all renew at once similarly to how they did in A1, leading to a second total crash of the resource bank to 0 cards by the final round of A2. Total participant orders during each round of the game in Condition A1 were considerably greater for 4 of the 6 total rounds, mirroring the orders Condition A1. Orders also increased during this condition due to multiple players having cities built on the game board. Of the 24 turns in Condition A2, four of the five resource types spent at least 10 turns crashed, while the other one spent 9 turns crashed. All resource types spent under 10 turns scarce, ranging from

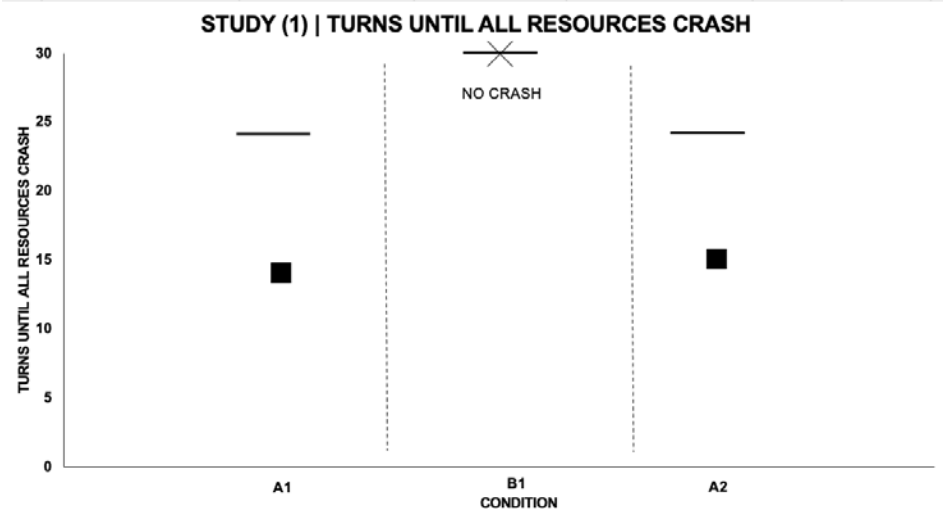
0-8 turns scarce during the condition. Resources spent less time scarce due to spending more time crashed, similarly to Condition A1. Two of the five resource types took at least 13 turns to recover, while the other three resources were not renewed at any point once crashed due to the condition ending before recovery could occur.

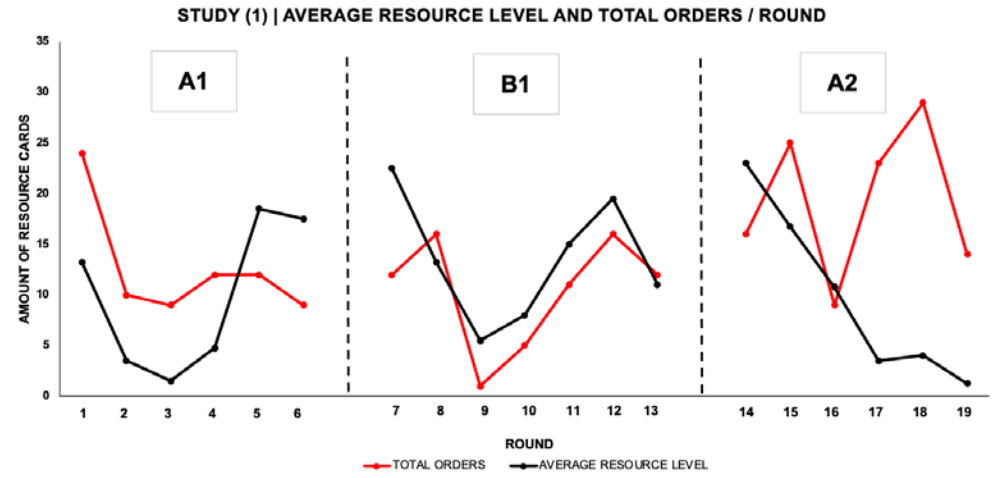
Figure 19

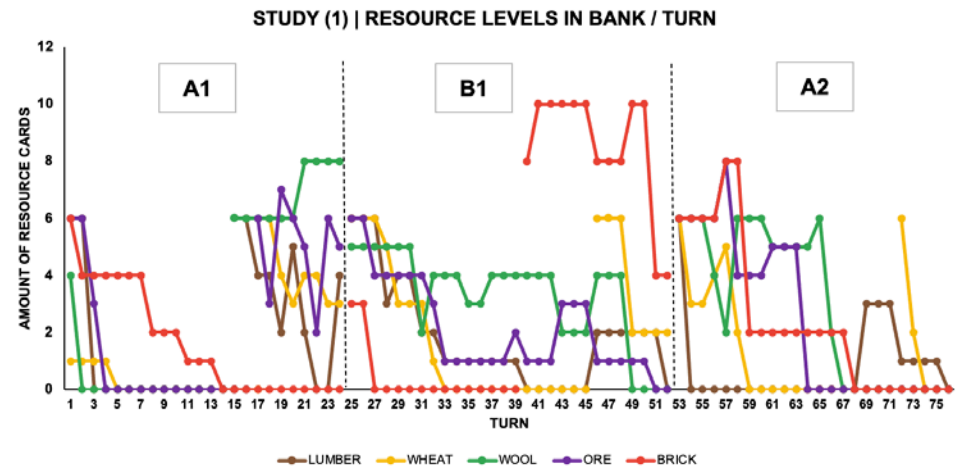
Study 1 Graphs

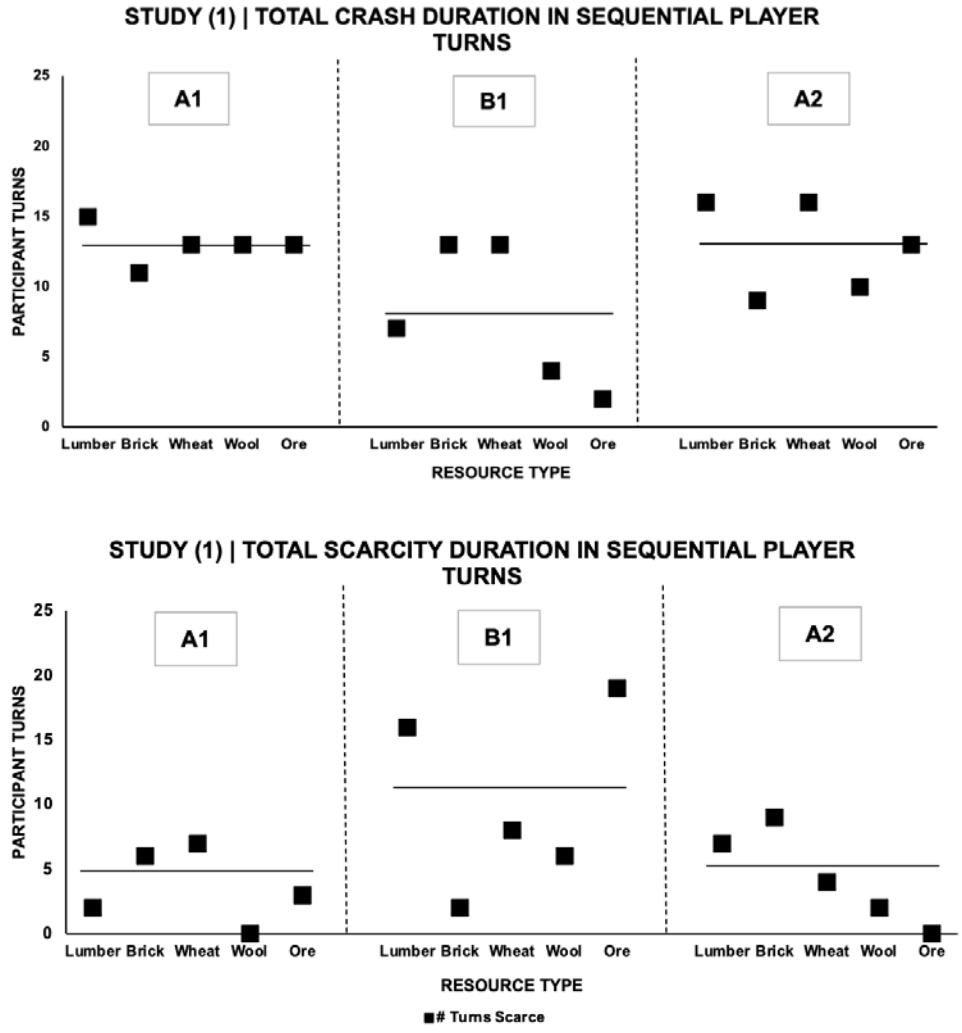
STUDY 1: # OF TURNS UNTIL RESOURCE CRASH			
	Condition		
Resource	Condition A1 24 turns	Condition B1 28 turns	Condition A2 24 turns
Brick	14	3	16
Lumber	3	16	2
Wheat	5	9	8
Wool	2	25	15
Ore	4	27	13
ALL COMBINED	14	> 28	16




STUDY (1) | TURNS UNTIL ALL RESOURCES CRASH
NO CRASH
TURNS UNTIL ALL RESOURCES CRASH
30
25
20
15
10
5
0
A1
B1
A2
CONDITION


STUDY (1) | AVERAGE RESOURCE LEVEL AND TOTAL ORDERS / ROUND
A1
B1
A2
AMOUNT OF RESOURCE CARDS
35
30
25
20
15
10
5
0
1 2 3 4 5 6
7 8 9 10 11 12 13
14 15 16 17 18 19
ROUND
TOTAL ORDERS
AVERAGE RESOURCE LEVEL


STUDY (1) | RESOURCE LEVELS IN BANK / TURN
A1
B1
A2
AMOUNT OF RESOURCE CARDS
12
10
8
6
4
2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75
TURN
LUMBER
WHEAT
WOOL
ORE
BRICK



Study 2

Figure 20 shows all data from Study 2, including all of the same measures included in Study 1. The sequence order of conditions was set to B1-A1-B2 for Study 2, meaning this second group of participants were instructed of Ostrom's rules at the start of the game rather than a third of the way through the game. Ostrom's rules were then removed at the start of round 7 and reintroduced into the game by the start of Round 13. Study 2 lasted a total of 18 rounds rather than the 19 that Study 1 lasted due to an increase in participant town hall meetings in Study 2.

During the first condition of Study 2, or Condition B1, participants sustained the total CPR and resources never simultaneously crashed to 0 cards during the entire condition. Two resources, both wool and brick, were the only resources to crash at Turns 12 and 17, after the halfway mark of Condition B1. Lumber, wheat, and ore all sustained throughout the condition. Total participant orders during each round of the game in Condition B1 were significantly lower than the average resource level in the bank throughout the condition. For all six rounds in B1, participant orders remained below the average resource level line. Participant orders plummeted to 0 by Round 5 in an attempt by the group to sustain the CPR from losing any more resources. The CPR initially lost cards for the first four rounds of the condition, and then was maximized when possible on Rounds 5 and 6. Of the 24 turns in Condition B1, brick and wool spent less than 10 turns crashed, while all other resource types spent 0 turns crashed, ranging from 0-8 turns crashed for all resource types. All resource types spent several participant turns scarce, ranging from 2-20 turns scarce during the condition, depending on the resource type. Resources spent more time scarce due to spending less time crashed, similarly to the B1 condition in Study 1. One of the five resource types, wool, took 6 turns to recover from a crash, while brick could not recover due to the condition ending.

Once the condition switched over to A1 and Ostrom's rules were removed crashes increased, however participants staggered crashes enough to sustain the five resources combined from ever depleting to 0 cards in the resource bank within the 6 total rounds of the A1 condition. Four resources crashed in A1, including ore (Turn 10), lumber (Turn 12), brick (Turn 14), and wheat (Turn 22). One of the five resources, wool, was sustained until the final round of the condition (Turn 24 of Condition B1/ Round 12 of the whole game). Total

participant orders during each round of the game in Condition A1 increased from B1 but remained below the average resource level in the bank for all 6 rounds in the second condition. Participant orders in A1 increased at a steady rate rather than declining as in the B1 condition, steadily decaying the average resource levels until Round 12 when the sheep resource grew 4 cards due to post-round automatic resource growth. Of the 24 turns in Condition A1, three of the five resource types spent over 10 turns crashed, ranging from 11-13 turns crashed during the condition. Wool did not crash during the condition, and when wheat crashed it was recovered due to trading within three participant turns. All resource types spent under 10 turns scarce, ranging from 0-7 turns scarce during the condition. Resources spent less time scarce due to spending more time crashed, compared to Condition B1 within Study 2.

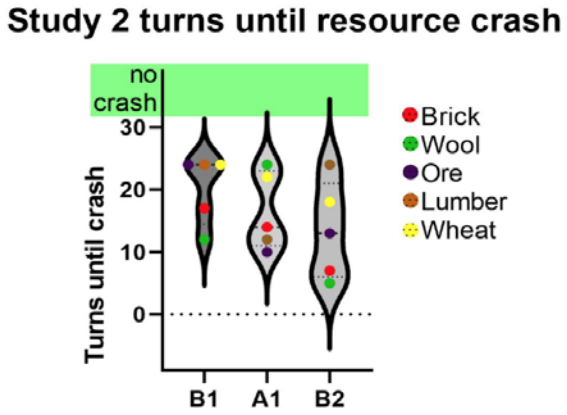
The condition changed back to B2 once Round 12 was completed. The bank sustained as a whole throughout the condition, without all five resources crashing simultaneously. The participants staggered crashes for five of the six resources, while sustaining lumber effectively until the end of the game. Total participant orders during each round of the game in Condition B2 increased from the previous conditions and remained below the average resource level in the bank for 4 of the 6 rounds in this condition. Participant orders surpassed the average resource level line by Round 17 of the game. Of the 24 turns in Condition B2, ore spent 12 turns crashed. Wool, wheat, and brick spent less than 10 turns crashed, while lumber spent 0 turns crashed during the condition. Three of the five resource types spent several participant turns scarce, ranging from 2-10 turns scarce during the condition, depending on the resource type. Lumber was never considered scarce, growing and sustaining throughout the condition. Ore was also never considered scarce, but that was due to an abrupt crash from participants by

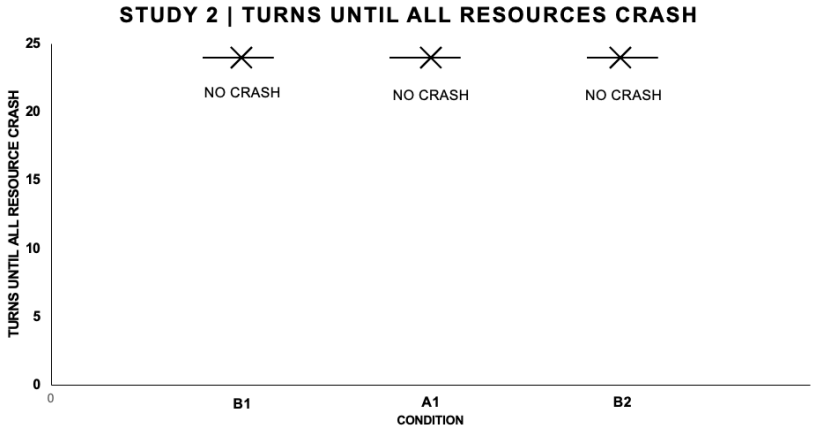
Turn 61 that never recovered afterwards. Three of the five resource types took less than 10 turns to recover from a crash, while ore could not recover due to the condition ending.

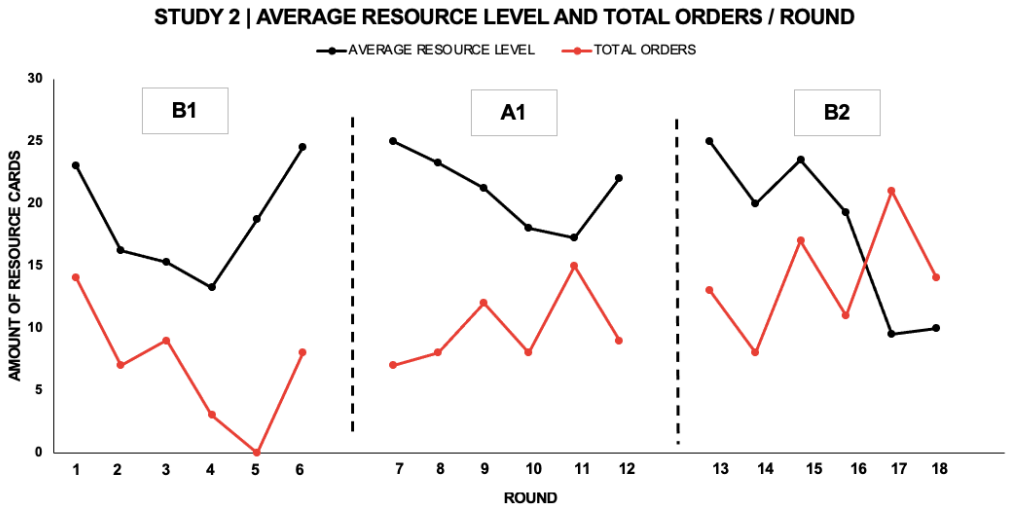
Figure 20

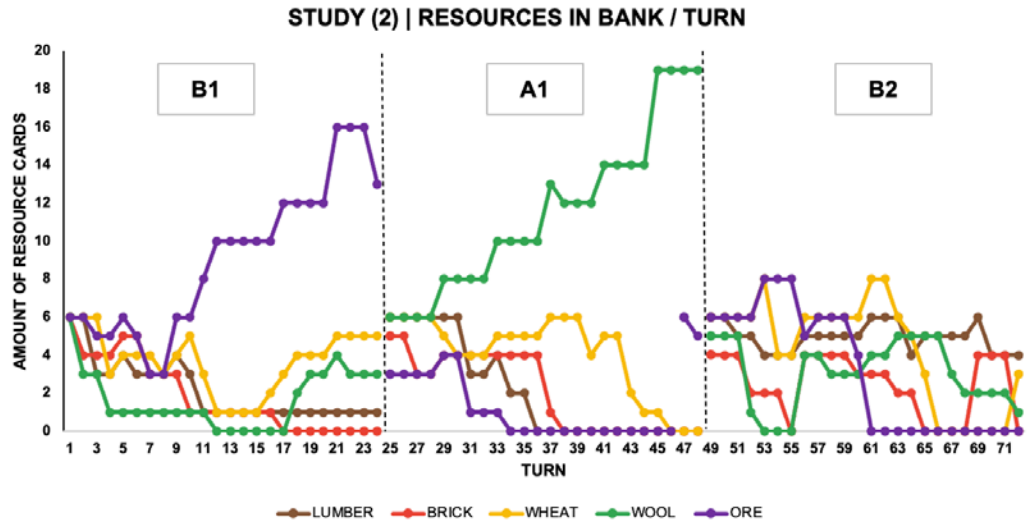
Study 2 Graphs

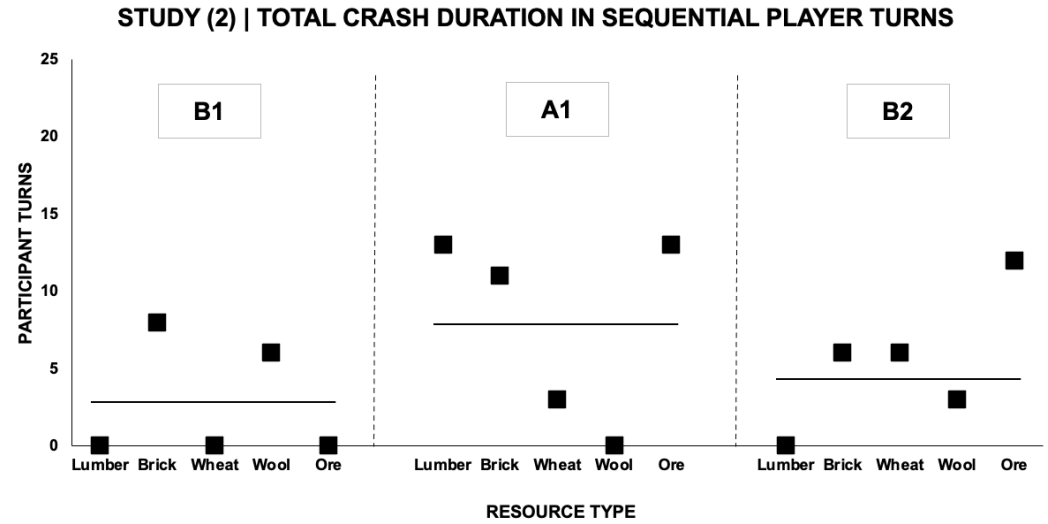
STUDY 2: # OF TURNS UNTIL RESOURCE CRASH			
	Condition		
	Condition B1	Condition A1	Condition B2
Resource	24 turns	24 turns	24 turns
Brick	17	14	7
Lumber	> 24	12	> 24
Wheat	> 24	22	18
Wool	12	> 24	5
Ore	> 24	10	13
ALL COMBINED	> 24	> 24	> 24

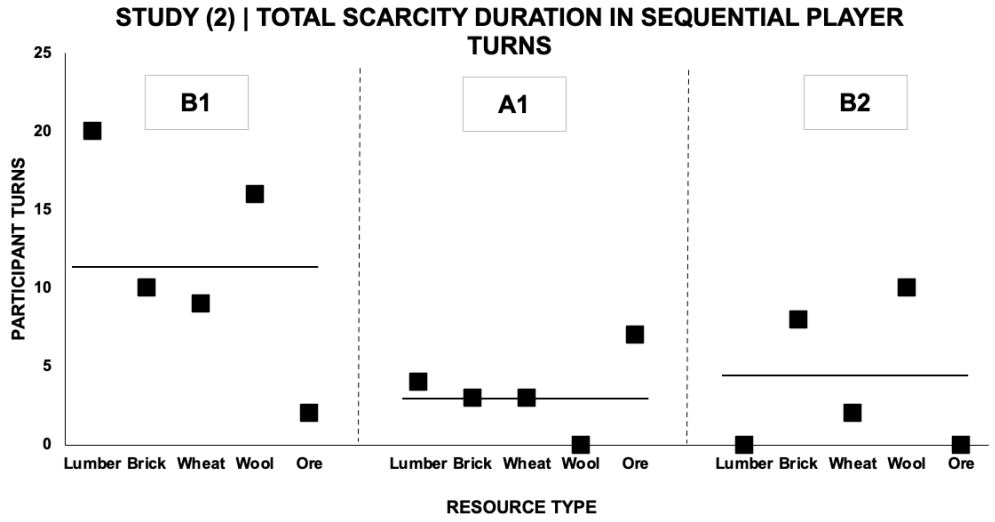





STUDY 2 | AVERAGE RESOURCE LEVEL AND TOTAL ORDERS / ROUND
AVERAGE RESOURCE LEVEL
TOTAL ORDERS
B1
A1
B2
AMOUNT OF RESOURCE CARDS
ROUND


STUDY (2) | RESOURCES IN BANK / TURN
B1
A1
B2
AMOUNT OF RESOURCE CARDS
TURN
LUMBER
BRICK
WHEAT
WOOL
ORE


STUDY (2) | TOTAL CRASH DURATION IN SEQUENTIAL PLAYER TURNS
B1
A1
B2
PARTICIPANT TURNS
Lumber
Brick
Wheat
Wool
Ore
RESOURCE TYPE



Study 3

Figure 21 shows all data from Study 3, including the same set of graphs inserted for both Study 1 and Study 2. The sequence order of conditions was set to A1-B1-A2 for Study 3, meaning the participants in this group were only instructed of baseline rules at the start of the game, exactly as the sequence of conditions arranged for Study 1. Ostrom's rules were introduced at the start of Round 7 and then removed from the game by the start of Round 13. Condition B1 was shortened compared to Study 1 due to time participants spent communicating during town hall meetings during the condition.

During the first A condition, or A1, participants crashed all resources to 0 cards in the resource bank by Turn 13 of the 24 total turns in the condition. Both ore and lumber crashed within the first round of the game, and the other three resources crashed by Round 4. Total participant orders during each round of the game in Condition A1 were considerably greater than the average resource level in the bank for 6 of the 6 total rounds. Several crashed resources were replenished automatically by Rounds 5 and 6, leading to an increase in average

resource levels for those rounds of the game. Exactly like previous studies, if resources had not been replenished, then the resource levels would have flatlined for the entire condition. Of the 24 turns in Condition A1, four of the five resource types spent over 10 turns crashed, while wool spent under 10 turns crashed, ranging from 7-18 turns crashed during the condition across resources. All resource types spent under 10 turns scarce, ranging from 1-7 turns scarce during the condition. Resources spent less time scarce due to spending more time crashed. Three of the five resource types took 13-14 turns to recover, wool took 7 turns to recover due to participant trading, and wheat was not renewed at any point once crashed due to the condition ending before recovery could occur.

Once the condition switched over to B1 and Ostrom's rules were presented to this group, participants sustained the five resources combined from ever depleting to 0 cards in the resource bank within the 6 total rounds of the B1 condition. Only one resource, brick, crashed during B1, at Round 4 of the condition. Four of the five resources were sustained until the final round of the condition (Round 13). Total participant orders during each round of the game in Condition B1 remained below the average resource level in the bank for 6 of the 6 total rounds, flipping the same lines from Condition A1. Of the 24 turns in Condition B1, only one of the five resource types, brick, crashed and spent 13 turns depleted until recovery. All resource types spent a wide range of participant turns scarce, ranging from 2-21 turns scarce during the condition. Resources spent more time scarce due to spending less time crashed.

The condition changed back to A2 once Round 12 was completed, and all resources in the bank were crashed simultaneously by Turn 14 of the 24 total turns in the condition. Brick sustained the longest of the five resources in the bank, not crashing until Round 4 of 6 in this

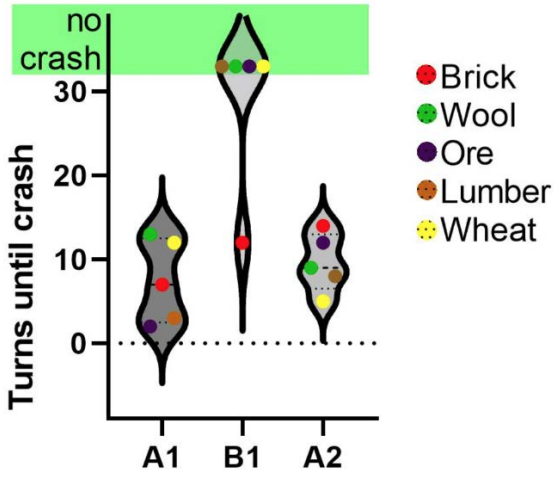
condition. Though participants staggered resource crashing more so in Condition A2 than A1, similarly to Study 1, resources were renewed later in the condition than in A1 and orders decreased to 0 by the final round of the game due to participants knowing that the game was likely ending soon because of time. Total participant orders during each round of the game in Condition A1 were considerably greater for 5 of the 6 total rounds, flipping the line again from Condition B1. Orders also increased during this condition due to multiple players having cities built on the game board. Of the 24 turns in Condition A2, four of the five resource types spent over 10 turns crashed, while ore spent under 7 turns crashed, ranging from 7-14 turns crashed during the condition across resources. All resource types spent under 10 turns scarce, ranging from 0-6 turns scarce during the condition. Resources spent less time scarce due to spending more time crashed. Three of the five resource types took 13 turns to recover, ore took 7 turns to recover due to participant trading, and brick was not renewed at any point once crashed due to the condition ending before recovery could occur.

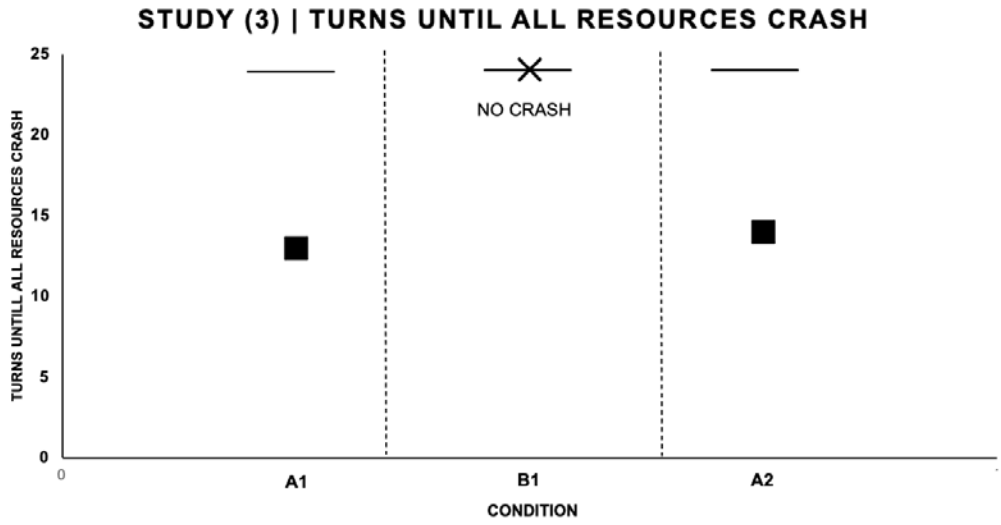
Figure 21

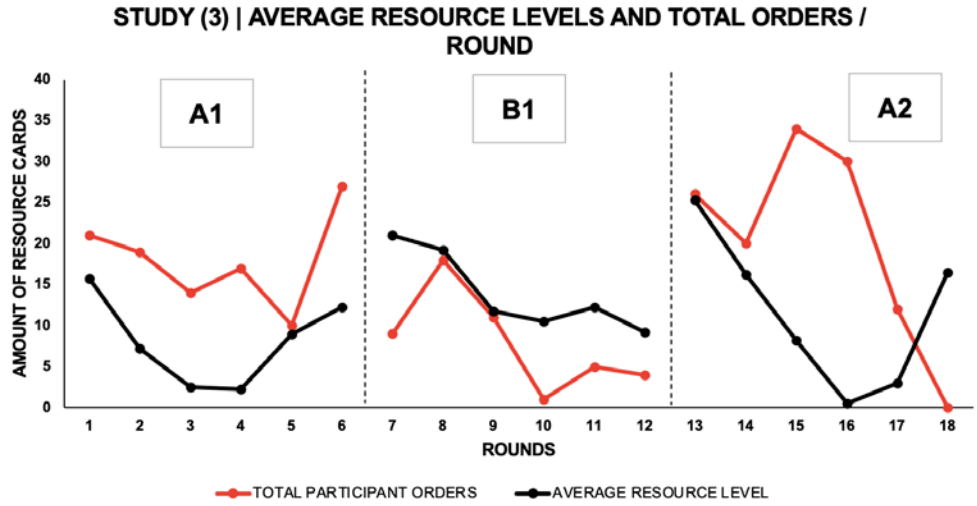
Study 3 Graphs

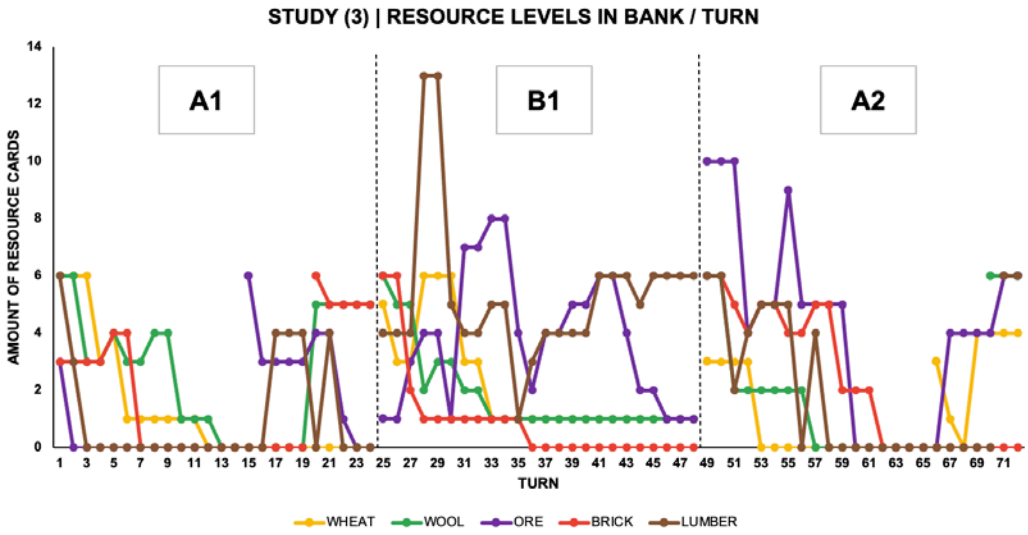
STUDY 3: # OF TURNS UNTIL RESOURCE CRASH			
	Condition		
	Condition A1	Condition B1	Condition A2
Resource	24 turns	24 turns	24 turns
Brick	7	12	14
Lumber	3	> 24	8
Wheat	12	> 24	5
Wool	13	> 24	9
Ore	2	> 24	12
ALL COMBINED	13	> 24	14

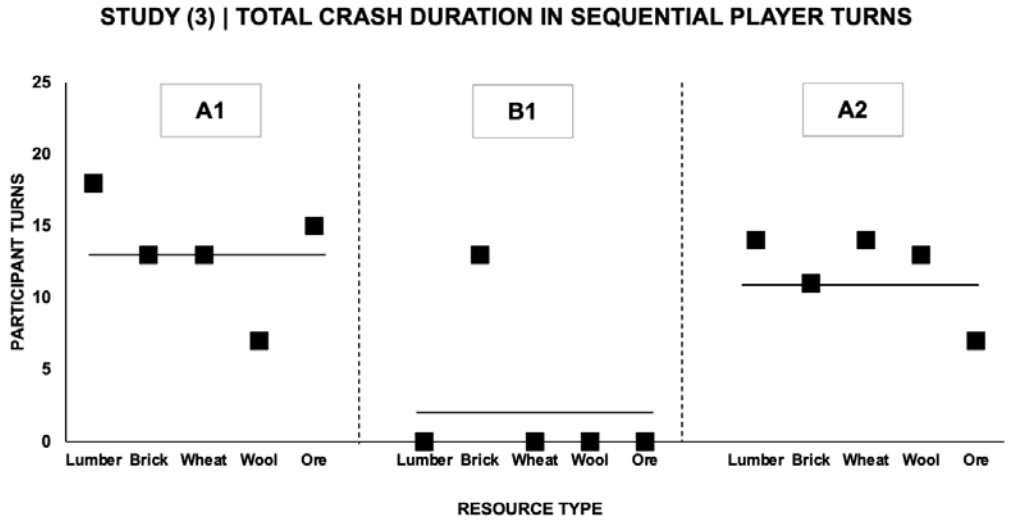
Study 3 turns until resource crash

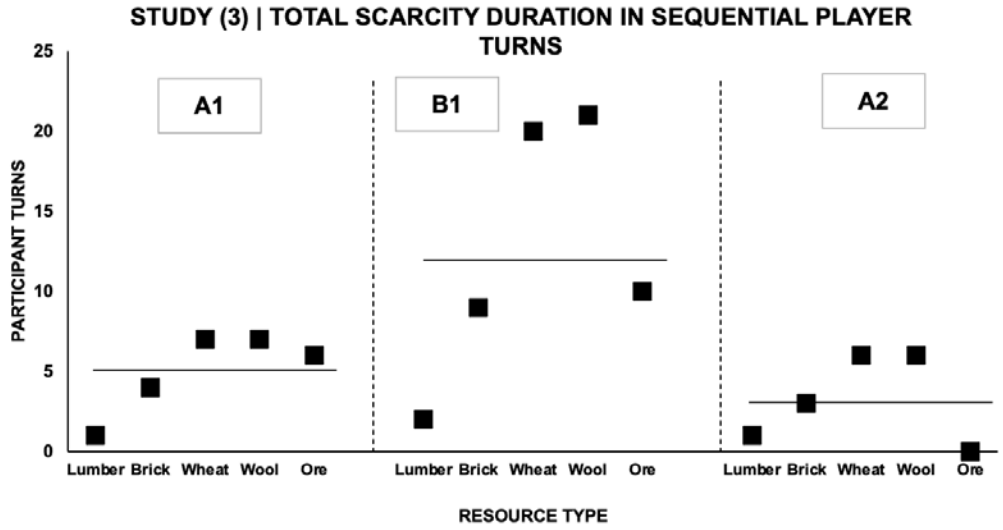







STUDY (3) | RESOURCE LEVELS IN BANK / TURN
A1
B1
A2
AMOUNT OF RESOURCE CARDS
TURN
WHEAT
WOOL
ORE
BRICK
LUMBER


STUDY (3) | TOTAL CRASH DURATION IN SEQUENTIAL PLAYER TURNS
A1
B1
A2
PARTICIPANT TURNS
Lumber Brick Wheat Wool Ore
RESOURCE TYPE


STUDY (3) | TOTAL SCARCITY DURATION IN SEQUENTIAL PLAYER TURNS
A1
B1
A2
PARTICIPANT TURNS
Lumber Brick Wheat Wool Ore
RESOURCE TYPE

DISCUSSION AND IMPLICATIONS

The results graphed for each study reinforces the hypothesis that when Elinor Ostrom's eight design principles are introduced to a group of individuals engaged in a CPR game, then participants will sustain a CPR more effectively than without Ostrom's principles in place. A clear difference in all dependent variables were captured across conditions and replicated across all three experiments. When Ostrom's rules were in place, the full CPR (all five resources combined) never crashed to 0 cards. The full CPR crashed in every A condition in studies (1) and (2). The full CPR never crashed with the sequence order of conditions set to B-A-B, hypothesized to be due to Ostrom's rules organizing participant behavior from the very start of the game and carry over effects lasting across conditions. However, future replications of the B-A-B study are critical before further assumptions can be made about condition effects on participant behavior.

Results from all studies also indicate that Ostrom's principles organize participant responses. When resources did crash in B conditions, participants tended to stagger the crashes so that they would crash later and in different rounds if they were to even crash at all. Typically, participants attempted to keep resources scarce or stocked enough for end-of-round renewal. If participants ordered a maximum amount of resource cards from the bank in B conditions, then other participants were quick to call town meetings and propose reward and sanction changes. Some participants made sure to order lower amounts of resource cards from the bank if participant orders were high during a participant turn in B conditions. Participants error-corrected when possible, set up rules for error-correction, traded, and donated in B conditions, whereas trades occurred in A conditions, but were less likely than in B conditions. Ostrom's

principles as game moves may have organized participant behavior through selection of decreased appropriation, or low participant orders, as well as increased provision through trades and donations to the resource bank. Participants were more likely to engage in game moves that benefit the group and sustainability of the CPR when Ostrom's principles were introduced. Participants were also more likely to modify and create rewards rather than to introduce new sanctions, an interesting note that could be investigated further.

Since participant behavior was organized by use of Ostrom's principles in B conditions, it is clear from the data that when given access to Ostrom's principles as game rules, participants will utilize them. Participant behavior change did not just occur with access to the principles, but engagement with the principles. All groups utilized the Ostrom game rules when given access, though all groups employed them differently. The monitors within each study used sanctions and rewards when possible, and tracked the resource bank. A majority of players called town meetings for the whole group in order to modify sanctions and rewards and give feedback to one another. The monitor was rarely sued by another player, but this move was used when players deemed necessary. Town halls were rarely called for resource groups, possibly due to the small size of the group. Further research is required on utilization of these principles within the game, particularly dependent on group size or multi-group interaction.

An analysis of resource crashes, scarcity, and recovery was completed in order to further examine resource changes across conditions. Participants selected high orders or max ordering across A conditions, and waited the entire twelve subsequent depletion turns for recovery. In B conditions, however, participants selected low orders, passed more from ordering, donated more to the bank, and increased trades in order to speed up recovery or

prevent depletion from occurring. When baseline game rules were introduced to participants from the start, participants crashed all resources in the first condition and each resource was slow to recover. When Ostrom rules were introduced to participants from the start, participants crashed less resources and one was quick to recover. Though resources tend to remain scarce longer in B conditions, they spent more time in play than crashed. Resources spent more time crashed than scarce in A conditions. If a resource crashed in B conditions, participants were quick to error correct by adding back to the resource bank as soon as possible. This behavior was not seen across A conditions, as most participants allowed the resource to remain crashed until full resource recovery. Though resources remained scarce in the majority of B conditions, participants worked hard to control the bank while also attempting to maximize their personal victory points.

There were several limitations that researchers came across throughout the current study. The nature of this experiment was complex, because it involved several combined controlling variables on individual behavior. Since management of all controlling variables required constant checks for experimental errors, a research team of three was required for game management and data collection. The complexity and randomness of some events in the experimental set up constituted an intentional attempt to model the complexity of a real-life tragedy of the commons scenario; these real-life scenarios usually also involve aa range of variables and probabilistic outcomes. Regardless of the complexity in variables added in the current experimental set up, results illustrated that Ostrom's principles gained experimental control of participant responding. Several participants reported post-experiment that the

complexity of the game was a fun aspect of the experiment and that they would play the game again in the future.

Management of participant communication throughout the game proved to be difficult across studies, hypothesized to be due to individual ontogenic histories of game play. Researchers frequently prompted to not strategize about the game until instructed to do so. Participants with a history of game play specifically with Catan attempted to track resource levels on the blank sheets of paper provided to them. Future studies should prohibit resource level tracking (unless a monitor is selected) since this was used as a way for participants to non-vocally strategize during baseline (A) conditions. The tendency to attempt self-organization also implies that poor CPR performance during B conditions may have been changed – in either direction – had communication in these conditions been allowed; a control experiment comparing such self-generated organization to Ostrom's prescribed organization would be useful.

A time limit and round amount was also specified to the participants in order for them to be aware of when the study was complete. This was a limitation for the study because participants' response patterns changed drastically in the final rounds of the game, since it was clear that the CPR would soon become meaningless to participants. The simulated CPR within the game of Catan was effective, though it did not resemble a CPR that majority, if not all, participants were used to appropriating or providing for in their day-to-day lives. This could be a limitation to the current study because it may not capture how individuals appropriate or provide for resources that they consider valuable in their real lives. Further research is required

to test for differences between CPRs that individuals commonly come into contact with versus not.

It is possible that participant access to communication alone, via Town Hall meetings, may have accounted for results found in B conditions. In order to further test the necessity of Ostrom's principles as a package, it is important to empirically test a condition where participants have access to communication during the game (without being told of Ostrom's principles as game rules). Because it is possible that the participants may actually generate some of the relations suggested by the principles even without formal rules, such a test would require the experimenter to track these interactions. The present study will be extended by adding three more experiments, including a second B-A-B group, and two other "Control" groups, with the sequence of conditions set to C-B-C. The extra control, or C condition, will test if participant access to self-guided communication about the game in order to strategize together is equally or more effective than when Ostrom's principles are presented to the group as game rules. Future research can build upon the present study by conducting component analyses on these design principles to examine each principle individually. A component analysis may uncover variables not captured in the present study, and additionally investigate if each principle is necessary and sufficient within the whole set. Future studies could also gather more information on this phenomenon and test for generality by setting up and analyzing studies where participants not in the same room as each other playing the game, across other CPR games, and across smaller and larger groups.

Implications from the present study suggest that Ostrom's design principles may be necessary for communities to engage in, particularly for a community that is new to an

environment that supports several common pool resources. Individual participant behavior that more effectively sustains a common pool is selected when Ostrom's principles are introduced to participants. If future studies support the evidence found in the present study, Ostrom's principles can be assessed as an appropriate intervention for communities that might be struggling to select interlocks that prevent a tragedy of the commons scenario from occurring. Though current evidence is compelling, further research on these principles are required to ensure that Ostrom's principles are all sufficient and necessary for application. The current study also demonstrates that single-subject/single group A-B-A and B-A-B reversal experimental designs can be used successfully to study CPR use. However, future research could further validate experimental control indicated from the present study through experimental replication and/or extension. Other experimental designs should also be tested on the current CPR game arrangement as well in order to further investigate possible variances in experimental control.

In conclusion, these design principles must be further analyzed by behavior analysts, because there may be more essential information or specification that is missing in order to empirically validate or dispel ideas about how self-governing systems maintain sustainability practices for the common pool resource in certain areas. In doing so, evidence-supported intervention and procedures can be applied to these systems to promote resource management. Perhaps with more research on this subject, the phenomena in question can be further pursued with behavioral conceptualizations and evidence that points the behaviorist in the right direction in hopes that communities will behave in such a way that "saves the world."

APPENDIX

CATAN GAME

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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

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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 <u>in the order listed</u>:

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.

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(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.

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- **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.

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Alternate Rule Activation

- At one point or 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 this phase/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 Monitor**
    - 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 whole group 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.

Ending the Game

➢ The game will last up to 20 rounds.
➢ The experimenter will let you know when we are on the final round.
➢ At any time, you can ask the experimenter for the current round number.

Winners

➢ **Most Successful Survivors**
- The players that have at least 8 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 Lexie Smith and Dr. April Becker for any further questions or concerns.

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

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Date
Primary
Reli
Group

Resource Crash
12 Rounds = Add 6 at first Red

O= Ordered from Bank (+) = Added to Hand

Player Orders

Red										Orange										White										Blue									
Lumber		Brick		Wheat		Sheep		Ore		Lumber		Brick		Wheat		Sheep		Ore		Lumber		Brick		Wheat		Sheep		Ore		Lumber		Brick		Wheat		Sheep		Ore	
O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)	O	(+)

Added / Removed from player hand

Player Trades

Red					Orange					White					Blue				
Lumber	Brick	Wheat	Sheep	Ore	Lumber	Brick	Wheat	Sheep	Ore	Lumber	Brick	Wheat	Sheep	Ore	Lumber	Brick	Wheat	Sheep	Ore

Bank Resources

Round	Player	Turn	Lumber	Brick	Wheat	Sheep	Ore
			6	6	6	6	6
1	Red	1	6	6	6	6	6
	Orange	2	6	6	6	6	6
	White	3	6	6	6	6	6
	Blue	4	6	6	6	6	6
2	Red	5	6	6	6	6	6
	Orange	6	6	6	6	6	6
	White	7	6	6	6	6	6
	Blue	8	6	6	6	6	6
3	Red	9	6	6	6	6	6
	Orange	10	6	6	6	6	6
	White	11	6	6	6	6	6
	Blue	12	6	6	6	6	6
4	Red	13	6	6	6	6	6
	Orange	14	6	6	6	6	6
	White	15	6	6	6	6	6
	Blue	16	6	6	6	6	6
5	Red	17	6	6	6	6	6
	Orange	18	6	6	6	6	6
	White	19	6	6	6	6	6
	Blue	20	6	6	6	6	6
6	Red	21	6	6	6	6	6
	Orange	22	6	6	6	6	6
	White	23	6	6	6	6	6
	Blue	24	6	6	6	6	6
7	Red	25	6	6	6	6	6
	Orange	26	6	6	6	6	6
	White	27	6	6	6	6	6
	Blue	28	6	6	6	6	6

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