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Synthesis

Archetypal games generate diverse models of power, conflict, and cooperation

Bryan Bruns [1] *and Christian Kimmich* [2,3]

ABSTRACT. Interdependence takes many forms. We show how three patterns of power generate diverse models for understanding dynamics and transformations in social-ecological systems. Archetypal games trace pathways that go beyond a focus on a few social dilemmas to recognize and understand diversity and complexity in a landscape of social situations, including families of coordination and defection problems. We apply the extended topology of two-person two-choice (2 × 2) games to derive simple archetypes of interdependence that generate models with overlapping opportunities and challenges for collective action. Simplifying payoff matrices by equalizing outcome ranks (making ties to show indifference among outcomes) yields three archetypal games that are ordinally equivalent to payoff structures for independence, coordination, and exchange, as identified by interdependence theory in social psychology. These three symmetric patterns of power combine to make an asymmetric archetype for zero-sum conflict and further structures of power and dependence. Differentiating the ranking of outcomes (breaking ties) transforms these primal archetypes into more complex configurations, including intermediate archetypes for synergy, compromise, convention, rivalry, and advantage. Archetypal models of interdependence, and the pathways through which they generate diverse situations, could help to understand institutional diversity and potential transformations in social-ecological systems, to distinguish between convergent and divergent collective action problems for organizations, and to clarify elementary patterns of power in governance.

Key Words: *asymmetric social situations; coordination games; ecology of games; equilibrium selection; interdependence theory; social dilemmas; system dynamics archetypes*

INTRODUCTION

"My mask protects you, your mask protects me," expresses interdependence in trying to control the spread of COVID-19. Each person has power to determine the other's outcome but has no control over their own fate. The Buddhist Avatamsaka Sutra describes two people chained in place, each with a spoon too long to feed themself, but each able to feed the other (Aruka 2001). In their *Atlas of Interpersonal Situations,* Kelley et al. (2003) use the phrase "I'll scratch your back if you scratch mine" to summarize this kind of reciprocity in an elementary exchange situation.

To practice "social distancing" during a pandemic and reduce the risk of infection when approaching each other in a hallway or along a sidewalk, each of us could move to the left or right. Either direction would be effective, but we are both better off coordinating on the choice, as with driving a vehicle on the left or right. This coordination creates a stable equilibrium outcome in which each person's action is the best response to what the other does. Lewis (2002) argues that conventions that are used to solve coordination problems are central to social life, including language, culture, and norms. As with the saying about fish not noticing the water, we live within a sea of conventions, usually taken for granted, that enable us to communicate, compete, and cooperate. Norms and their emergence, maintenance, and disappearance play a crucial role in social life (Bicchieri 2005, Legros and Cislaghi 2020), including the governance of natural resources in social-ecological systems (Ostrom 2000, 2005).

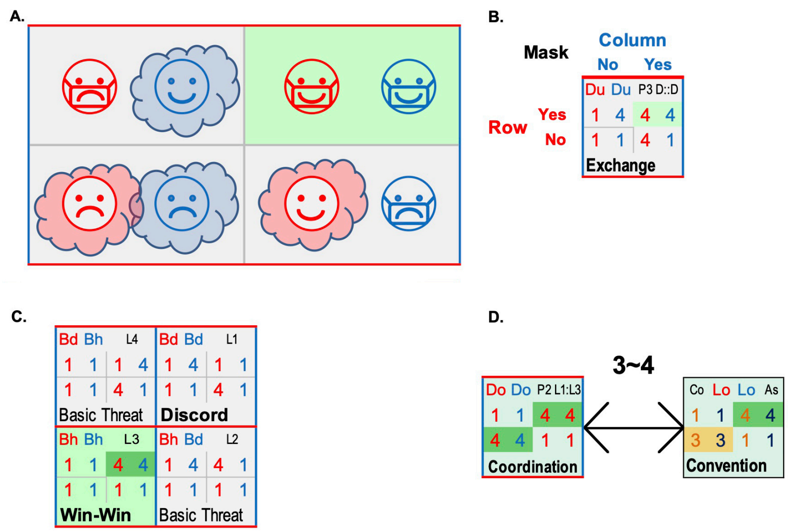
I might wear a mask seeking only to protect myself. A mask with an unfiltered exhaust might protect me but not others (Pejó and Biczók 2020). In this case, our actions for self-protection would be independent. "We go our separate ways" (Kelley et al. 2003), regardless of what the other person may do. Each person has a dominant strategy, a strategy that is better whatever the other person does, which, in this (hypothetical) case, still allows each person to get their best outcome.

These three symmetric situations illustrate archetypal games, which are elementary models for interdependence in social-ecological situations. Archetypal patterns can help us to recognize and analyze interactions and dynamics in social-ecological systems (Cullum et al. 2017, Eisenack et al. 2019, Oberlack et al. 2019, Sietz et al. 2019). Social dilemmas such as the "Prisoner's Dilemma" are not the only forms of interdependence that matter in environmental governance (McAdams 2009, Kimmich 2013, Bisaro and Hinkel 2016). There is a need to better our understanding of the diversity of interdependence in strategic situations and the different challenges to cooperation (Curry et al. 2020). Rules with enforcement by punitive sanctions may help to solve some dilemmas but may be counterproductive in coordination problems. Different situations may require different solutions such as common knowledge, trust building, shared expectations, norms, compromise, reciprocity, or changing rules to improve outcomes.

We apply the extended topology of 2 × 2 games (Robinson and Goforth 2005, Heilig 2011, Hopkins 2014, Bruns 2015; Robinson et al., *unpublished manuscript* https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.619.4992&rep=rep1&type=pdf) to develop a set of archetypes for interdependence. These archetypes go beyond a few famous games to trace systematic relationships between elementary models of strategic interaction. Rather than a jumble of stories or a scattering of payoff matrices, archetypal games offer landmarks and pathways for navigating a landscape of cooperation and conflict. Archetypal games can aid in understanding the diversity of situations, their dynamics, and their potential transformations. We use a deductive approach to identify the simplest archetypes. We select additional intermediate archetypes based on their relevance for modeling collective action. We find convergence with empirically relevant situations identified in interdependence theory in social psychology (Kelley et al. 2003) and show an efficient way to map relationships between archetypes. These archetypes for interdependence can help to understand a

[1]Independent Researcher and Consultant, [2]Institute for Advanced Studies (IHS), Vienna, Austria, [3]Masaryk University, Brno, Czechia

Fig. 1. Payoff matrices for simple 2 × 2 situations. (A) "My mask protects you, your mask protects me." (B) Primal Exchange: payoff matrix for wearing a mask that only protects others, ranking of outcomes for row and column actors if only one's own outcomes matter. (C) Basic archetypes with one preference each and ties (indifference) for the three lowest ranked outcomes. Payoffs from two symmetric games combine to form a pair of asymmetric threat games. (D) Breaking ties. Ranking one outcome lower (3,3) than the other (4,4) transforms Primal Coordination into Convention. In reverse, equalizing payoffs (making ties) simplifies Convention into Primal Coordination.



diverse range of situations, including harmony, coordination, exchange, advantage, power, dependence, and conflict.

METHODS

The smiling and frowning faces in Fig. 1A show the relative ranking of different outcomes for wearing a mask that only protects the other person. Numbers from 1 to 4 can indicate the ranks in the normal form payoff matrices used in game theory (Fig. 1B). In this hypothetical case, each person only cares whether the other wears a mask. Either both outcomes are best (4) if the other person wears a mask, or both are worst (1) if the other person does not wear a mask.

Key aspects of the methods can be explained using even simpler preference structures in which each actor prefers a single outcome. Simplification of 2 × 2 games into matrices with ties for the three lowest-ranked outcomes identifies basic archetypes (Fig. 1C and Table 1; Appendix 1). Each actor prefers a single outcome (shown as 4) and is indifferent among the other three outcomes. If the best outcomes are in the same cell, there is agreement on the same win-win outcome. Diagonally opposed preferences create discord, which, in repeated interaction, might be resolved by taking turns.

In symmetric games such as "Win-win" and "Discord," both actors face the same set of possible outcomes and payoffs. If they switched positions as column and row player, the choices would look the same. Payoffs from symmetric games combine to form asymmetric games. Thus, payoffs from Win-win and Discord combine to form games in which the best outcomes for each actor are either in the same row or in the same column. In this situation, if there is communication or repeated interaction, then one actor has the power to threaten to deny a good outcome for the other unless there is an acceptable agreement such as taking turns to

Table 1. Basic archetypes. In these archetypes, there is one preferred outcome ("like") for each actor.

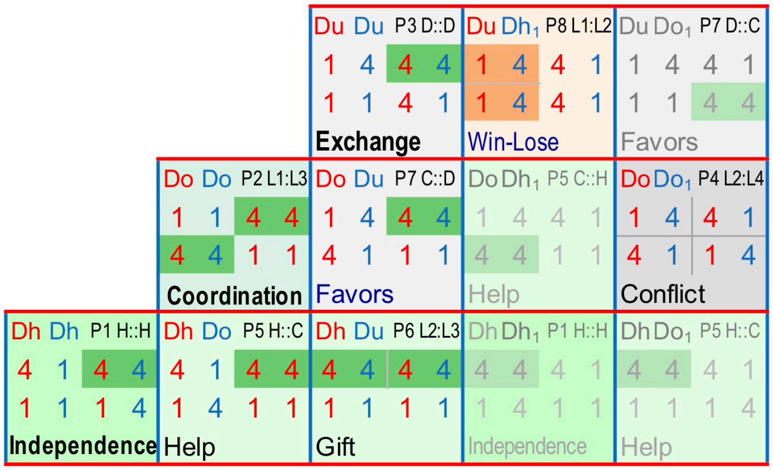
Archetype name	Archetype description	2×2ID†
Basic Win-Win	"One best way;" best outcomes for both actors in a single cell; a single attractor	BhBh, Basic Harmony
Basic Discord	"We disagree;" opposed interests; best outcomes in diagonally opposite cells; for repeated interaction, reciprocity by taking turns may be a solution	BdBd, Basic Discord
Basic Threat	"Take turns, or else;" Row Threat or Column Threat; best outcomes in same row or column; asymmetry favors one actor, but the other can threaten to block unless there is an acceptable outcome, e.g. taking turns	BhBd/BdBh, Basic Harmony and Basic Discord

†Game identifiers from Bruns (2015).

get the best outcome. This potential threat resembles the "Strict Threat" game with four ranked outcomes (Guyer and Rapoport 1970). Switching position as "Row" or "Column" player forms pairs of asymmetric games. One of the two games can be treated as a representative asymmetric archetype, in this case, a "Row Threat" game, to the right (southeast) of the diagonal formed by the two symmetric games.

Asymmetric games can be located and identified using names and abbreviations for the symmetric game payoffs that combine to create their payoff structure (Fig. 1C; Bruns 2015). Interchanging columns or rows (or both) is assumed to represent the same strategic situation, i.e., a variant of the same game (Rapoport et al. 1976). Thus, for example, any game with the two highest ranked

Fig. 2. Primal archetypes. Payoff patterns from three symmetric primal archetypes for exchange, coordination, and independence combine to form asymmetric archetypes. Each row has the same payoffs for the row actor and each column has the same payoffs for the column actor. Changes in the ranking of outcomes link neighboring games, i.e., swapping a “1” and a “4.” Matrices for variants that are equivalent by interchanging rows, columns, or positions are omitted or payoffs are shaded in gray and are discussed further in Appendix 1.



outcomes together in the same cell and indifference among the lower ranked outcomes would still be a variant of Win-win. Here, we use a simplified version of Robinson and Goforth’s (2005) Cartesian-style convention, putting Row’s highest payoff in the right-hand column and Column’s highest payoff in the upper row (Row’s 4 right, Column’s 4 up). A convention for consistently displaying payoff matrices makes it easier to compare games. It is particularly helpful for the many asymmetric games that do not have an obvious “cooperative” outcome.

In coordination situations, a social convention or norm helps to select one of the possible equilibria as the preferred solution, for example, driving on the right. In the simplest coordination game, the two alternatives are equally ranked (Fig. 1D). In a second situation, one alternative is preferred and one is ranked lower (Fig. 1D). For games with three ranks, the number 3 is used to show the second-best outcome for simplicity in displaying payoff matrices and for consistency with strict games with four ranks. “Primal Coordination” models an initially arbitrary choice between a convention to keep to the left or to keep to the right. Once agreed, the convention is preferred, and the other outcome is ranked lower. This procedure breaks the ties in payoffs and changes the game. The reverse operation of making ties to show indifference among outcomes simplifies “Convention” into Primal Coordination. The operations of making and breaking ties extend to other archetypal games (see *Results* and Appendix 1).

Here, we analyze and identify archetypes in game theory payoff matrices using the operations of making ties, breaking ties, and combining payoff patterns. Symmetric payoff patterns combine to make asymmetric games, including asymmetric archetypes. Transforming payoff matrices by equalizing outcome ranks (making ties to show indifference) yields simpler archetypes. Differentiating payoff rankings (breaking ties) transforms simpler archetypes into more complex configurations.

RESULTS

We first show how the three symmetric primal archetypes combine payoff patterns to make asymmetric primal archetypes. We then show how breaking ties in primal archetypes generates families of games linked by making and breaking ties, including intermediate archetypes that exemplify important issues in collective action, such as various types of coordination and defection problems. We present a list of archetypal games that model situations of power, conflict, and cooperation as landmarks for understanding diversity in elementary strategic situations. Selected additional archetypes illustrate overlapping problems of collective action, including trust, externalities, and biased advantage and disadvantage in opportunities and results.

Primal archetypes

Simple games with two “likes” and two “dislikes”, i.e., ties for the two highest and two lowest ranked outcomes, offer interesting examples of elementary interdependence in social or strategic situations, in which each person’s outcomes may depend on what the other person does. Robinson et al. (*unpublished manuscript* https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.619.4992&rep=rep1&type=pdf) pointed out that this class of payoff structures includes “archetypal games” that exemplify collective action problems, such as the simplest coordination game. Fig. 2 (left side) shows three symmetric primal archetypes matching the situations described in the introduction. In “Primal Independence,” each player can act on their own to achieve their preference (i.e., “we go our separate ways”). Primal Coordination requires joint action to select between alternative equilibria (as in “drive on the left or on the right”). In “Primal Exchange,” each controls the partner’s outcome while having no control over their own payoff (as in “my mask protects you, your mask protects me”).

The payoff patterns for Primal Independence, Primal Coordination, and Primal Exchange combine to form five asymmetric archetypes. These asymmetric archetypes can model patterns of power, dependence, and conflict. In “Primal Help,” one actor's decision empowers the other actor to have a choice, enabling a result where both obtain their best outcome. Kelley et al. (2003) describe this result as a "helping hand." In "Primal Gift," one actor's choice determines that both reach win-win, regardless of what the other does, benevolently "making us both win." Primal Gift would also be an archetype for situations in which one person has sufficient incentive to provide a collective good, which then benefits others, what Olson (1971) called a "privileged" group. In "Primal Win-Lose," one's choice determines that the first actor gets the best outcome and the other gets the worst, a "best for me, worst for you" result. Finally, interchanging columns (or rows) for one actor in Primal Coordination and combining the resulting payoff pattern with the original pattern for Primal Coordination creates "Primal Conflict." From each outcome, one person would always prefer to change their move, creating a cyclic game. This situation is often called "Matching Pennies," based on a simple game with coins that has an equivalent payoff structure. Kelley et al. (2003) summarize this result as "match or mismatch." It represents a zero-sum conflict of completely opposed interests whereby if one person gains, the other loses.

Each row in Fig. 2 has the same pattern of payoffs for the Row actor and each column has the same pattern for the Column actor. Neighboring games are linked by payoff swaps that switch the ranking of two outcomes. This situation can be visualized as moving one of the 4s into a different cell. Swapping a 4 for Column horizontally, for example, moves to the right, turning Primal Independence into Primal Help, i.e., in the next column of games. Swapping a highest payoff (4) for Row results in moving up into the next row of games, for example, turning Primal Help into Primal Coordination. Thus, this diagram maps possible transformations between one payoff structure and another, "changing the game."

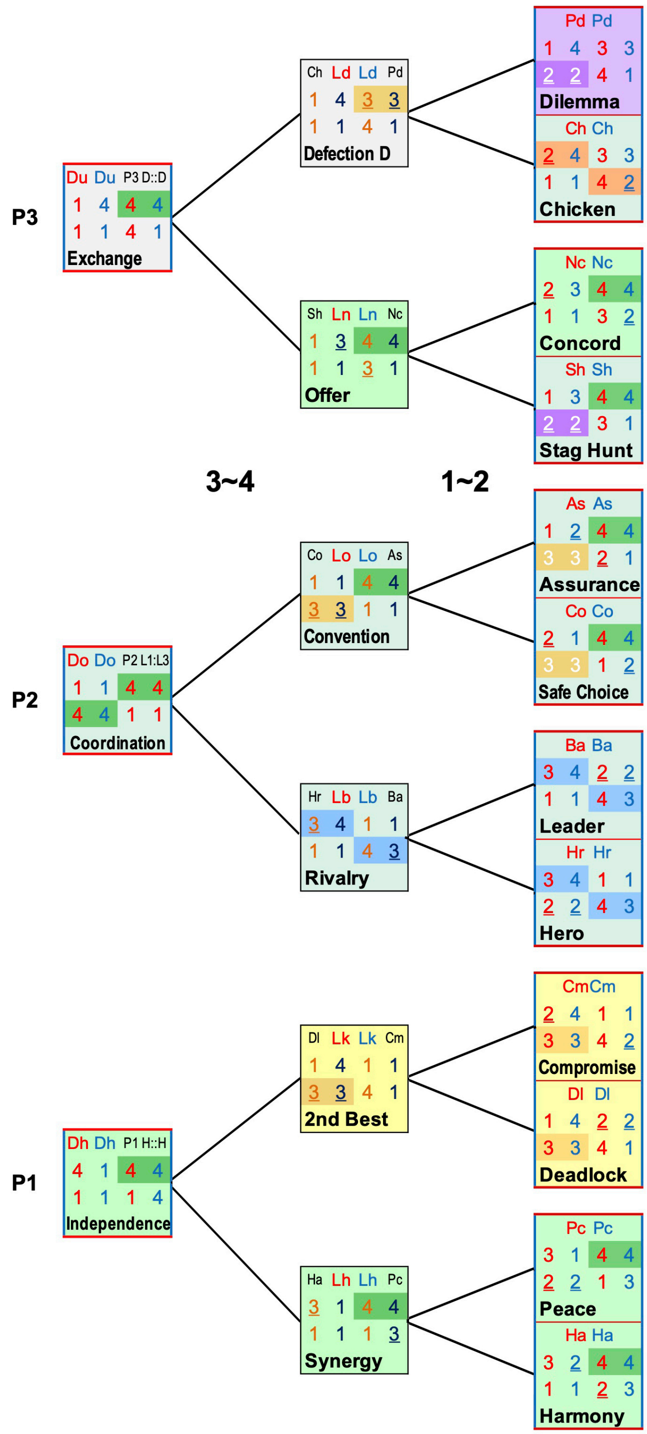
Families of archetypes

Breaking ties creates more complex games, as in the three families of descendants from primal archetypes (Fig. 3). These families contain games that differ in shared characteristics such as coordination in selecting between multiple equilibria, dominant strategies leading to a single equilibrium with relatively good results, or motivations to defect from a Pareto-optimal outcome.

Primal Coordination differentiates into a Convention game by breaking ties symmetrically for the highest ranked payoffs, so both receive a higher payoff in one of the two equilibria. This situation exemplifies conventions and norms that coordinate on a mutually preferred equilibrium outcome such as driving on the right. Schelling (1960) suggested that such situations with multiple equilibria could be resolved by identifying a prominent focal point based on some salient characteristic. In Lewis's (2002) discussion of the role of conventions, culture can provide focal points for coordination. The Convention payoff structure is sometimes known as "Hi-lo," and is used to analyze the problem of coordinating selection of an equilibrium with higher payoff for both (Gold and Colman 2020).

Breaking ties in Primal Coordination so that the equilibria have different payoffs for each actor creates games with rivalry among alternative equilibria whereby one or the other does better. Game theorists often discuss this kind of coordination problem in terms

Fig. 3. Primal archetypes generate diverse games. Breaking high ties and low ties differentiates the three symmetric primal archetypes into families of games with two equally ranked outcomes (ties) for each actor and into the 12 strict symmetric ordinal games, with four ranked payoffs and no ties. Moving from left to right, payoffs from breaking ties are underlined.



of the "Battle of the Sexes" story about two people who want to do something together but differ about what each would most like for their joint entertainment (Luce and Raiffa 1957). Such models have been used to analyze international relations between rival nations, each seeking its own advantage (Snidal 1985). In an environmental example, fishing sites may yield different production potential; to reduce unproductive conflict, lotteries to assign fishing spots could provide a coordination mechanism for a fair solution (Kaivanto 2018).

Convention and "Rivalry" are intermediate archetypes, with a single pair of ties for each actor, showing indifference between the two lowest ranked outcomes. Breaking ties in the lowest ranked payoffs in Rivalry then creates two strict (no ties) games with four ranked outcomes and rival equilibria ("Hero" and "Leader"). These games differ in the payoff for the actor who changes their move away from a risk-minimizing strategy that avoids the worst outcome for both. In one situation, the Leader does best, whereas in the other situation, the Hero gets second-best (Rapoport 1967).

Breaking low ties in Convention generates two games. In "Safe Choice," avoiding risk also maximizes payoff. However, in "Assurance," if both players cooperate, they can both get the best outcome; however, there is a risk of getting the worst outcome if the other player does not cooperate, so cooperation conflicts with caution. This game (and "Stag Hunt," discussed below) can model issues such as trust and thresholds (tipping points/critical mass) for cooperation in general (Sen 1967, Skyrms 2003), among herders (Runge 1981, Cole and Grossman 2010), for political mobilization (Heckathorn 1996, Oliver and Marwell 2001), and in irrigation technology adoption (Müller et al. 2018).

Breaking high ties in Primal Independence generates another family of games. In "Synergy," cooperation makes both players better off. Alternatively, breaking ties in Primal Independence generates a situation with a "Second-Best" equilibrium. Breaking low ties in Second-Best generates descendant games that differ in the alignment of the two lowest ranked payoffs: "Deadlock" and "Compromise." In either case, the equilibrium with second-best payoffs is also the least risky choice. In this case, it is also the choice that offers a chance of getting the best outcome if the other player makes a mistake ("trembling hand").

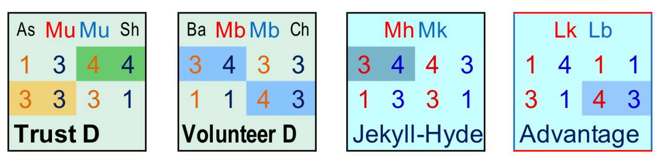
Primal Exchange, in which each player controls the partner's fate, differentiates to form the three most famous and well-studied 2 × 2 models of collective action: Prisoner's Dilemma, "Chicken," and Stag Hunt. In these social dilemmas (broadly defined), selfish motives conflict with cooperation (Dawes 1980, Kollock 1998, Van Lange et al. 2014). In Prisoner's Dilemma, incentives lead away from cooperation to converge on an inferior equilibrium outcome. A narrow definition of social dilemmas would be restricted to situations in which dominant strategies lead to an inferior equilibrium, and further restricted to those in which both players "cooperating" would be better than taking turns "defecting." However, social dilemmas are often discussed more loosely in terms of a variety of conflicts between individual and collective interests and temptations to defect from cooperation. These dilemmas are often discussed as free-rider problems (Olson 1971). In Chicken, incentives lead away from cooperation to rival equilibria in which one or the other player does best and the other gets second-worst, but with the risk of both getting the worst outcome. Stag Hunt poses a conflict between cooperation to get the outcome that is best for both vs. cautious risk avoidance leading to second-worst for both, similar to the Assurance problem discussed above (Medina 2007). The fourth descendant of Primal Exchange, "Concord," is called "Max-Diff" by social psychologists. In this situation, dominant strategies could lead harmoniously to a win-win outcome. However, a competitive actor concerned with their own relative advantage and expecting the other actor to follow their dominant strategy might forego win-win, trying to get an unequal outcome in which they do relatively better (Kelley and Thibaut 1978). Such an approach risks getting caught in a spiteful dynamic of "beggar thy neighbor" in which both players end up at the worst outcome.

Starting from the three primal archetypes, breaking ties ultimately generates 12 strict symmetric ordinal games (Fig. 3, right side). Thus, differentiating each primal archetype generates a family of games descending from a common ancestor. The reverse process of simplification, i.e., making ties, creates simpler intermediate games, which can be seen as lying "in between" the strict games. In Appendix 1, we further describe asymmetric descendants for all the primal archetypes and relationships between the resulting families of models within the topology of 2 × 2 games.

Archetypal games

We summarize names and brief descriptions for eight primal archetypes and eight intermediate archetypes in Table 2. This summary combines games derived by simplification or differentiation (Figs. 2 and 3) along with a few additional archetypes (Fig. 4). The 2 × 2 game identifiers use a binomial nomenclature based on how payoff patterns for the 38 symmetric ordinal 2 × 2 games combine to form asymmetric games (Table 2; Bruns 2015). This nomenclature provides a way to identify ordinal games uniquely, including cases in which the same ordinal payoff structure may be discussed using different names, as with Chicken, "Hawk-Dove," and "Snowdrift."

Fig. 4. Payoff matrices for additional intermediate archetypes: Trust Dilemma (Rousseau's Hunt), Volunteer's Dilemma, Jekyll-Hyde, and Advantage.



Kelley et al. (2003) illustrate the situations (entries) in *An Atlas of Interpersonal Situations* using payoff matrices with various values. Standardizing payoff ranks to 1–4 and aligning best payoffs (with Row's 4 right and Column's 4 up) makes ordinally equivalent matrices that facilitate identifying and comparing games (Robinson and Goforth 2005, Bruns 2015). Appendix 1 (Fig. A10) presents ordinal equivalents for the atlas entries. Standardizing the payoff matrices shows that the examples of the three "single-component" games of independence, coordination, and exchange identified by Kelley et al. (2003) have the same ordinal structure as the simple archetypal games identified by

Table 2. Primal and intermediate archetypes.

Code	Archetype name	Archetype description	2×2ID†	AIS code‡	Payoff matrix§
P1	Primal Independence	"We go our separate ways;" all incentives lead to win-win; each actor controls their own outcome; AIS: BAC Bilateral Actor (Reflexive) Control	DhDh, Double Harmony	1	2, 3, A2, A4, A7–10
P1.1	Synergy	"Best together;" fully aligned incentives lead to a win-win outcome for both actors; between Harmony and Peace; AIS: Cooperation	LhLh, Low Harmony	p. 85	3, A2, A4, A6, A8
P1.2	Second-Best	"Good enough;" dominant strategies lead to compromise on second-best; between Deadlock and Compromise	LkLk, Low Lock	—	3, A2, A4, A6, A8, A9
P2	Primal Coordination	Joint control; "getting in sync;" selection between equally good equilibria; AIS: Corresponding Mutual Joint (Behavior) Control	DoDo, Double Coordination	3	1–3, A1, A4, A6–10
P2.1	Convention	Norm; Hi-Lo; "drive on the right;" two equilibria, one is better for both actors, payoff-dominant; between Safe Choice and Assurance	LoLo, Low Coordination	(3)	1, 3, A1, A4–6, A8–10
P2.2	Rivalry	"Whose favorite?" One or the other actor does best at rival equilibria; between Hero and Leader; AIS: Hero "Let's do it your way"	LbLb, Low Battle	8	3, A1, A4, A6, A8
P3	Primal Exchange	"I'll scratch your back if you scratch mine;" each actor controls the other's outcome; win-win focal point; AIS: MPC Mutual Partner (Fate) Control	DuDu, Double Hunt	2	1–3 A2, A4, A6–8, A10
P4	Primal Conflict	Matching Pennies; "match or mismatch;" zero-sum game of complete conflict: one actor's gain is always the other's loss; cyclic: someone always wants to change their choice (Double Coordination and Interchanged Double Coordination, interchanging rows or columns); AIS: Conflicting Mutual Joint (Behavior) Control	$DoDo_1$	4	2, A1, A4, A7, A10
P5	Primal Help	"Helping hand;" dominant strategy enables the other actor also to choose to win	DhDo	11.2, p. 258	2, A2, A4, A7, A10
P5.1	Advantage	"The lion's share;" actor with dominant strategy does better; power pays off	LkLb/LbLk, Low Lock and Low Battle	—	4
P6	Primal Gift	Benevolence; "you make us both win;" dependent win-win; privileged group; dominant strategy ensures both win; AIS: Concordant unilateral dependence	DhDu	p. 48	2, A1, A4, A7, A10
P7	Primal Favors	"Returning the favor;" one actor can ensure the other wins, in which case, the other can also make the first win; a cross between coordination and exchange; one has partner control while the other has joint control; AIS: Asymmetric dependence	DoDu	p. 48–49	2, A2, A4, A6, A7, A10
P8	Primal Win-Lose	Frustration; vanquish; "best for me, worst for you;" dominant strategy makes other actor lose; parental override in "desert only after dinner" (Double Hunt and Interchanged Double Harmony, interchanging rows and columns); AIS: Discordant unilateral dependence	$DuDh_1$	11.1	2, A1, A4, A7, A10
Additional middle ties archetypes					
M1	Trust Dilemma	Rousseau's Hunt; "work together?" caution conflicts with cooperation; assurance problem of mutual trust; avoiding the worst outcome (maximin strategy) leads to the Pareto-inferior equilibrium; choosing the cooperative move if the other actor does not is worst; indifferent about other actor's outcome; between Assurance and Stag Hunt. AIS: Conjunctive Interdependence; "together we can do it"	MuMu, Middle Hunt	9	4, A4, A6, A8–10
M2	Volunteer's Dilemma	"Let George do it;" everyone wants it done, but prefers that someone else pays the cost; between Chicken and Leader; AIS: Disjunctive Interdependence	MbMb, Middle Battle	10	4, A4, A6, A8, A10
M3	Jekyll-Hyde	Middle Threat; "one kind, one cruel;" incentives induce positive externalities by one actor and negative externalities by the other; dominant strategies lead to one actor doing better, but the other actor can threaten to make both worse off unless given a more equitable result, e.g., by taking turns or changing the rules to make a win-win game; AIS: Threat; "trading loyalty for justice"	MhMk/MkMh, Middle Hunt and Middle Lock	6	4, A10

†Game identifiers from Bruns (2015).
‡Game (or its strategic issues) discussed under this entry code or page number in Kelley et al. (2003).
§Numbers refer to associated figures in the paper and Appendix 1.

Robinson et al. (*unpublished manuscript* https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.619.4992&rep=rep1&type=pdf).

More generally, a standardized way of presenting payoffs makes it easier to see the relationships between different games and to compare research from different sources (Robinson and Goforth 2005, Bruns 2015). We put the games identified by Kelley et al. (2003) into context by showing how different games are systematically related through recombining payoff patterns and making and breaking ties. The topology of payoff swaps in 2 × 2 games (Robinson and Goforth 2005), and the "periodic table" display (Appendix 1), offer a visualization that elegantly displays a complex pattern of overlapping relationships. This framework improves on the branching taxonomy suggested by Rapoport et al. (1976) and maps the overlapping properties categorized by Holzinger (2008; see also Holzinger, *unpublished manuscript* https://doi.org/10.2139/ssrn.399140). Families of archetypal games can offer a somewhat simpler way to see and understand these relationships among different 2 × 2 game theory models. In Appendix 1, we discuss additional ways of analyzing how the potential for cooperative solutions varies between social situations, including dimensions for best response Nash equilibria, coordination, and externalities (Guisasola and Saari 2020).

Several of these archetypal games have also been highlighted by previous researchers. In their synthesis of research on 2 × 2 games, Rapoport et al. (1976) concentrated on strict games (those without ties). However, they also included the payoff structure for Primal Exchange as one of the few non-strict games (games with ties), listed as game #79. They listed Primal Coordination as game #85. Aruka (2001) analyzed Primal Exchange as the Avatamsaka game.

In addition to primal archetypes, we list selected intermediate archetypes that exemplify important situations for collective action (Table 2). These situations include synergy from aligned incentives, compromise on second-best, conventions favoring one of multiple equilibria, and rivalry over alternative equilibria. The payoff structure of the "Defection Dilemma" (between Prisoner's Dilemma and Chicken in Fig. 3) has occasionally been noted in game theory literature, for example, by Rapoport et al. (1976). However, it does not seem to have been applied much for analyzing collective action. For this reason, Defection Dilemma, and the "Offer" game (between Concord and Stag Hunt) are not listed as intermediate archetypes. However, the topology of 2 × 2 games provides a framework that analysts can use to identify additional archetypes to suit their needs. For example, some descendants of Primal Exchange and Primal Combination are cyclic but have Pareto-optimal outcomes that offer attractive focal points for cooperation (Appendix 1).

When primal archetypes differentiate by breaking ties, their emergent properties converge in some cases, despite starting from different primal archetypes. Primal Exchange differentiates into Stag Hunt, which entails a coordination conflict between risk and trust, similar to Assurance, even though Assurance descends from Primal Coordination. Making middle ties (equalizing the second- and third-ranked outcomes) creates an intermediate game between Assurance and Stag Hunt. In a sense, this game bridges the border between two archetypal families, revealing the process of emergent convergence in the properties of 2 × 2 game theory models. This game (see Fig. 4) represents an intermediate archetype for Assurance and Stag Hunt problems of mutual trust, a "Trust Dilemma." Rousseau (2004) described a hunter choosing between the certainty of getting a hare or sharing a stag if the others cooperate. With no concern for the other's outcome, the remaining outcomes would be ranked equally (Rousseau 2004). Hence, this Trust Dilemma (Cronk and Leech 2013) could also be called "Rousseau's Hunt."

Primal Exchange also differentiates into Chicken, which shares the problem of coordination between rival equilibria with Leader and Hero, another example of emergent convergence. Forming middle ties between Chicken and Leader makes "Volunteer's Dilemma" (see Fig. 4), in which all players would like something done but prefer that the other player does it (Diekmann 1985). Volunteer's Dilemma was also one of the entries in *An Atlas of Interpersonal Situations* (Kelley et al. 2003). Volunteer's Dilemma also bridges between families descended from Primal Coordination and Primal Exchange.

Asymmetry, mismatched externalities, and structural bias

Because many situations in life are not symmetric in terms of opportunities or results, asymmetric games deserve more attention for understanding social situations and collective action (Thurow 1975, Ernst 2005, Hauser et al. 2019, Nockur et al. 2020). Asymmetry is relevant to relationships of inequality such as parent-child, teacher-student, supervisor-subordinate, principal-agent, and ruler-ruled, and is also relevant to differences related to factors including, but not limited to, power, knowledge, gender, race, ethnicity, class, education, productivity, and wealth. Examples in social-ecological systems include head- and tail-enders in irrigation (Ostrom and Gardner 1993, Janssen et al. 2011), and unequal access to electricity supply for irrigation pumps (Kimmich 2013).

"Jekyll-Hyde" (see Fig. 4) is a particularly interesting asymmetric game discussed by Kelley et al. (2003) in terms of threat dynamics and has distinctive externalities analyzed by Robinson and Goforth (2005). Robinson and Goforth (2005) examined how the arrangement of incentives and externalities could create common or conflicting interests, systematizing earlier work by Schelling (1960) and building on Greenberg's (1990) analysis of inducement correspondences. In contrast to situations of pure common interest or complete conflict, Robinson and Goforth (2005) identified "Type" games, such as the payoff structure in Jekyll-Hyde, which exemplify mismatched situations. For each of the other person's choices, one actor's incentives always induce moves that give the other a higher payoff, whereas the other person's incentives always induce moves that give the first person a lower payoff. One person's choices would always have positive externalities and the other's choices would always have negative externalities. In a sense, incentives make one cruel and one kind, one harms and one helps.

In Jekyll-Hyde, both players have dominant strategies, and this structure favors one actor who gets their best outcome while the other does worse. Kelley et al. (2003) analyze this situation in terms of the threat that the other actor might be able to make. This situation resembles the Basic Threat game discussed earlier and the Strict Threat game studied by Guyer and Rapoport (1970). In some cases, the actor who does worse might accept the inequality as an act of "loyalty." However, with communication or repeated interaction, the disadvantaged actor might threaten to deprive the first actor of their best outcome unless given a more equitable result, i.e., "justice." An agreeable solution might be achieved, for example, by taking turns, using side payments, or changing rules to transform the situation into a win-win game.

In the asymmetric game "Advantage," only one actor has a dominant strategy and they end up doing best at equilibrium. This is a descendant of Primal Help. Advantage can reflect a crude model of rent-based accumulation in which "the rich get richer." It is an intermediate archetype for the "Protector" game used by Snyder and Diesing (1978) in their models of international relations. Advantage and Jekyll-Hyde are part of a large set of what we call "bias games." In this type of asymmetric situation, dominant strategies for one or both actors create a single equilibrium that favors one actor while the other does worse.

These have been called “suasion games” (Martin 1992) because the dissatisfied or “aggrieved” (Stein 1982) actor may try to change the game through persuasion or other means. They have also been called “Rambo” games (Zürn 1993, Hasenclever et al. 1997, Holzinger 2008) because one actor can get their way without having to compromise.

Asymmetric situations with an unequal equilibrium outcome can make the disadvantaged actor want to find a way to change the outcome, by persuasion, threats, requesting compensatory side payments, or changing the rules to obtain a better outcome. In the topology of possible 2 × 2 games (Appendix 1), bias games, i.e., those with dominant strategies leading to unequal outcomes at a single equilibrium, are more common than games with equal equilibrium payoffs. In the payoff space of possible 2 × 2 games, the inequality (distributional) problems of bias games, as exemplified by Advantage and Jekyll-Hyde, are much more prevalent than the efficiency problems of Pareto-inferior equilibria in tragic dilemmas and assurance problems. Bias games are another example of how a better menu of models can contribute to understanding institutional diversity in power, conflict, and unequal results.

The 2 × 2 games show cross-cutting problems of collective action (Holzinger 2008): failure or success in achieving Pareto-optimal results; assurance or disagreement problems in choosing among multiple equilibria; and unequal distribution of benefits; as well as instability and zero-sum conflict. The topology of payoff swaps in 2 × 2 games displays similar differences between games according to the presence, Pareto-efficiency, and distribution of equilibrium payoffs (Robinson and Goforth 2005, Bruns 2015). Analysis of archetypes (e.g., Fig. 3; Figs. A1 and A2 in Appendix 1) reveals how families of games descended from primal archetypes display overlapping types of collective action problems:

- Risk and rivalry in coordinating equilibrium selection,
- Dealing with damaging externalities of defection from exchange,
- Settling for the good or pursuing the best amidst partial harmony,
- Coping with instability and opposed (zero-sum) interests,
- Finding feasible focal points for cooperation in the absence of stable equilibrium solutions, and
- Structural advantage and disadvantage generating inequality.

DISCUSSION

Archetypes in changing systems

Archetypes have been applied to recognize and analyze recurrent patterns in the dynamics of systems (Senge 1990, Kim and Anderson 1998). In systems dynamics, archetypes highlight typical positive and negative feedback loops. Overuse and deterioration of a shared resource, as in a tragedy of the commons, is one archetype; another is competitive escalation of threatening actions with potential collapse, as in the game of Chicken; a third is breakdown in trust, as in Stag Hunt and Assurance problems. Archetypal patterns show how deliberate actions can have unintended consequences. Reinforcing feedbacks can create additional problems, whereas balancing feedbacks can restrict achievement. System archetypes reveal how a more holistic perspective, looking over time and across boundaries, may help in designing suitable solutions (Wolstenholme 2003). System archetypes offer generic models of processes that can be adapted to analyze current conditions or assess planned changes (Braun, *unpublished manuscript* https://www.albany.edu/faculty/gpr/PAD724/724WebArticles/sys_archetypes.pdf). Transformations between archetypes illustrate changes in the structure and dynamics of systems (Greenwood and Hinings 1993).

As examples for social-ecological systems, analysis using system archetypes can offer a holistic understanding of limits to growth and related tragedy of the commons problems in water resources management, providing insights into options for management and monitoring (Bahaddin et al. 2018). Comparative analysis of pasture social-ecological systems illustrates how archetypes can provide more general insights into the dynamics of problems and potential solutions, including whether archetypes of different system problems are linked or independent (Neudert et al. 2019). As with generic system dynamics archetypes, the archetypal games identified here can provide a menu of models for use in analyzing social-ecological systems.

Archetypal models of interdependence offer insights into incentive structures, their dynamics, and potential transformations. Archetypes can help to go beyond a tendency to concentrate on the (often misdiagnosed and not inevitable) tragedy of the commons and its two-person analog, Prisoner’s Dilemma, and instead consider a broader range of models for situations and the challenges and opportunities they pose for environmental governance, including, but not limited to, various coordination and defection problems. Archetypes can act as building blocks or components to understand forces favoring and hindering cooperation, not only for static equilibrium situations, but also as archetypal models of potential pathways for transformation, such as the following.

- Aligned incentives for independent action may shift to yield synergy whereby cooperation makes both actors better off or may transform toward compromise to settle on second-best;
- Norms facilitate coordination. However, coordination problems could turn into contestation over rival options or tension between cautious risk avoidance and trust that could assure cooperation, such as investing in a new technology. For example, although there may be an official requirement to adopt quality-approved irrigation pumps, farmers may stick with poor-quality pumps when nobody else conforms, leaving all in a low-equilibrium trap of a deteriorating electricity system (Kimmich 2013);
- Social dilemmas and other descendants from Primal Exchange share incentive structures in which individuals are motivated to defect from cooperation. They also share an underlying interdependency of actors’ power over each other’s outcomes. For repeated interaction, this situation may provide the power to create cooperation, as in the simple check-and-balance reciprocity embodied in tit-for-tat (Axelrod 1984) or through more sophisticated strategies

(Press and Dyson 2012). Transformation into a Stag Hunt or Concord situation may offer an escape from defection problems in social dilemmas, such as controlling emissions of greenhouse gasses to cope with climate change (Bruns 2022);

- Asymmetric power could be arranged to enable, to benevolently ensure, or to paternalistically prohibit a desired outcome. The arrangement of power may also shift between these and other structures, for example, from benevolent despotism to authority that allows at least a semblance of choice (a "Hobson's choice") or more genuinely empowering assistance (Ellerman 2005);
- Action that also helps another person to succeed, resulting in success for both, could turn into a more unbalanced relationship in which one or the other does better. A repeated version of the Advantage game illustrates the positive feedback loops of the "success to the successful" systems dynamics archetype (Kim and Anderson 1998) in which "the rich get richer," amplifying inequality as one person gets "the lion's share," and;
- Advantage, Jekyll-Hyde, and other bias games illustrate how structural incentives that lead to unsatisfactory outcomes may stimulate efforts to change the situation. Asymmetric incentive structures often lead toward unequal results that could encourage attempts to negotiate, resist, exit, or change the rules and results of the game.

Organizational configurations in an ecology of games

Researchers have used archetypes to characterize businesses and other organizations and the relationships between organizations. Such archetypes comprise sets of variables based on typologies deduced from theoretical concepts or from taxonomies inductively based on empirical observation (see reviews by Miller and Friesen 1978, Greenwood and Hinings 1993, Meyer et al. 1993, Short et al. 2008, Misangyi et al. 2017). The difference between coordination and defection problems appears in how relationships within or between firms may depend on convergent or divergent incentive structures (Grandori 1997, Meuer 2014). In situations with convergent incentives (as with descendants of Primal Coordination and Primal Independence), communitarian strategies that emphasize information sharing, teamwork, coordination, and trust may lead to better performance. Other situations have divergent incentives, such as temptations to defect from cooperation (as with descendants of Primal Exchange). These situations might be controlled better through bureaucratic structures and procedures if problems and outcomes are predictable. However, when situations with divergent incentives are more complex or outcomes are more uncertain, an alternative solution may be to create shared incentives through ex-post benefits from property rights, as in a joint venture.

Qualitative comparative analysis provides a way to analyze organizational archetypes in different situations, looking at strategic configurations of organization attributes together with information on contexts and performance. As a means of understanding institutional diversity, qualitative comparative analysis can examine which sets of conditions are causally necessary or sufficient for outcomes and which are complements or substitutes, for example, in assessing the effectiveness of organizational strategies (Ragin 2008, Fiss et al. 2013, Grandori and Furnari 2013, Greckhamer et al. 2018, Villamayor-Tomas et al. 2020). Qualitative comparative analysis and game theory can also be used to study networks of games in social-ecological systems (Kimmich and Villamayor-Tomas 2019).

Differences may exist in the prevalence of coordination or defection problems in an interorganizational ecology of games in water governance, and such problems could affect the choice of institutions for coping with such challenges (Long 1958, Berardo and Scholz 2010, Lubell et al. 2010, Berardo and Lubell 2019). Thus, in networks of organizations, relationships may mainly concern building bridging social capital for mutual understanding and trust between groups or may instead emphasize bonding social capital within groups to overcome temptations to defect from cooperation. When adjacent action situations are interdependent in networks (McGinnis 2011), different situations may face different problems for collective action, and solving coordination problems may also resolve adjacent social dilemmas (Kimmich and Sagebiel 2016, Kimmich and Villamayor-Tomas 2019). Archetypal configurations and their potential prevalence in different contexts may help to explain observed patterns of organizational behavior, illuminate challenges and potential solutions, and contribute to designing improved institutions and monitoring their outcomes.

Elementary patterns of power in governance

The primal archetypes exemplify various forms of power: "power to," "power with," and "power over." Primal Independence exemplifies "power to" as capability or freedom to act independently on one's own (Sen 2000, Nussbaum 2011). Primal Coordination typifies "power with" to achieve mutual outcomes through cooperation (Follett 1924, Ostrom 1997), as in joint production and coproduction. The symmetrically balanced power in Primal Exchange is technically a reciprocal form of "power over." However, as long as it stays balanced, it could function as "power with" to obtain mutual gains in an equitable partnership. Maintaining such a potentially precarious balance could depend on mutual adjustment, including voice and exit, as with responsive governance and availability of competitive options (Polanyi 1951, Ostrom et al. 1961, Hirschman 1970). "Power with" could also occur if "power over" is combined with "power with" in an asymmetric but still somewhat balanced way, as when coordination and exchange payoff patterns blend together in Primal Favors. One partner could ensure that the other partner gets a best outcome, but they need to have the favor returned through the other's choice. Primal Favors could also generate a variety of asymmetric situations with more unequal results (see Appendix 1). Another three primal games offer exemplars of asymmetric "power over": enabling a choice to win in Primal Help, determining that both actors win in Primal Gift, or determining that one actor gets their best outcome and the other their worst in Primal Win-Lose.

The three symmetric primal archetypes also offer elementary models of principles for organizing social order based on liberty, association, and exchange. Asymmetric power could enable autonomy, ensure a benevolent outcome, or despotically determine who wins and who loses. The primal archetypes for asymmetric power can model governance in ruler-ruled relationships in which the choices of rulers who hold power (executive, governor, collective choice in a legislature, parent, etc.) grant permission, impose a preferred outcome, or prohibit someone from getting their preference. In institutional grammar, deontic rules determine whether someone subject to the rules may, must, or must not do something (Crawford and Ostrom 1995). Thus, archetypal games illustrate elementary relationships that shape social order and governance. These relationships contrast with the cyclic instability and zero-sum opposition of interests in Primal Conflict, as in a “war of all against all” (Hobbes 1651, Ostrom et al. 1992, Ostrom 1997). Archetypal games offer models to help understand and diagnose governance relationships while showing how simple archetypes generate a diversity of more complex situations.

CONCLUSIONS

Analysis of archetypal games affirms the value of distinguishing coordination problems of equilibrium selection from defection problems in social dilemmas and similar situations while tracing how various kinds of coordination or defection problems are related. In turn, these archetypes are part of a larger diversity of situations that pose challenges and opportunities for collective action, including cyclic conflict, asymmetric power, and structural advantage and disadvantage in opportunities and results. Archetypal games show convergence of ideas and potential for further application in understanding transformations in system dynamics; coordination, defection, and other types of problems among networked organizations; best response, coordination, and externality dimensions of behavior in situations of interdependence; and diversity of elementary patterns of power in governance.

Making ties (indifference) between two outcomes for each actor in strict ordinal 2×2 games forms archetypes for harmony, social conventions and norms, compromise on second-best, rivalry, Assurance/Stag Hunt tensions between caution and trust in cooperation, and structural bias of advantage and disadvantage. Simplifying payoff rankings to like two outcomes and dislike two outcomes yields three primal archetypes for independence, coordination, and exchange. These symmetric patterns of power combine to create asymmetric models for conflict and structures of power and dependence. Breaking ties differentiates primal archetypes to generate further diversity in interdependence. Half of the primal archetypes generate strict games with relatively good results at equilibrium (best or second-best) while the other half generate a diverse and less stable set of games, most of which yield poor outcomes or severe inequality. Families of games that are descended from primal archetypes display overlapping collective action problems, including risk and rivalry in equilibrium selection, externalities of defection from exchange, partial harmony of good and best, zero-sum opposition of interests, focal points for cooperation, and the prevalence of unequal outcomes at equilibrium.

Simple two-person two-choice games, with ties showing indifference between outcomes, model archetypal situations of interdependence. These archetypes offer insights into similarities, diversity, and potential transformations in social-ecological systems, challenges for cooperation in resource management, and opportunities for improving environmental governance. Archetypes offer starting points and building blocks for understanding more complex situations, networks of action situations, and comparative analysis. Archetypal games can help expand thinking and analysis beyond a few famous games and trace cascading connections in a menu of models for thinking about the diversity and dynamics of interdependent relationships.

Responses to this article can be read online at:
https://www.ecologyandsociety.org/issues/responses.php/12668

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Data Availability:

Appendix 1 and other supplementary information, including spreadsheets with data and figures, are openly available in the osf.io repository at https://doi.org/10.17605/OSF.IO/XTR4N.

LITERATURE CITED

Aruka, Y. 2001. Avatamsaka game structure and experiment on the web. Pages 115-132 in Y. Aruka, editor. Evolutionary controversies in economics: a new transdisciplinary approach. Springer, Tokyo, Japan. https://doi.org/10.1007/978-4-431-67903-5

Axelrod, R. 1984. The evolution of cooperation. Basic Books, New York, New York, USA.

Bahaddin, B., A. Mirchi, D. Watkins Jr., S. Ahmad, E. Rich, and K. Madani. 2018. System archetypes in water resource management. Pages 130-140 in World environmental and water resources congress 2018: watershed management, irrigation and drainage, and water resources planning and management. American Society of Civil Engineers, Reston, Virginia, USA. https://doi.org/10.1061/9780784481400.012

Berardo, R., and M. Lubell. 2019. The ecology of games as a theory of polycentricity: recent advances and future challenges. Policy Studies Journal 47(1):6-26. https://doi.org/10.1111/psj.12313

Berardo, R., and J. T. Scholz. 2010. Self-organizing policy networks: risk, partner selection, and cooperation in estuaries. American Journal of Political Science 54(3):632-649. https://doi.org/10.1111/j.1540-5907.2010.00451.x

Bicchieri, C. 2005. The grammar of society: the nature and dynamics of social norms. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9780511616037

Bisaro, A., and J. Hinkel. 2016. Governance of social dilemmas in climate change adaptation. Nature Climate Change 6 (4):354-359. https://doi.org/10.1038/nclimate2936

Bruns, B. 2015. Names for games: locating 2 × 2 games. *Games* 6 (4):495-520. https://doi.org/10.3390/g6040495

Bruns, B. 2022. Transforming climate dilemmas from tragedy to cooperation. In S. R. Foster and C. F. Swiney, editors. The Cambridge handbook of commons research innovations. Cambridge University Press, Cambridge, UK. *In press.* [online] URL: https://www.cambridge.org/us/academic/subjects/law/environmental-law/cambridge-handbook-commons-research-innovations?format=HB

Cole, D. H., and P. Z. Grossman. 2010. Institutions matter! Why the herder problem is not a prisoner's dilemma. Theory and Decision 69(2):219-231. https://doi.org/10.1007/s11238-008-9121-3

Crawford, S. E. S., and E. Ostrom. 1995. A grammar of institutions. American Political Science Review 89(3):582-600. https://doi.org/10.2307/2082975

Cronk, L., and B. L. Leech. 2013. Meeting at Grand Central: understanding the social and evolutionary roots of cooperation. Princeton University Press, Princeton, New Jersey, USA.

Cullum, C., G. Brierley, G. L. W. Perry, and E. T. F. Witkowski. 2017. Landscape archetypes for ecological classification and mapping: the virtue of vagueness. Progress in Physical Geography: Earth and Environment 41(1):95-123. https://doi.org/10.1177/0309133316671103

Curry, O. S., D. Hare, C. Hepburn, D. D. P. Johnson, M. D. Buhrmester, H. Whitehouse, and D. W. Macdonald. 2020. Cooperative conservation: seven ways to save the world. Conservation Science and Practice 2(1):e123. https://doi.org/10.1111/csp2.123

Dawes, R. M. 1980. Social dilemmas. Annual Review of Psychology 31:169-193. https://doi.org/10.1146/annurev.ps.31.020180.001125

Diekmann, A. 1985. Volunteer's dilemma. Journal of Conflict Resolution 29(4):605-610. [online] URL: https://www.jstor.org/stable/174243

Eisenack, K., S. Villamayor-Tomas, G. Epstein, C. Kimmich, N. Magliocca, D. Manuel-Navarrete, C. Oberlack, M. Roggero, and D. Sietz. 2019. Design and quality criteria for archetype analysis. Ecology and Society 24(3):6. https://doi.org/10.5751/ES-10855-240306

Ellerman, D. 2005. Helping people help themselves: from the World Bank to an alternative philosophy of development assistance. University of Michigan Press, Ann Arbor, Michigan, USA. https://doi.org/10.3998/mpub.93546

Ernst, Z. 2005. A plea for asymmetric games. Journal of Philosophy 102(3):109-125. [online] URL: https://www.jstor.org/stable/3655705

Fiss, P. C., A. Marx, and B. Cambré. 2013. Configurational theory and methods in organizational research: introduction. Pages 1-22 in Configurational theory and methods in organizational research. Emerald, Bingley, UK. https://doi.org/10.1108/S0733-558X(2013)0000038005

Follett, M. P. 1924. *Creative experience*. Longmans, Green and Company, New York, New York, USA. https://doi.org/10.1037/14781-000

Gold, N., and A. M. Colman. 2020. Team reasoning and the rational choice of payoff-dominant outcomes in games. Topoi 39 (2):305-316. https://doi.org/10.1007/s11245-018-9575-z

Grandori, A. 1997. An organizational assessment of interfirm coordination modes. Organization Studies 18(6):897-925. https://doi.org/10.1177/017084069701800601

Grandori, A., and S. Furnari. 2013. Configurational analysis and organization design: towards a theory of structural heterogeneity. Pages 77-105 in P. C. Fiss, B. Cambré, and A. Marx, editors. Configurational theory and methods in organizational research. Emerald, Bingley, UK. https://doi.org/10.1108/S0733-558X(2013)0000038008

Greckhamer, T., S. Furnari, P. C. Fiss, and R. V. Aguilera. 2018. Studying configurations with qualitative comparative analysis: best practices in strategy and organization research. Strategic Organization 16(4):482-495. https://doi.org/10.1177/1476127018786487

Greenberg, J. 1990. The theory of social situations: an alternative game-theoretic approach. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9781139173759

Greenwood, R., and C. R. Hinings. 1993. Understanding strategic change: the contribution of archetypes. Academy of Management Journal 36(5):1052-1081. https://doi.org/10.2307/256645

Guisasola, S., and D. Saari. 2020. With potential games, which outcome is better? Games 11(3):33. https://doi.org/10.3390/g11030033

Guyer, M., and A. Rapoport. 1970. Threat in a two-person game. Journal of Experimental Social Psychology 6(1):11-25. https://doi.org/10.1016/0022-1031(70)90073-9

Hasenclever, A., P. Mayer, and V. Rittberger. 1997. Theories of international regimes. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9780511521720

Hauser, O. P., C. Hilbe, K. Chatterjee, and M. A. Nowak. 2019. Social dilemmas among unequals. Nature 572:524-527. https://doi.org/10.1038/s41586-019-1488-5

Heckathorn, D. D. 1996. The dynamics and dilemmas of collective action. American Sociological Review 61(2):250-277. https://doi.org/10.2307/2096334

Heilig, S. 2011. When prisoners enter battle: natural connections in 2 × 2 symmetric games. Honor's thesis, Saint Peter's College, Jersey City, New Jersey, USA. [online] URL: https://repository.saintpeters.edu/concern/peacock_scholarships/vt150j30b?locale=en

Hirschman, A. O. 1970. Exit, voice, and loyalty: responses to decline in firms, organizations, and states. Harvard University Press, Cambridge, Massachusetts, USA.

Hobbes, T. 2002 [1651]. Leviathan: leviathan or the matter, forme, and power of a common-wealth ecclesiasticall and civill. Project Gutenberg edition. Project Gutenberg, Urbana, Illinois, USA. [online] URL: https://www.gutenberg.org/files/3207/3207-h/3207-h.htm

Holzinger, K. 2008. Transnational common goods: strategic constellations, collective action problems, and multi-level provision. Palgrave Macmillan, New York, New York, USA.

Hopkins, B. 2014. Expanding the Robinson-Goforth system for 2 × 2 games. Pages 177-187 *in* K.-D. Crisman and M. A. Jones, editors. The Mathematics of decisions, elections, and games: AMS special sessions on the mathematics of decisions, elections, and games. American Mathematical Society, Providence, Rhode Island, USA.

Janssen, M. A., J. M. Anderies, and J.-C. Cardenas. 2011. Head-enders as stationary bandits in asymmetric commons: comparing irrigation experiments in the laboratory and the field. Ecological Economics 70(9):1590-1598. https://doi.org/10.1016/j.ecolecon.2011.01.006

Kaivanto, K. 2018. Community-level natural resource management institutions: a noncooperative equilibrium example. International Journal of the Commons 12(1):548-572. https://doi.org/10.18352/ijc.847

Kelley, H. H., J. G. Holmes, N. L. Kerr, H. T. Reis, C. E. Rusbult, and P. A. M. Van Lange. 2003. An atlas of interpersonal situations. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9780511499845

Kelley, H. H., and J. W. Thibaut. 1978. Interpersonal relations: a theory of interdependence. Wiley, New York, New York, USA.

Kim, D. H., and V. Anderson. 1998. Systems archetype basics: from story to structure. Pegasus Communications, Waltham, Massachusetts, USA.

Kimmich, C. 2013. Linking action situations: coordination, conflicts, and evolution in electricity provision for irrigation in Andhra Pradesh, India. Ecological Economics 90:150-158. https://doi.org/10.1016/j.ecolecon.2013.03.017

Kimmich, C., and J. Sagebiel. 2016. Empowering irrigation: a game-theoretic approach to electricity utilization in Indian agriculture. Utilities Policy 43(B):174-185. https://doi.org/10.1016/j.jup.2016.10.002

Kimmich, C., and S. Villamayor-Tomas. 2019. Assessing action situation networks: a configurational perspective on water and energy governance in irrigation systems. Water Economics and Policy 5(01):1850005. https://doi.org/10.1142/S2382624X18500054

Kollock, P. 1998. Social dilemmas: the anatomy of cooperation. Annual Review of Sociology 24:183-214. https://doi.org/10.1146/annurev.soc.24.1.183

Legros, S., and B. Cislaghi. 2020. Mapping the social-norms literature: an overview of reviews. Perspectives on Psychological Science 15(1):62-80. https://doi.org/10.1177/1745691619866455

Lewis, D. 2002. Convention: a philosophical study. Blackwell, Oxford, UK.

Long, N. E. 1958. The local community as an ecology of games. American Journal of Sociology 64(3):251-261. https://doi.org/10.1086/222468

Lubell, M., A. D. Henry, and M. McCoy. 2010. Collaborative institutions in an ecology of games. American Journal of Political Science 54(2):287-300. https://doi.org/10.1111/j.1540-5907.2010.00431.x

Luce, R. D., and H. Raiffa. 1957. Games and decisions: introduction and critical survey. Dover, Mineola, New York, USA.

Martin, L. L. 1992. Interests, power, and multilateralism. International Organization 46(4):765-792. https://doi.org/10.1017/S0020818300033245

McAdams, R. H. 2009. Beyond the prisoners' dilemma: coordination, game theory, and law. Southern California Law Review 82(2):209-258. [online] URL: https://southerncalifornialawreview.com/2009/01/04/beyond-the-prisoners-dilemma-coordination-game-theory-and-law-article-by-richard-h-mcadams/

McGinnis, M. D. 2011. Networks of adjacent action situations in polycentric governance. Policy Studies Journal 39(1):51-78. https://doi.org/10.1111/j.1541-0072.2010.00396.x

Medina, L. F. 2007. A unified theory of collective action and social change. University of Michigan Press, Ann Arbor, Michigan, USA. https://doi.org/10.3998/mpub.168625

Meuer, J. 2014. Archetypes of inter-firm relations in the implementation of management innovation: a set-theoretic study in China's biopharmaceutical industry. Organization Studies 35 (1):121-145. https://doi.org/10.1177%2F0170840613495339

Meyer, A. D., A. S. Tsui, and C. R. Hinings. 1993. Configurational approaches to organizational analysis. Academy of Management Journal 36(6):1175-1195. https://doi.org/10.5465/256809

Miller, D., and P. H. Friesen. 1978. Archetypes of strategy formulation. Management Science 24(9):921-933. https://doi.org/10.1287/mnsc.24.9.921

Misangyi, V. F., T. Greckhamer, S. Furnari, P. C. Fiss, D. Crilly, and R. Aguilera. 2017. Embracing causal complexity: the emergence of a neo-configurational perspective. Journal of Management 43(1):255-282. https://doi.org/10.1177/0149206316679252

Müller, M., C. Kimmich, and J. Rommel. 2018. Farmers' adoption of irrigation technologies: experimental evidence from a coordination game with positive network externalities in India. German Economic Review 19(2):119-139. https://doi.org/10.1111/geer.12117

Neudert, R., A. Salzer, N. Allahverdiyeva, J. Etzold, and V. Beckmann. 2019. Archetypes of common village pasture problems in the South Caucasus: insights from comparative case studies in Georgia and Azerbaijan. Ecology and Society 24(3):5. https://doi.org/10.5751/ES-10921-240305

Nockur, L., L. Arndt, J. Keller, and S. Pfattheicher. 2020. Collective choice fosters sustainable resource management in the presence of asymmetric opportunities. Scientific Reports 10:10724. https://doi.org/10.1038/s41598-020-67757-1

Nussbaum, M. C. 2011. Creating capabilities: the human development approach. Harvard University Press, Cambridge, Massachusetts, USA. https://doi.org/10.4159/harvard.9780674061200

Oberlack, C., D. Sietz, E. Bürgi Bonanomi, A. De Bremond, J. Dell'Angelo, K. Eisenack, E. C. Ellis, G. Epstein, M. Giger, A. Heinimann, C. Kimmich, M. T. J. Kok, D. Manuel-Navarrete, P. Messerli, P. Meyfroidt, T. Václavík, and S. Villamayor-Tomas. 2019. Archetype analysis in sustainability research: meanings, motivations, and evidence-based policy making. Ecology and Society 24(2):26. https://doi.org/10.5751/ES-10747-240226

Oliver, P. E., and G. Marwell. 2001. Whatever happened to critical mass theory? A retrospective and assessment. Sociological Theory 19(3):292-311. https://doi.org/10.1111%2F0735-2751.00142

Olson, M. 1971. The logic of collective action: public goods and the theory of groups. Harvard University Press, Cambridge, Massachusetts, USA.

Ostrom, E. 2000. Collective action and the evolution of social norms. Journal of Economic Perspectives 14(3):137-158. https://doi.org/10.1257/jep.14.3.137

Ostrom, E. 2005. Understanding institutional diversity. Princeton University Press, Princeton, New Jersey, USA.

Ostrom, E., and R. Gardner. 1993. Coping with asymmetries in the commons: self-governing irrigation systems can work. Journal of Economic Perspectives 7(4):93-112. https://doi.org/10.1257/jep.7.4.93

Ostrom, E., J. Walker, and R. Gardner. 1992. Covenants with and without a sword: self-governance is possible. American Political Science Review 86(2):404-417. https://doi.org/10.2307/1964229

Ostrom, V. 1997. The meaning of democracy and the vulnerability of democracies: a response to Tocqueville's challenge. University of Michigan Press, Ann Arbor, Michigan, USA.

Ostrom, V., C. M. Tiebout, and R. Warren. 1961. The organization of government in metropolitan areas: a theoretical inquiry. American Political Science Review 55(4):831-842. https://doi.org/10.1017/S0003055400125973

Pejó, B., and G. Biczók. 2020. Corona games: masks, social distancing and mechanism design. Pages 24-31 in T. Anderson, J. Yu, and A. Züfle, editors. Proceedings of the 1st ACM SIGSPATIAL international workshop on modeling and understanding the spread of COVID-19. Association for Computing Machinery, New York, New York, USA. https://doi.org/10.1145/3423459.3430757

Polanyi, M. 1951. The logic of liberty. Routledge, London, UK. https://doi.org/10.4324/9781315006635

Press, W. H., and F. J. Dyson. 2012. Iterated Prisoner's Dilemma contains strategies that dominate any evolutionary opponent. Proceedings of the National Academy of Sciences 109 (26):10409-10413. https://doi.org/10.1073/pnas.1206569109

Ragin, C. C. 2008. Redesigning social inquiry: fuzzy sets and beyond. University of Chicago Press, Chicago, Illinois, USA. https://doi.org/10.7208/chicago/9780226702797.001.0001

Rapoport, A. 1967. Exploiter, leader, hero, and martyr: the four archetypes of the 2 × 2 game. Behavioral Science 12(2):81-84. https://doi.org/10.1002/bs.3830120202

Rapoport, A., M. J. Guyer, and D. G. Gordon. 1976. The 2×2 game. University of Michigan Press, Ann Arbor, Michigan, USA.

Robinson, D., and D. Goforth. 2005. The topology of the 2×2 games: a new periodic table. Routledge, London, UK.

Rousseau, J. J. 2004 [1761]. A discourse upon the origin and the foundation of the inequality among mankind. Project Gutenberg edition. Project Gutenberg, Urbana, Illinois, USA. [online] URL: https://www.gutenberg.org/cache/epub/11136/pg11136.html

Runge, C. F. 1981. Common property externalities: isolation, assurance, and resource depletion in a traditional grazing context. American Journal of Agricultural Economics 63(4):595-606. https://doi.org/10.2307/1241202

Schelling, T. C. 1960. The strategy of conflict. Harvard University Press, Cambridge, Massachusets, USA.

Sen, A. 1967. Isolation, assurance and the social rate of discount. Quarterly Journal of Economics 81(1):112-124. https://doi.org/10.2307/1879675

Sen, A. 2000. Development as freedom. Anchor Books, New York, USA.

Senge, P. M. 1990. The fifth discipline: the art and practice of the learning organization. Doubleday/Currency, New York, New York, USA.

Short, J. C., G. T. Payne, and D. J. Ketchen Jr. 2008. Research on organizational configurations: past accomplishments and future challenges. Journal of Management 34(6):1053-1079. https://doi.org/10.1177/0149206308324324

Sietz, D., U. Frey, M. Roggero, Y. Gong, N. Magliocca, R. Tan, P. Janssen, and T. Václavík. 2019. Archetype analysis in sustainability research: methodological portfolio and analytical frontiers. Ecology and Society 24(3):34. https://doi.org/10.5751/ES-11103-240334

Skyrms, B. 2003. The stag hunt and the evolution of social structure. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9781139165228

Snidal, D. 1985. Coordination versus prisoners' dilemma: implications for international cooperation and regimes. American Political Science Review 79(4):923-942. https://doi.org/10.2307/1956241

Snyder, G. H., and P. Diesing. 1978. Conflict among nations: bargaining, decision making, and system structure in international crises. Princeton University Press, Princeton, New Jersey, USA. https://doi.org/10.1515/9781400871186

Stein, A. A. 1982. Coordination and collaboration: regimes in an anarchic world. International Organization 36(2):299-324. https://doi.org/10.1017/S0020818300018968

Thurow, L. C. 1975. Generating inequality: mechanisms of distribution in the U.S. economy. Basic Books, New York, New York, USA.

Van Lange, P. A. M., D. Balliet, C. D. Parks, and M. Van Vugt. 2014. Social dilemmas: the psychology of human cooperation. Oxford University Press, Oxford, UK.

Villamayor-Tomas, S., I. Iniesta-Arandia, and M. Roggero. 2020. Are generic and specific adaptation institutions always relevant? An archetype analysis of drought adaptation in Spanish irrigation systems. Ecology and Society 25(1):32. https://doi.org/10.5751/ES-11329-250132

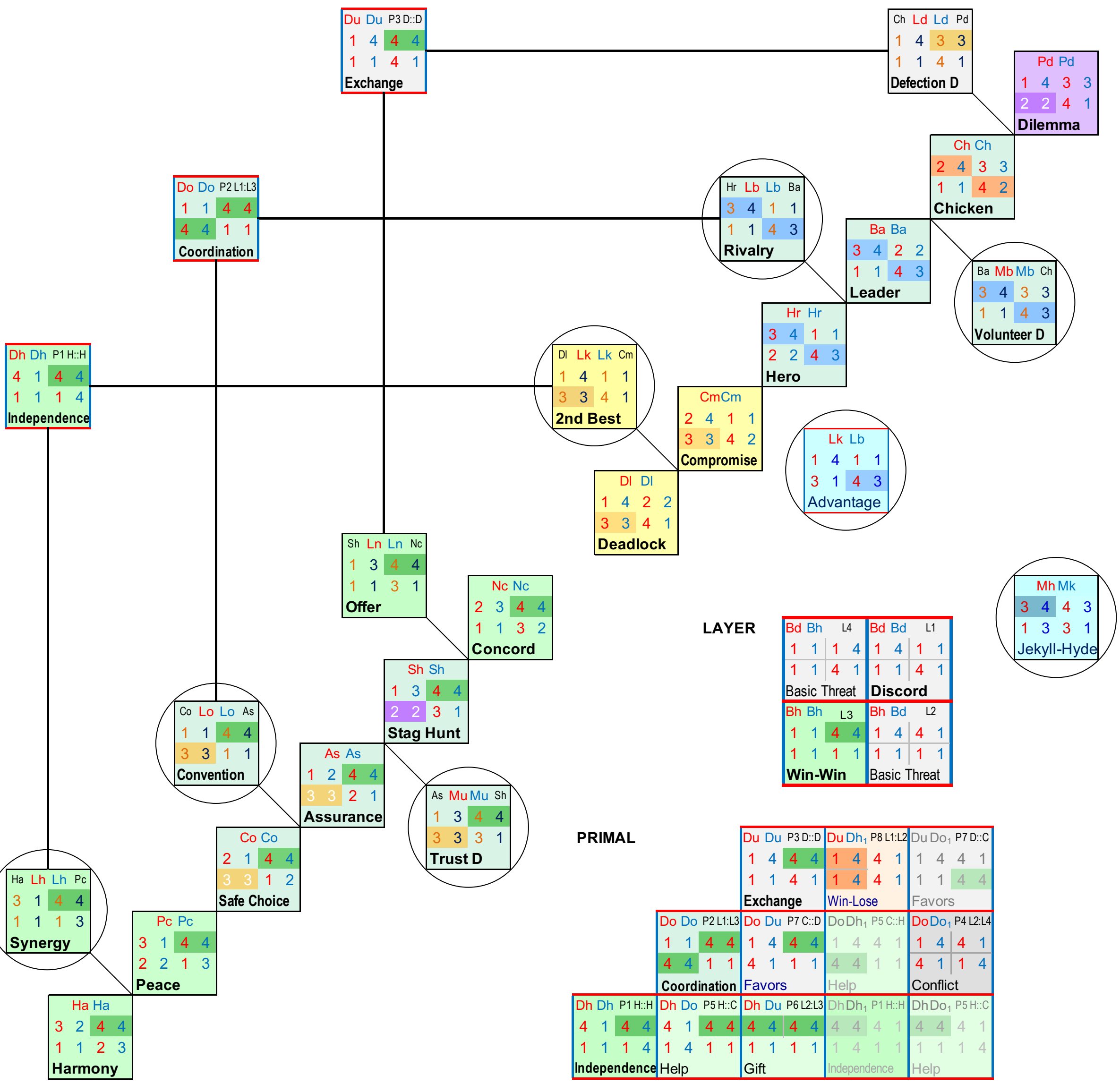
Wolstenholme, E. F. 2003. Towards the definition and use of a core set of archetypal structures in system dynamics. System Dynamics Review 19(1):7-26. https://doi.org/10.1002/sdr.259

Zürn, M. 1993. Problematic social situations and international institutions: on the use of game theory in international politics. Pages 63-84 in F. R. Pfetsch, editor. International relations and pan-Europe: theoretical approaches and empirical findings. Lit, Münster, Germany.

Appendix. Archetypes in the topology of 2x2 games

Appendix to Bruns, B., and C. Kimmich. 2021. Archetypal games generate diverse models of power, conflict, and cooperation. *Ecology and Society*.

Graphical abstract. Simplifying two-person two-choice (2x2) games by making ties in payoff ranks (indifference between outcomes) derives three primal archetypes of interdependence. Payoff patterns from the symmetric archetypes for independence, coordination, and exchange combine to form asymmetric archetypes for power, dependence, and conflict. Breaking ties in primal archetypes generates intermediate archetypes for synergy, compromise, conventions, rivalry, and advantage. Archetypal games provide a menu of models for understanding institutional diversity and transformation in social-ecological situations.



Contents

1. Introduction to the appendix

This appendix provides further results and discussion about families of asymmetric archetypes, the topology of 2x2 games, games with ties that lie between the strict ordinal games, the prevalence of bias games, payoff matrices for examples of interdependence, changing preferences, dimensions of interdependence, and some limitations and extensions of this approach to archetypal games.

The main paper identified archetypes for 2x2 games and showed how they generate diverse models for interdependence:

- Simple game theory models of independence, coordination, and exchange combine payoff patterns to make asymmetric situations of power, dependence and conflict.
- These archetypal games differentiate (by breaking ties in outcome rankings) to generate archetypes for synergy, compromise, conventions, rivalry, and advantage.
- Archetypal games offer a menu of models for understanding institutional diversity and transformation in social-ecological systems.

This appendix discusses how archetypes fit into the topology of 2x2 games. In a sense, the topology of 2x2 games provides an intellectual framework and scaffolding for identifying archetypal games. The main paper introduces families of archetypal games, while this appendix puts the archetypal games into the context of the topology of 2x2 games.

- Breaking ties in primal archetypes generates families of strict 2x2 games.
- The topology of payoff swaps in two-person two-choice (2x2) games maps overlapping relationships among archetypes with various challenges for cooperation.
- Ties make simpler games between strict 2x2 games.
- Making high ties and low ties in the strict 2x2 games derives primal archetypes including variants equivalent by interchanging rows and columns.
- Symmetric 2x2 games mostly offer relatively good outcomes at equilibrium (best or second-best) except for an unstable region around Prisoner's Dilemma.
- Most 2x2 games have unequal payoffs at equilibrium

- Standardizing payoff matrices shows equivalence in models between the Atlas of Interpersonal Situations and the topology of 2x2 games.
- Making and breaking ties represents changes in preferences. There are many reasons why payoff values might change.
- Archetypal games illustrate dimensions of independence including Nash best response equilibria, coordination, and externalities.
- The ways in which simple archetypes generate more diverse situations offer tools for understanding similarity and diversity in interdependence.

2. Asymmetric archetypes differentiate into families of hotspots and pipes

Figures A1 and A2 show how all eight primal archetypes differentiate into symmetric and asymmetric descendants.

- Primal Coordination differentiates into games with rival equilibria or games where achieving the best payoff for both may conflict with avoiding risk.
- Primal Conflict, also known as Matching Pennies, differentiates into a family of cyclic games with no equilibria. These are situations of completely opposed interests where if one gains the other does worse.
- Primal Win-Lose yields further asymmetric inequality in high bias (4,2) games where one gets second-worst at equilibrium.
- Primal Gift, Primal Independence, and Helping Hand produce families of games with relatively good outcomes that each contain win-win (4,4), moderate bias (4,3), and second-best (3,3) outcomes.
- Primal Exchange and Primal Combination have particularly diverse descendants, including asymmetric dilemmas with inefficient equilibria, games with highly unequal (4,2) equilibrium outcomes, and cyclic games where a focal point (4,3 or 3,3) could offer a Pareto-optimal solution better than cyclic instability or the poor payoff from a mixed strategy. Most of these games, including the social dilemmas of Prisoner's Dilemma, Chicken, and Stag Hunt as well as their asymmetric neighbors, share defection problems where there are motivations to move away from a cooperative Pareto-optimal solution and instead become trapped in a result that is unsatisfactory for one or both.

Figure A1. Hotspot families. Primal archetypes for Coordination, Conflict, Win-lose, and Gift differentiate into two tiles composed of four strict ordinal games linked by low swaps (1><2).

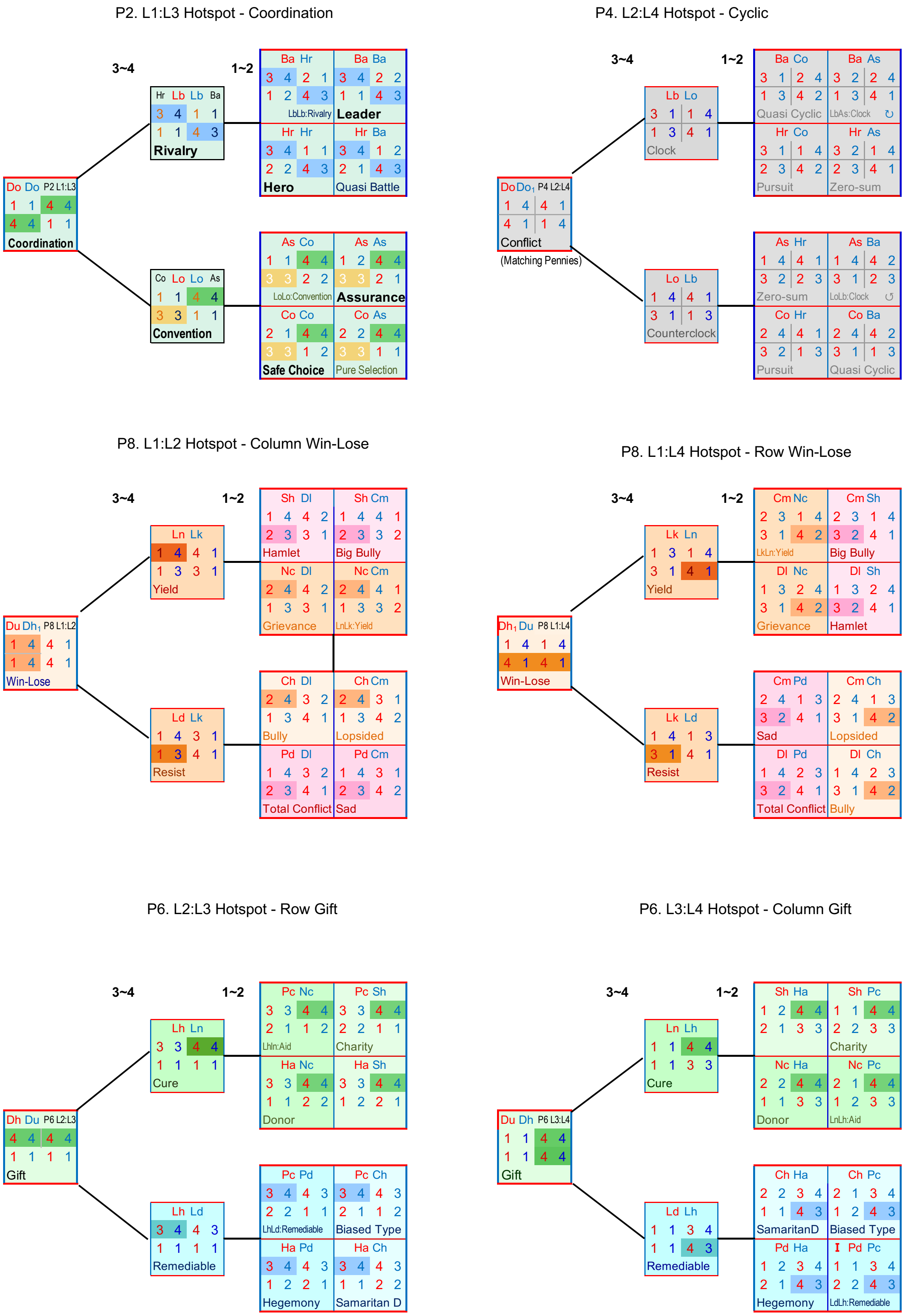
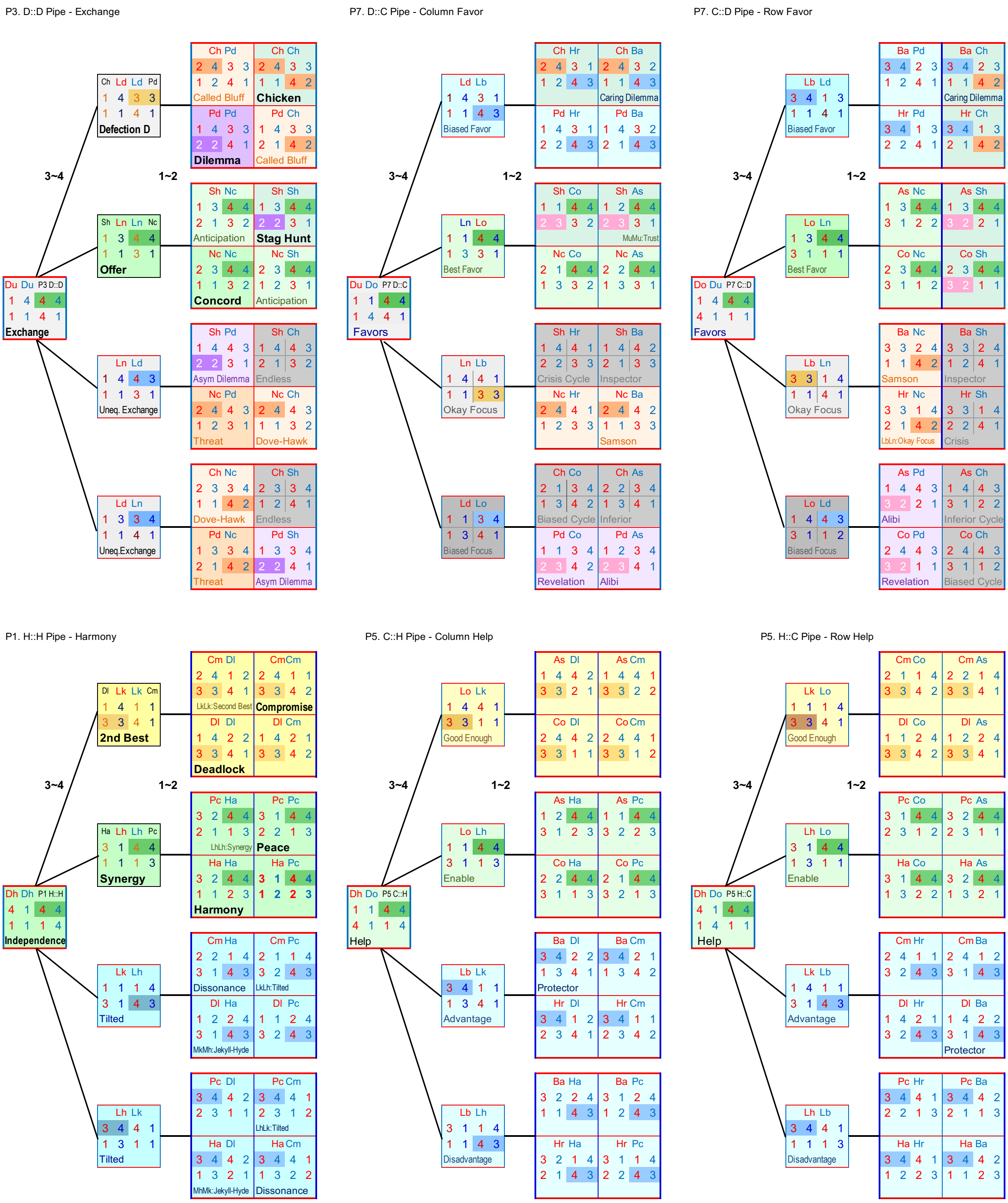


Figure A2. Pipe families. Primal archetypes for Exchange, Independence (Harmony), Favors, and Help differentiate into four tiles with sixteen strict games.



3. The topology of payoff swaps in 2x2 games

Figure A3 displays the topology of 2x2 games (Robinson and Goforth 2005, Robinson et al. 2007, Bruns 2015), which provides the framework for analysis in this paper. Symmetric games form a diagonal axis from lower left to upper right. Their payoffs combine to make asymmetric games. Making ties in payoff ranks simplifies games to form archetypes, breaking ties differentiates primal archetypes into the strict ordinal 2x2 games shown in the table.

In the topology of 2x2 games, games linked by swaps in the two lowest-ranked outcomes are considered nearest neighbors. Four games linked by low swaps (1><2) form a *tile*, as on the right hand side of Figures A1 and A2. In Figure A3, an example is the tile with Assurance, Safe Choice, and the combinations of their payoff patterns. Middle swaps (2><3) create a neighboring game to start a new tile. Continuing this process until the payoff structures repeat creates a *layer* of nine tiles and thirty-six games. High swaps (3><4) start a new layer, for example when Stag Hunt turns into an Asymmetric Dilemma. Each layer forms a torus (doughnut) shape that can be “cut open” and displayed on a flat square. So, payoff swaps link games at the top of a layer to those at the bottom. Payoff swaps also link games from side-to-side in a layer (like an early video game where a spaceship leaving one edge reappears on the other).

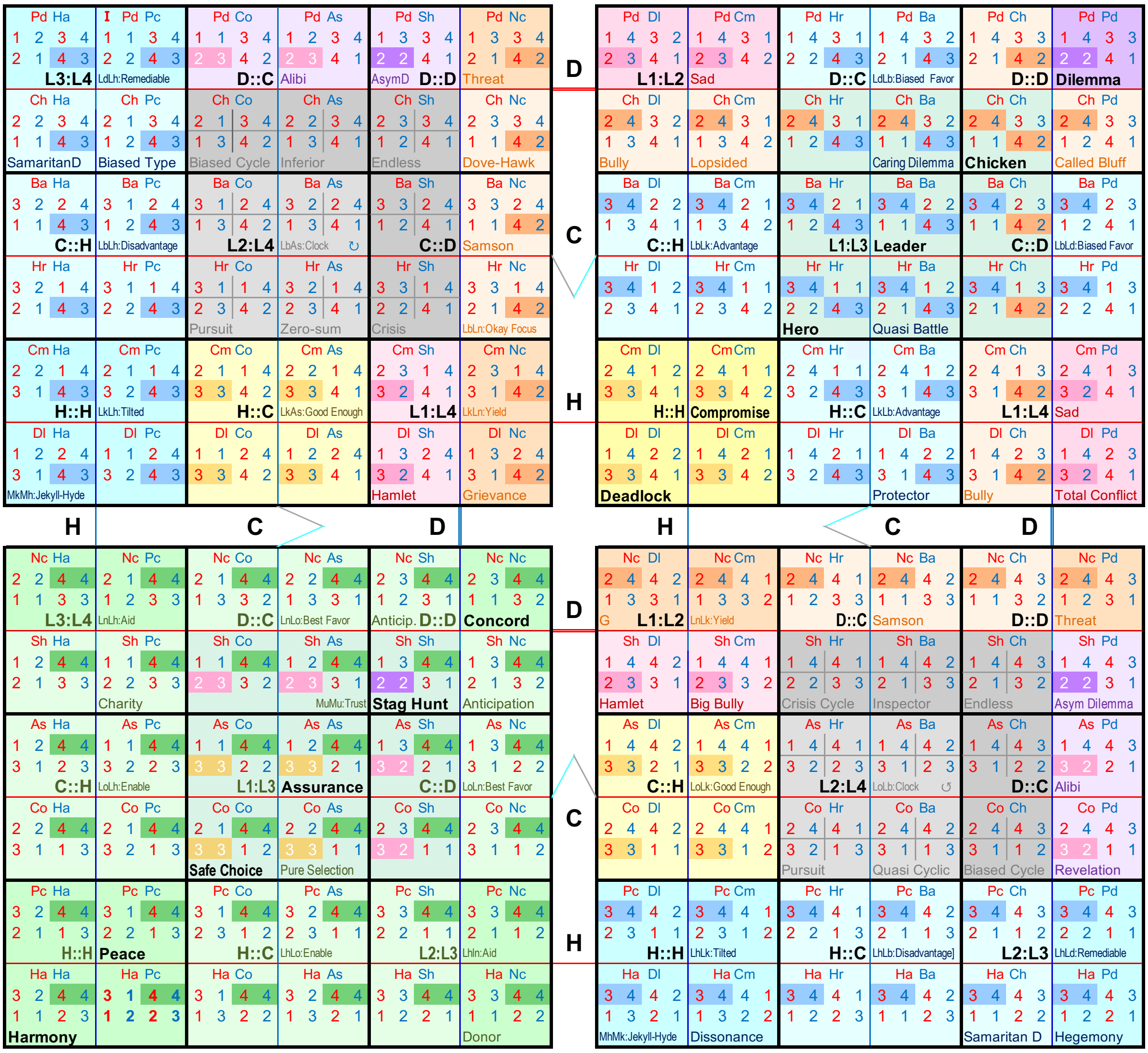
Each actor could have payoff swaps for low, middle, or high payoffs (1><2, 2><3, 3><4). Therefore each game has six neighbors. Low and middle swap neighbors are shown in each layer, while high swaps transform into games on another layer. The topology of 2x2 games provides a map of the “adjacent possible” (Kauffman 1995) of potential transformations resulting from changes in the ranking of outcomes.

The four layers in the topology of 2x2 games differ by the alignment of the best outcomes. In the discord layer (Layer 1) on the upper right of Figure A3, the best outcomes are in diagonally opposed cells. In the win-win layer (Layer 3) on the lower left, the best outcomes (4,4) are in the same cell. In Layers 2 and 4 the best outcomes are in the same row or column. Making ties for the three lowest payoffs simplifies all the games in a layer into one of the four basic archetypes: Win-Win for Layer 3, Discord for Layer 1, or Row or Column Threat (top outcomes in the same row or column) for Layers 2 and 4.

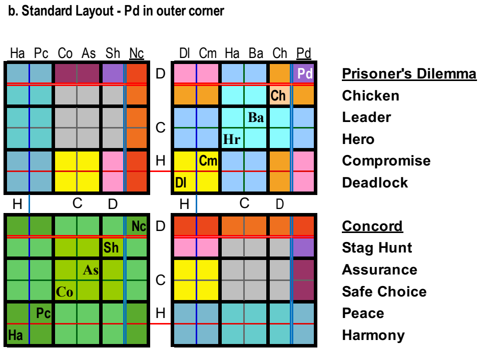
As shown in Figure A1, some primal archetypes such as Primal Coordination and Primal Conflict ultimately generate eight strict ordinal games. These are arranged in two tiles that form a *hotspot*. In a hotspot, two tiles on different layers are linked by swaps in the two highest-ranked payoffs (3><4). Other primal archetypes, such as Primal Independence, Primal Exchange, and their neighbors generate sixteen strict ordinal games in four tiles, forming *pipes*, as shown in Figure A2. In a pipe, high swaps connect four tiles, one on each layer.

Figure A3 locates the hotspots and pipes in the topology of 2x2 games. Hotspots can be identified by the layers they link. Thus the coordination hotspot links layers 1 and 3. The cyclic hotspot links layers 2 and 4. Pipes link tiles in equivalent locations on each of four layers. For example, high swaps link the Harmony tile to equivalently located tiles on the lower left of each layer (H::H pipe). Neighboring tiles above or to the right are similarly linked in quartets of tiles (C::H and H::C). The same applies for the tiles (D::D) on the upper right of each layer, and their neighboring tile quartets to the left and below (C::D, D::C). As shown in Figures A1 and A2, each hotspot or pipe simplifies into a primal archetype, an ancestor (progenitor) that differentiates into a family of games.

Figure A3. Hotspots and pipes in a “standard layout” of the topology of 2x2 games with Prisoner’s Dilemma in an outer corner. Figures A3b and A3c show how “scrolling” the display of the torus-shaped layer moves Prisoner’s Dilemma from an outer corner to an inner corner. This splits open tiles and creates the dominant strategy layout shown in Figure A4.



b. Standard Layout - Pd in outer corner



c. Dominant Strategy Layout - Pd in center

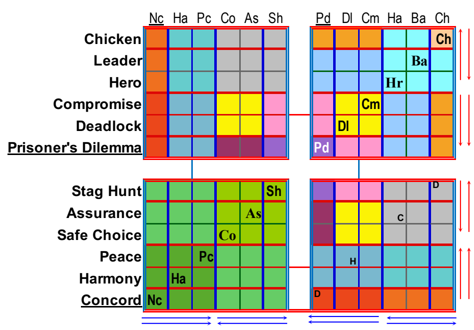


Figure A4 is a “dominant strategy” layout visualizing the topology of 2x2 games that elegantly displays many of the relationships between games (Robinson and Goforth 2005, Bruns 2015). Compared to Figure A3, the display in each layer “scrolls” to move Prisoner’s Dilemma to the inner corner, as shown in Figures A3b and A3c. In this layout, the quadrants within each layer differ by the alignment and number of dominant strategies. Games in the lower left quadrant of each layer have two dominant strategies. In the upper left and lower right quadrants, only one actor has a dominant strategy. If the other player can anticipate the dominant strategy, then their best move becomes clear. Games in these three quadrants all have a single equilibrium, resulting from dominant strategies for one or both actors. Games in the upper right quadrants have no dominant strategy. In pure (unmixed) strategies, they have either two equilibria, as in the coordination games, or no equilibrium, as in the cyclic games. Thus there are two quadrants of coordination games. In more colloquial terms, the diversity of 2x2 games without dominant strategies includes a herd of risky stag hunts and a bunch of rivalrous battles, as well as two clumps of cyclic conflicts.

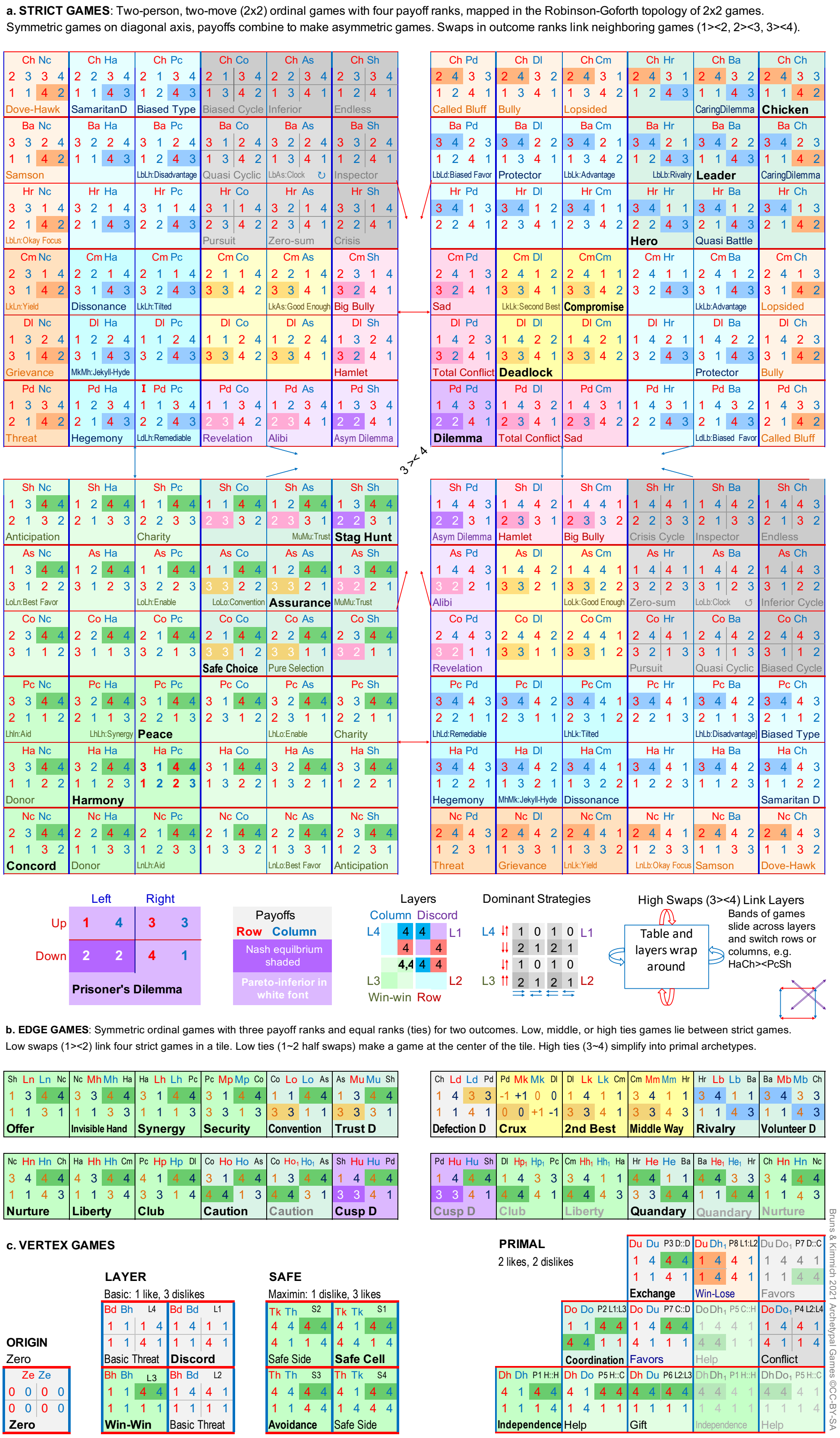
In the dominant strategy layout, high swaps (3><4) link across layers so that at the center, Prisoner’s Dilemma turns into an Asymmetric Dilemma and then Stag Hunt. High swaps also link the entire table top-to-bottom and side-to-side. The high swap links in this layout help visualize many of the most interesting and important high swap transformations. These involve defection dilemmas and other descendants of Primal Exchange and Primal Favors. Asymmetric Dilemmas may turn into Endless conflicts and then into win-win games of Anticipation. Low swaps turn Prisoner’s Dilemma into lopsided results in Called Bluff and then the complex tensions of Chicken. High swaps convert Chicken into unbalanced brinksmanship in Dove-Hawk, which could then turn into resentful resistance in Threat or cooperation in Concord.

High swap linkages can be visualized more generally in terms of horizontal (and vertical) *bands* of three tiles which link to equivalently located bands on other layers. The way in which the table wraps around from side-to-side and top-to-bottom already shows the linkages for the Dilemma (D) bands, since these tiles have been “split open” and form the borders of each layer. The other linkages require a bit more imagination to visualize.

As an initial example, high swaps for the column player wrap around the table to transform Samaritan’s Dilemma (HaCh) into a Donor game (HaNc). This can model a conditional donor whose requirements reshape recipient behavior. High swaps for the row player convert Samaritan’s Dilemma into a Charity game (PcSh). This transformation could model a giver who becomes more sympathetic or more understanding and accepting of a recipient’s existing efforts and capabilities (Bruns 2010).

More generally, the Harmony pipe in the lower left links tiles on four layers. The Harmony (H) bands slide horizontally for row swaps (and vertically for column swaps). High swaps for Row payoffs “slide” horizontally to the next layer and turn into the games above or below in the corresponding tile, as with the change from Samaritan’s Dilemma into Charity (HaCh >< PcSh). Similarly, column swaps slide vertically and link to the corresponding games to the left or right in the equivalently located tile. A series of four high swaps returns to the original tile and game. These links form the structure of the pipes shown in Figures A2 and A3. The pattern of high swap links can be summarized as “bands slide and switch,” as illustrated by the initial example of a high swap turning Samaritan’s Dilemma (HaCh) into Charity (PcSh). Similarly, Bully (DlCh) becomes Big Bully (CmSh) through a high swap for the row actor.

Figure A4. A periodic table of elementary social situations, based on the topology of 2x2 games. Dominant strategy layout of strict ordinal games above. Games with ties below.



A high swap transforms Safe Choice or Assurance into an asymmetric game combining payoffs from Leader and Hero. High swaps link the two tiles to form a hotspot. The cyclic tiles on Layers 2 and 4 are similarly linked diagonally. Thus, the Central (C, as in coordination and cyclic) bands criss-cross diagonally. This linkage provides useful landmarks for visualizing high swaps. Other games in these bands similarly "slide and switch." Within each tile, row swaps again turn into games above or below on the linked tile. Column swaps turn into games on the left or right. Thus a column swap for Protector (DlBa) slides diagonally and turns into a win-win game (HaCo). One player still has a dominant strategy, but now the other player can also get their best outcome. A row swap for the other version of Protector (BaDl), correspondingly turns into CoHa.

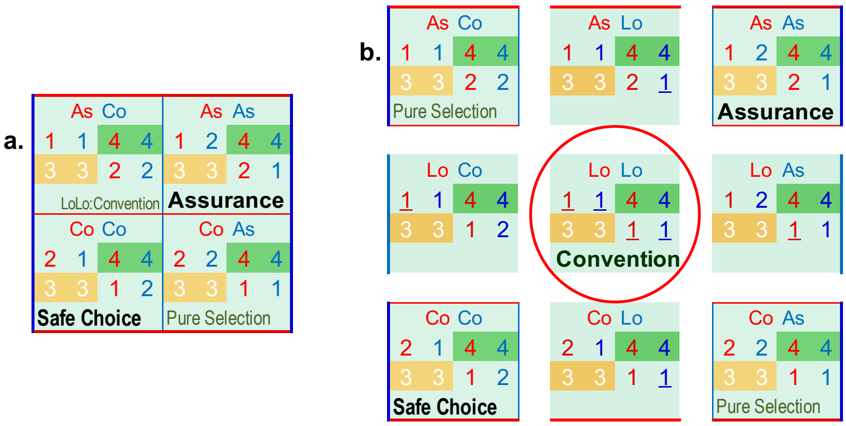
Another way to think about the high swap links is to remember that high swaps for both Row and Column turn Compromise into Harmony and Deadlock into Peace. Other games in the same row or column follow the same pattern. A swap only for Row would slide horizontally and switch rows to link to the equivalently located tile on Layer 2, while a swap for Column would slide vertically and switch columns to link to the equivalently located tile on Layer 4. The combination of these linkages joins the four tiles into the Harmony pipe. Hotspots similarly link two layers, as in the cyclic hotspot connecting Layer 2 and Layer 4.

Visualization of payoffs at equilibrium in the topology of 2x2 games shows broad regions of better and worse outcomes that differ in their stability in response to changes in preferences (Bruns 2015). Analysis of how archetypal games generate strict games further illustrates these broad differences in results and robustness with half the archetypes generating hotspots and pipes of games with good results (best or second-best, shown in green, blue, and yellow) and the other half of the families usually yielding poor results for at least one actor. Families of primal archetypes as well as high swap linkages show how the landscape of 2x2 games depicted in the dominant strategy layout consists of "highland plateaus of stability" with relatively good outcomes at equilibrium which are bordered by "chaotic terrain" with poor results for one or both. More colloquially, these could be called "nice" games with good outcomes and "nasty" games that generate inequality. In the precipitous region of unequal equilibrium outcomes, game structures and outcomes are sensitively dependent on changes in the ranking of outcomes. This includes the risk of getting stuck in a canyon, trapped in a deeply unsatisfactory situation where both get second-worst results. Those trying to navigate such institutional landscapes face diverse challenges of miscoordination, instability, inequality and inefficiency.

4. Ties make games between

Games with ties lie "between" the strict ordinal games, linked by "half-swaps" that make or break ties (Robinson et al. 2007, Heilig 2012, Hopkins 2014, Bruns 2015). Figure A5a shows a tile of games linked by low swaps (1><2) for Assurance, Safe Choice, and the games that combine their payoffs (CoAs and AsCo). Figure A5b shows an expanded tile with games created by the half-swaps that make (or break) ties (1~2). The games with ties lie between the four strict games, with Convention (LoLo) as an intermediate archetype in the center of the tile.

Figure A5. Tiles of games. a. Swaps in lowest payoffs (1><2) link four games to make a tile. b. Expanded tile shows games with ties between strict games (1~2). Making low ties simplifies all the games in a tile into a single game with low ties, such as Convention (LoLo).



The strict ordinal games can be visualized as located in the center of each game shown in the table in Figure A4. Grid lines mark the boundaries between different ordinal games. Games with low ties or middle ties for both actors then lie at the intersection of grid lines.

The middle of Figure A4 shows all the symmetric ordinal games with ties, including low (1~2), middle (2~3), and high (3~4) ties. The games with low and middle ties can be visualized as lying along the diagonal axis of the topology of 2x2 games, located between the strict ordinal games. This is shown by the abbreviations in the upper corners of the cell displaying payoffs for each game with ties. Figures A3 and A4 also show names for low ties games at the center of tiles, preceded by abbreviations.

The bottom of Figure A4 also shows the simplest archetypes with only two payoff ranks, likes and dislikes. This includes the primal archetypes discussed above, with ties for the two highest and two lowest-ranked outcomes. The Layer (or Basic) games have a single like, and ties for the three lowest-ranked outcomes. Similarly, there are games with a single dislike, and indifference between the higher-ranked outcomes (triple ties for the highest rank). Such Safe or "dislike" games may be useful in thinking about situations where actors emphasize caution and risk avoidance. In three out of the four possible dislike games, action by one to avoid risk is sufficient to ensure that both avoid the worst outcome and get to win-win. However, in the fourth possibility, with dislikes in diagonally opposed cells, both need to avoid risk to reach the Safe Cell (or else somehow coordinate on the alternative risky win-win outcome). The Safe games are relatively easy to solve and do not seem to have received much attention in analyzing collective action. Therefore, they are not proposed as archetypes in this analysis.

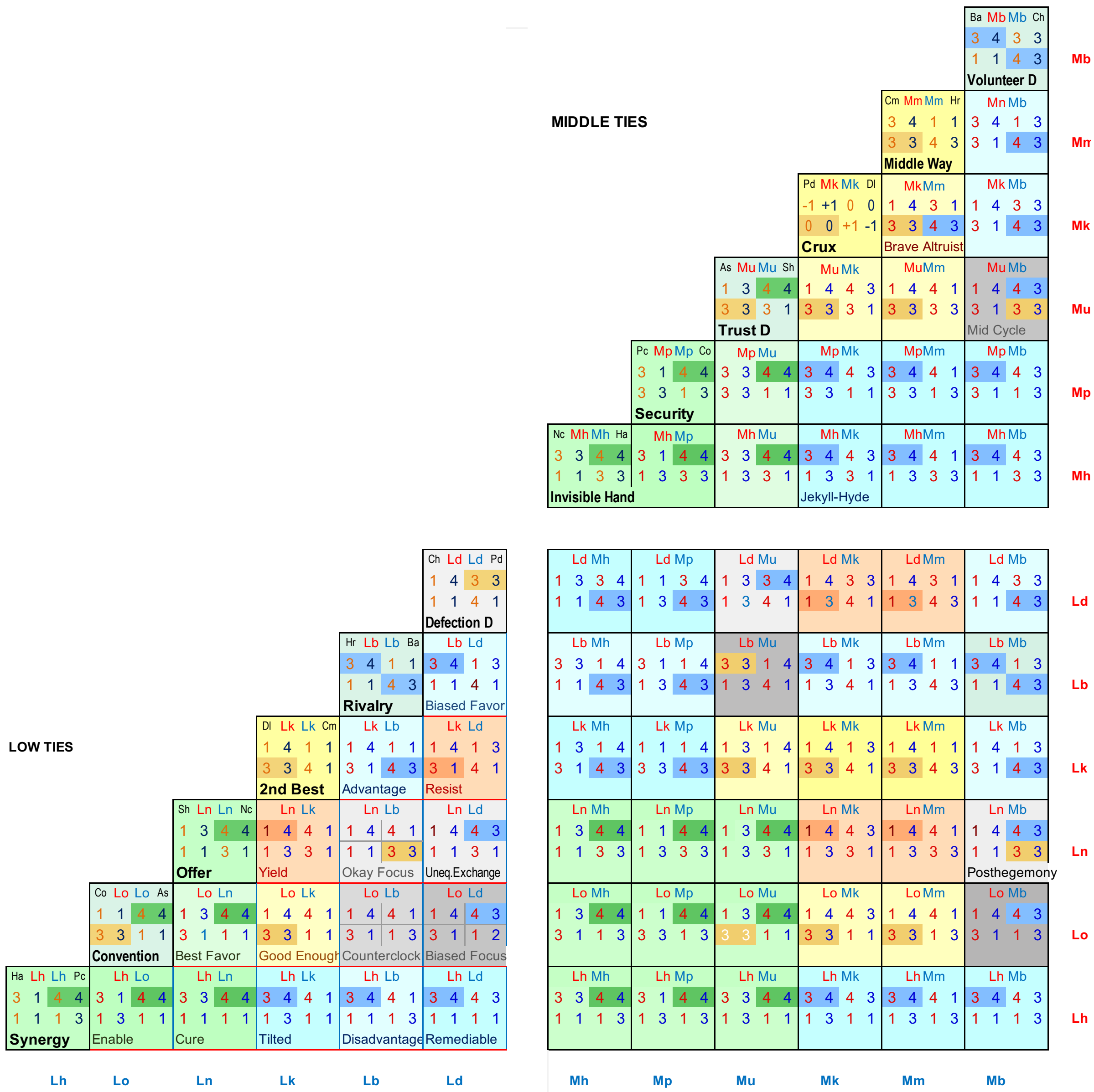
Figure A6 shows ordinal games with middle or low ties. This includes Advantage (LkLb) and Jekyll-Hyde (MhMk), which were discussed earlier, as well as other games that could be considered as intermediate archetypes or which might offer useful models for analysis. As mentioned above, symmetric games on the diagonal lie between the strict symmetric ordinal games. Asymmetric games of possible interest include Unequal Exchange (LnLd) where balanced exchange has become asymmetric and delivers unequal results at equilibrium, and Brave Altruist (MkMm) as a possible model of cheap but risky kindness. The unequal equilibrium outcome in the Remediable game (LhLd) (and the four strict games on the tile it forms) might be addressed in multiple ways: by taking turns, based on the threat by the disadvantaged actor; or transformed into a win-win game by high swaps for either Row or

Column. However, the tiles for the Tilted and Disadvantage game are not as easy to improve, with the only transformative solution being a high swap for the disadvantaged player.

The middle ties Crux game (MkMk) is located between Prisoner's Dilemma and Deadlock and is unique in being the only symmetric zero-sum game (zero-rank sum for ordinal payoffs). Therefore, in Figures A4 and A6 and elsewhere it is shown with payoff values of +1,0,–1. Crux lies at the intersection of the axis of symmetric games and the axis of conflict games that includes the zero-sum games of Total Conflict (PdDl/DlPd), Big Bully (ShCm/CmSh), and Zero-sum Cycle (AsHr/HrAs).

The names suggested in Figure A6 and elsewhere are intended as heuristic and exploratory. More generally, names for payoff structures can invoke metaphors and stories for which the games may provide relevant models. The abbreviations in the 2x2 game identifiers provide a systematic nomenclature for identifying payoff structures and their relative locations, which can coexist with multiple and evolving common names and stories.

Figure A6. Ordinal games with low and middle ties. Symmetric games are on the diagonal axis. Their payoffs combine to form asymmetric games.



5. Primal archetypes and their variants

Figure 2 shows primal archetypes, omitting many variants that are equivalent by interchanging rows or columns or switching positions of Row and Column actors. Figure A7 shows the corresponding full set of primal archetypes and variants derived by simplifying the games in the topology of 2x2 games displayed in Figure A3. As in the display of the strict topology of 2x2 games, symmetric games form a diagonal axis from lower left to upper right. Payoff patterns from symmetric games combine to form asymmetric games. Games on either side of the axis are equivalent by switching positions for Row and Column. Primal Conflict on Layer 2 cycles counterclockwise while its chiral reflection on Layer 4 cycles clockwise.

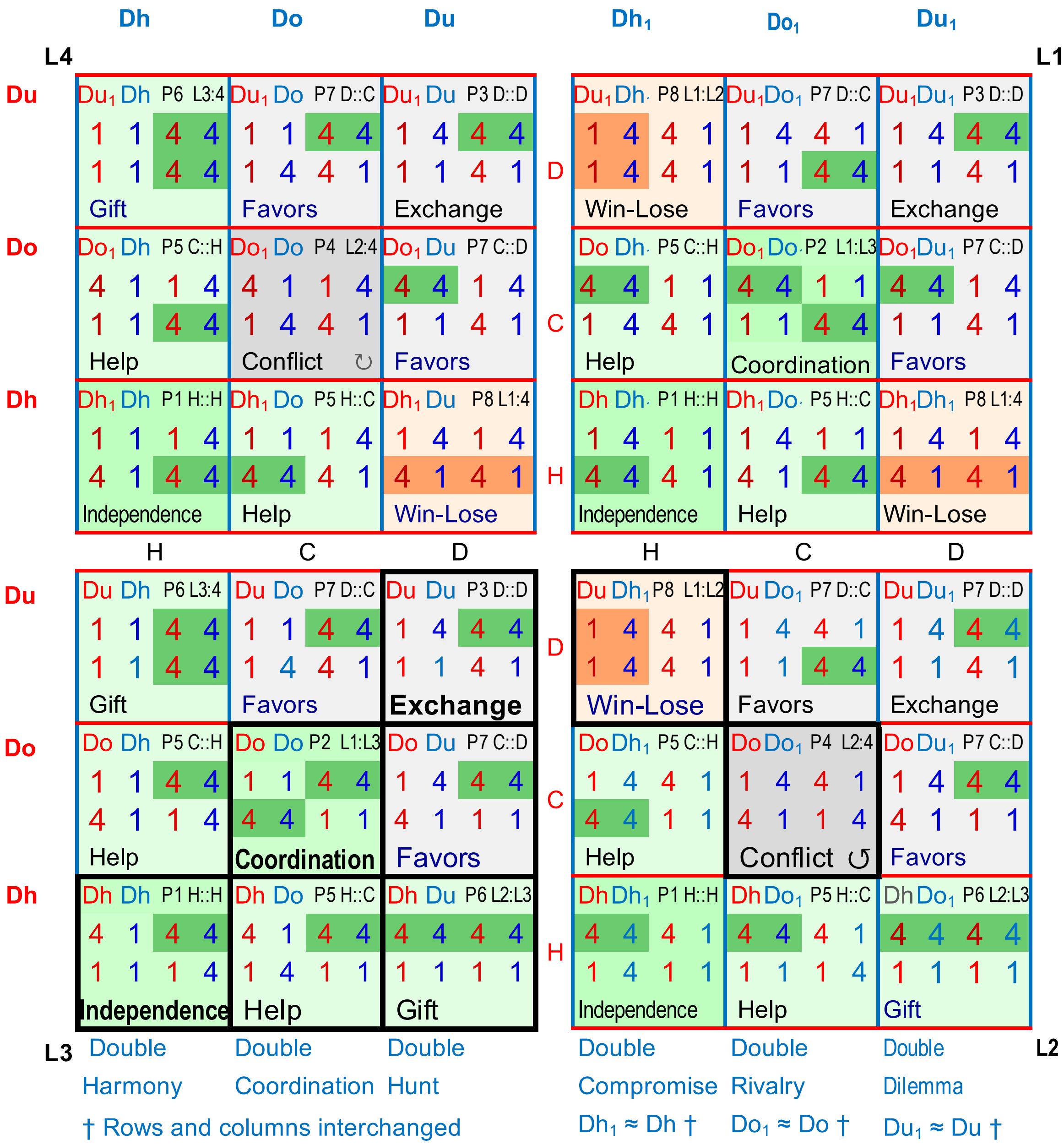
Starting from the topology of strict ordinal 2x2 games shown in Figure A3, making ties for the two lowest-ranked payoffs simplifies each tile into a single game. This reduces the 12 by 12 matrix of games to 6 by 6. Making further ties for the two highest-ranked payoffs creates primal games as shown in Figure A7. Variants appear at equivalent locations on each layer. This follows the structure of hotspots and pipes discussed above and shown in Figure A3. Hotspots are identified according to the layers they link. Pipes are identified by their location in vertical and horizontal bands of tiles: harmony pipes (H::H, C::H, H::C) are on the lower left and dilemma pipes (D::D, C::D, D::C) are on the upper right.

The three symmetric primal archetypes appear on Layer 3 on the lower left. A variant of Primal Independence with rows and columns interchanged is on Layer 1, along with a variant of Primal Coordination with interchanged rows (or with interchanged columns creating the same result). Starting from Figure A3, simplified payoffs from Harmony and Peace are equivalent to those from Deadlock and Compromise by interchanging rows and columns. Simplified payoffs from Safe Choice and Assurance are equivalent to those from Hero and Leader by interchanging rows or columns. Payoffs simplified from Prisoner's Dilemma and Chicken end up identical to those from Concord and Stag Hunt since the convention to orient payoffs with Row's 4 right and Column's 4 up creates a unique (or indistinguishable) orientation rather than allowing two interchanged variants.

The primal archetypes in these pipes and hotspots illustrate many of the basic solution concepts in game theory.

- In the harmony pipes dominant strategies lead to win-win equilibria, for Primal Independence and, with anticipation by one actor, in the neighboring pair of asymmetric variants of Primal Help.
- Primal Gift and Primal Win-Lose also have dominant strategies, leading respectively to win-win or win-lose.
- Primal Coordination poses a problem of equilibrium selection, including the Layer 1 variant where the two alternative equilibria are aligned on the diagonal from lower right to upper left.
- Primal Conflict is a zero-sum game. For repeated interaction, a mixed strategy offers an equilibrium solution, randomly choosing each move half the time.
- In the dilemma pipes, the archetypal games of Primal Exchange and Primal Favors do not have dominant strategies. Therefore focal points or other solution concepts are necessary to reach win-win.

Figure A7. Primal archetypes with variants that interchange rows and columns or positions. These are formed by making ties in the topology of strict 2x2 games for the two highest-ranked and two lowest-ranked outcomes. Each tile of four games in Figure A3 collapses into a single game. Symmetric games still form an axis of symmetry from lower left to upper right. Games on either side of the axis are still equivalent by switching positions as Row or Column. Equivalently-located tiles form hotspots linking two layers or pipes linking four layers.



6. A map of symmetric 2x2 games with ties

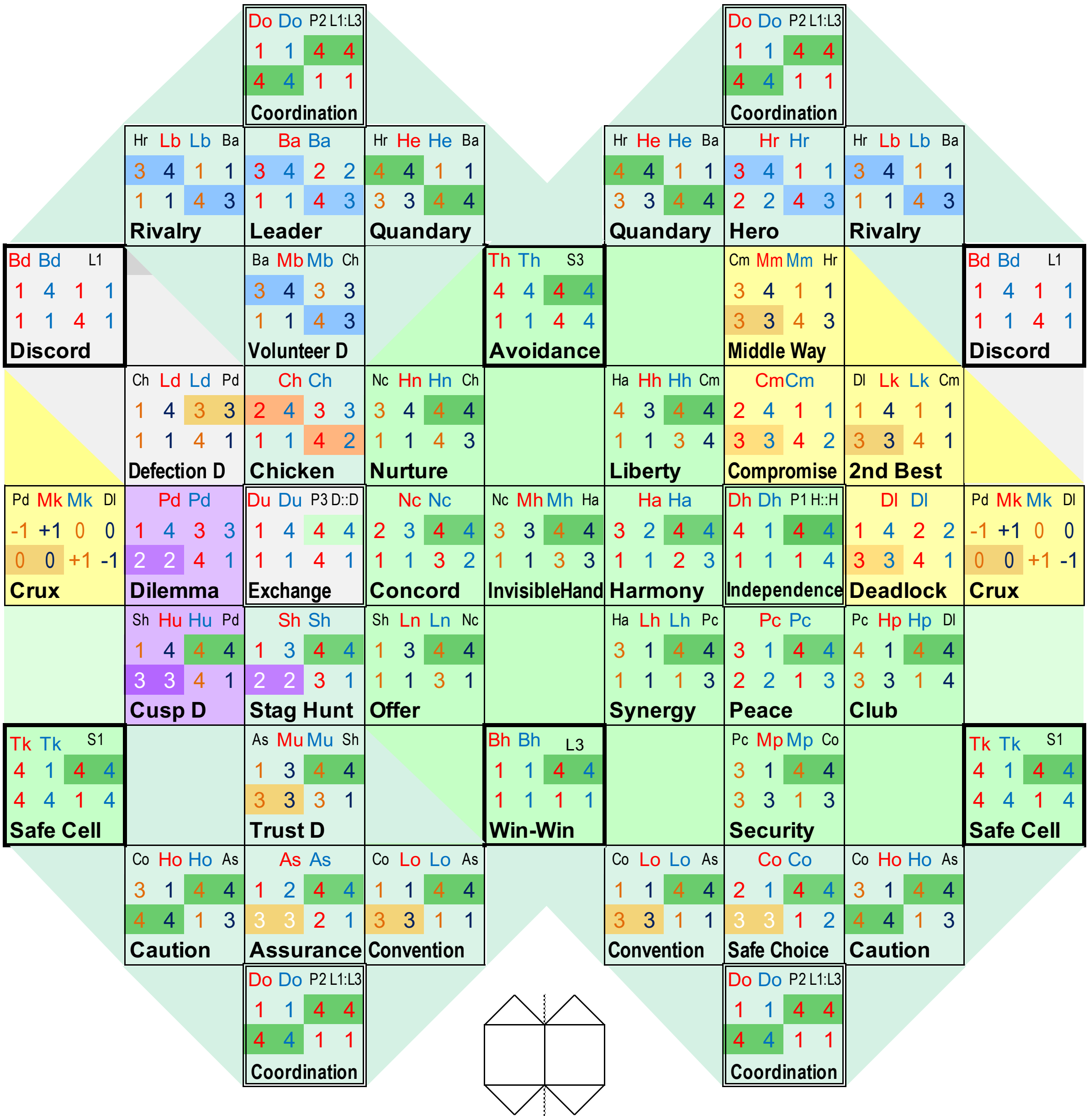
Figure 3 showed how the three symmetric primal archetypes differentiate to form twelve strict symmetric games. Figure A8 offers an alternative and more systematic view of the relationships among symmetric games, including those with two high ties or two middle ties for each actor. The combinations of ordinal payoffs in 2x2 games and the ways in which payoff swaps change one game into another can be visualized on the sides of a cube (Huertas-Rosero 2003, Goforth and Robinson 2012). Slicing the cube diagonally, games on two sides are equivalent by interchanging rows and columns (or algebraically by switching the "temptation" and "sucker" payoffs in a Prisoner's Dilemma). So, only twelve games are needed to show the relationships. The visualization shows half of a box (disdyakis cube) cut on the diagonal and unfolded. The other half of the box would have another set of the same games.

The three primal archetypes lie at the center of sides of the box (faces of a cube). Breaking ties generates neighboring games. Breaking either high ties or low ties generates neighbors on the diagonal. Breaking both pairs of ties generates horizontal or vertical neighbors, strict games above or below or left or right of the primal archetypes.

Overall, descendants of Independence and their neighbors form part of a large region of stable games with win-win or second-best outcomes, shown in yellow and green. Descendants of Primal Exchange are diverse: many turn into coordination problems of trust or rivalry, some become concordant win-win games and a few are particularly interesting and challenging for collective action, notably Prisoner's Dilemma, Chicken, and Stag Hunt.

Rivalry games are on top of the box, and trust games on the bottom, with Primal Coordination like a "wormhole" that links the two types of coordination games (Goforth and Robinson 2012). Middle ties games, such as Volunteer's Dilemma and Trust Dilemma (Rousseau's Hunt) are on edges between sides of the box. This figure can also be folded back on itself to provide a simple way to visualize the relationships between the twelve strict symmetric 2x2 games and their neighbors formed by half-swaps to make ties.

Figure A8. Topology of symmetric 2x2 games with ties. The simplest Basic and Safe symmetric games with three ties and one like or dislike form the corners of a box (disdyakis cube). Independence and Exchange are each in the center of sides of the box, surrounded by their descendants created by symmetrically breaking ties. Coordination games form triangular "flaps" at the top and bottom, with Primal Coordination making a "wormhole" link.



7. Prevalence of bias games

Figure A9 shows a schematic visualization of the topology of 2x2 games displaying the bias games, also called suasion (Martin 1992) or rambo games (Zürn 1993, Hasenclever et al. 1997, Holzinger 2003), where dominant strategies lead to unequal payoffs at a single equilibrium. This shows the proportions in the payoff space of possible 2x2 games. The proportions of games in the topology of 2x2 games are also those that would be expected if payoffs are generated randomly (Simpson 2010, Bruns 2015). Out of 144 games, 66 games (46%) are bias games, with a single equilibrium that has unequal payoffs. Nine more symmetric games have two equilibria that both have unequal payoffs, for a total of 75 games (52%). By comparison, 51 games (35%) have equal payoffs at equilibrium, most of which are win-win (4,4). That includes 4 stag hunts (3%) that have equal payoffs at the Pareto-superior equilibrium and unequal payoffs at the inferior equilibrium. The remaining 18 games (12.5%) are cyclic, with no equilibrium. In summary, just over a third of games have equal payoffs at equilibrium, while slightly over half have unequal payoffs at equilibrium (and the remaining eighth of games are cyclic, with no equilibrium in pure strategies).

The inefficiency problems of Prisoner's Dilemma and Stag Hunt/Assurance problems have received most attention in game theory research. However, only 16 games (11%) have Pareto-inferior equilibria, 9 stag hunts and 7 dilemmas. That includes four dilemmas with unequal payoffs at equilibrium that are also bias games. Overall, in the payoff space of possible games, inequality problems are much more prevalent than efficiency problems.

It should be noted that the term "bias games" here concerns structural bias in incentives and equilibrium outcomes. This differs from usage of the term "biased games" by Caragiannis, Kurokawa, and Procaccia (2014) in their analysis of strategic bias in the selection of mixed strategies visible to the other actor in repeated interaction.

Figure A9. Bias games. Dominant strategies lead to unequal payoffs at equilibrium.

Nc	Na	Pc	Co	Ar	Sh	Pd	Dl	Cm	Hr	Ba	Ch	
4,2	4,3	4,3	↻	↻	↻	2,4	2,4	2,4	/	/	/	Ch
4,2	4,3	4,3	↻	↻	↻	3,4	3,4	3,4	/	/	/	Ba
4,2	4,3	4,3	↻	↻	↻	3,4	3,4	3,4	/	/	/	Hr
4,2	4,3	4,3	3,3	3,3	3,2	3,2	3,3	3,3	3,4	3,4	4,2	Cm
4,2	4,3	4,3	3,3	3,3	3,2	3,2	3,3	3,3	3,4	3,4	4,2	Dl
4,2	4,3	4,3	2,3	2,3	2,2	2,2	2,3	2,3	3,4	3,4	4,2	Pd
4,4	4,4	4,4	\	\	\	2,2	2,3	2,3	↺	↺	↺	Sh
4,4	4,4	4,4	\	\	\	3,2	3,3	3,3	↺	↺	↺	Ar
4,4	4,4	4,4	\	\	\	3,2	3,3	3,3	↺	↺	↺	Co
4,4	4,4	4,4	4,4	4,4	4,4	3,4	3,4	3,4	3,4	3,4	3,4	Pc
4,4	4,4	4,4	4,4	4,4	4,4	3,4	3,4	3,4	3,4	3,4	3,4	Ha
4,4	4,4	4,4	4,4	4,4	4,4	2,4	2,4	2,4	2,4	2,4	2,4	Nc

Nash equilibria with unequal payoffs shaded

Zero-sum games Pareto-inferior equilibria

8. Ordinal payoffs for entries in the Atlas of Interpersonal Situations

Figure A10 shows the original payoff values used by Kelley et al. (2003) to illustrate entries in the Atlas of Interpersonal Situations and equivalent ordinal payoffs ranked from 1 to 4. The ordinal payoffs have been standardized to put Row's highest payoff in the right-hand column and Column's highest payoff in the upper row (Row's 4 right, Column's 4 up). As discussed in the main text, this standardization of ordinal payoffs and orientation of best outcomes shows the convergence between interdependence theory and the extended topology of 2x2 games in identifying archetypal games.

Figure A10. Illustrative payoff matrices for entries in the Atlas of Interpersonal Situations and ordinal equivalents in standardized orientation (Row's 4 right, Column's 4 up).

Entry #	Page		Original				Standardized				
Primal Independence (DhDh)											
1		Independence: We go our separate ways									
	141	E1.1	10	8	10	0	4	4	4	1	
			0	8	0	0	1	4	1	1	
	141	E1.2	0	8	0	-6	4	4	4	1	
			-10	8	-10	-6	1	4	1	1	
Primal Exchange (DuDu)											
2		Mutual partner control: I scratch your back, you scratch mine									
	149	E2.1	8	10	0	10	1	4	4	4	
			8	0	0	0	1	1	4	1	
	149	E2.2	-10	0	0	0	1	4	4	4	
			-10	-2	0	-2	1	1	4	1	
Primal Coordination (DoDo)											
3		Corresponding mutual joint control: Getting in sync									
	160	E3.1	5	10	0	0	4	4	1	1	
			0	0	5	10	1	1	4	4	
	160	E3.2	-10	-10	0	0	1	1	4	4	
			0	0	-10	-10	4	4	1	1	
Primal Conflict ($DoDo_1$)											
4		Conflicting mutual joint control: Match or mismatch									
	171	E4.1	5	-5	-5	5	4	1	1	4	Primal Conflict, Matching Pennies
			-5	5	5	-5	1	4	4	1	
	172	E4.2	-10	-10	-10	0	1	4	1	1	Basic Discord, L1
			0	-10	-10	-10	1	1	4	1	
Prisoner's Dilemma (PdPd)											
5		Prisoner's dilemma: Me versus we									
	189		5	5	-5	10	1	4	3	3	
			10	-5	0	0	2	2	4	1	
Threat/Jekyll-Hyde (MhMk)											
6		Threat: Trading loyalty for justice									
	202	E6.1	12	6	6	12	3	4	4	3	
			6	0	0	6	1	3	3	1	

Chicken (CkCk)

7 Chicken: Death before dishonor

211	E7.1	-3	-3	-9	3	2	4	3	3	
		3	-9	-15	-15	1	1	4	2	
212	E7.2	15	15	9	21	2	4	3	3	
		21	9	3	3	1	1	4	2	

Hero (HrHr)

8 Hero: Let's do it you way

226	E8.1	8	12	0	0	3	4	1	1	
		4	4	12	8	2	2	4	3	
	E8.2	4	4	12	8	3	4	1	1	
		8	12	0	0	2	2	4	3	

Stag Hunt (ShSh)

9 Conjunctive problems: Together we can do it

237	E9.1	7	7	0	0	1	1	4	4	Win-Win
		0	0	0	0	1	1	1	1	
	E9.2	7	7	0	3	1	3	4	4	Stag Hunt
		3	0	3	3	3	3	3	1	

Volunteer's Dilemma (MbMb)

10 Disjunctive problems: Either of us can do it

247	E10.1	10	10	10	10	4	4	4	4	Avoidance
		10	10	0	0	4	4	1	1	
	E10.2	7	7	7	10	3	4	3	3	
		10	7	0	0	1	1	4	3	

Primal Win-Lose ($DuDh_1$)

11.1 Asymetric dependence: You're the boss

266	E11.1	10	-4	-4	10	1	4	4	1
		10	-4	-4	10	1	4	4	1

Primal Help (DhDo) Helping Hand

11.2	267	E11.2	4	-4	-4	10	1	1	4	4
			-4	-4	4	10	4	1	1	4
	48	2.8.II.2	0	10	5	0	1	1	4	4
			5	10	0	0	4	1	1	4

Primal Gift (DhDu)

48	2.8.I.1	10	5	0	0	1	1	4	4
		10	5	0	0	1	1	4	4

Primal Favors (DoDu)

48	2.8.II.2	0	10	5	0	1	1	4	4
		5	10	0	0	4	1	1	4

Convention (LoLo) issues discussed using payoff for Middle Harmony (MhMh), Invisible Hand

85	4.2.2	12	12	6	6	3	3	4	4
		6	6	0	0	1	1	3	3

9. Indifference and changing preferences

Making and breaking ties represents changes in preferences. It can sometimes be convenient to assume fixed preferences, as in much of game theory and economic theorizing. However, there are many reasons why payoff values might change. Individual preferences and choice behavior may be stochastic and dynamic, influenced by multiple external and internal processes (Symmonds and Dolan 2012). New information, better understanding, or careful consideration might show why one outcome is superior. Prominent examples or social norms might focus attention on desirable outcomes. Persuasion could cause more concern about what happens to another person (other-regarding preferences), such as putting a higher value on mutually beneficial win-win outcomes. Similar changes in preferences about others' outcomes might come from bonding within a group or focusing on what is best for the group (team reasoning). Interaction could also result in antipathy or rivalry, competitive feelings, and a willingness to punish or suffer losses if it makes the other worse off.

Conversely, changes might erase differences, equalizing outcome ranks, creating indifference between outcomes. Some outcomes may come to appear irrelevant and not worth attention. More information, instability, or uncertainty might make some comparisons seem meaningless. Decisions might focus on a few outcomes, ignoring others or acting indifferent, as if they were equally ranked, due to simple heuristics, urgency, or exhaustion. People might cease caring or paying attention to what happens to the other person. Thus, changes could blur or dissolve the difference between some outcomes, simplifying payoff structures, or they could sharpen differences, resolving into a more complex configuration of payoffs.

Payoff swaps and simplification and differentiation of payoff structures can also be seen in terms of payoffs that vary (trembling payoffs). These might vary , perhaps in a predictable way, such as seasonal changes in water availability or risks that can be estimated with reasonable accuracy. Or payoffs could be uncertain, in the sense of incomplete information that limits the ability to form accurate expectations, such as the dynamics of poorly-understood aquifers. More fundamentally, preferences may be incomplete in more profound ways, perhaps only resolved to the extent necessary to make specific decisions, using heuristics as part of bounded rationality (Simon 1990). Values may be diverse and not easily reconcilable, within a community or even within a single decisionmaker (Berlin 2012).

To the extent outcomes can be valued more precisely, the topology of payoff swaps can be extended to more fully map the payoff space of 2x2 games. For simplicity in exposition, in this paper we mostly present ideas using ordinal games with ranked outcomes. Where payoffs can be measured more precisely, on interval (ratio) or cardinal (real) scales, those values can also be normalized to a 1-4 scale and mapped onto a continuous version of the topology of 2x2 games. A continuous payoff space models more detailed differences in the ranking of outcomes and more gradual transitions in ranking that transform one game into another. Symmetric ordinal games provide coordinates for naming and locating games within a payoff space of 2x2 games, like integers on a number line or Cartesian coordinates. Within this space, archetypes offer useful landmarks for understanding the structure and diversity of interdependence, including opportunities and challenges for cooperation.

10. Dimensions of interdependence

Analysis of archetypal games shows areas of potential for further research and synthesis concerning the relationships between different kinds of social situations. As described above, analysis of archetypal games based on the topology of 2x2 games converges with interdependence theory in social psychology (Kelley and Thibaut 1978, Kelley et al. 2003, Balliet et al. 2017) in identifying a central role for the three symmetric situations exemplifying elementary independence, coordination, and exchange. Interdependence theory uses an analysis of variance approach to decompose payoff matrices into row, diagonal, and column components. These three components are exemplified by the “single component” games for independence (control over the actor’s own outcome), coordination (joint control), and exchange (control over the partner’s outcome). Any payoff matrix can be composed and analyzed as the weighted combination of the single component games. Interdependence theory arranges games in three dimensions related to independence, congruence (coordination or conflict), and dependence. Analysis using the topology of 2x2 games offers an alternative and potentially more easily understood way to map the relationships between different elementary social situations, including archetypes and regions modelling different problems of collective action.

The normalized payoffs in the continuous topology of 2x2 games form a subspace of the eight-dimensional space of 2x2 games analyzed by Saari and colleagues (Jessie and Saari 2019, Guisasola and Saari 2020). With an interest in explaining equilibrium selection in coordination games, Guisasola and Saari (2020) make a decomposition of payoff matrices (with a full range of payoff values, not just ordinal or normalized values) into three orthogonal components somewhat similar to those of interdependence theory: 1) a Nash equilibrium (best response) component under each actor’s own control, 2) a joint coordination/anti-coordination component, and 3) an externality component for how each actor’s actions increase or decrease the other’s payoffs. They also have a “kernel” scaling factor for each actor’s payoff values. For diagnostic analysis and design, their coordinate system helps examine how the mutual gains from coordination and the impact of externalities may outweigh incentives towards a Nash equilibrium. This seems to offer a general framework to examine the question of how changes in payoff values increase or reduce “pressures” that affect behavior in 2x2 games (Rapoport et al. 1976, Kelley et al. 2003).

Interdependence Theory and Guisasola and Saari’s game coordinate system decomposition both map the payoff space of 2x2 games in three dimensions with components for independent control over one’s own fate, as in Primal Independence; joint control as in Primal Coordination; and control over each other’s outcome, as in Primal Exchange. The topology of 2x2 games maps regions of related games according to the number of Nash equilibria (resulting from dominant strategies), displays coordination and cyclic (anti-coordination/conflict) games as compact connected regions, and also groups games according to their externalities (inducement correspondences) (Robinson and Goforth 2005, Bruns 2015). This seems to offer a fruitful opportunity for further comparison and analysis. Interdependence theory and the coordinate systems developed by Saari and colleagues assume orthogonal dimensions completely distinct from each other (uncorrelated). As an alternative, the topology of 2x2 games suggests partially overlapping regions and a more complex distribution of characteristics. The structure of interdependence in the payoff space of 2x2 games might also be further analyzed using additional approaches, such as correlated dimensions as in factor analysis, crisp or fuzzy categories of cases as in QCA (Ragin 2009), or regions with emergent and distinctive properties as in non-linear dynamics (Strogatz 2018).

Another approach to applying archetypes is to concentrate on a smaller set of games. Rapoport (1967) originally identified four symmetric archetypes for conflict, based on Prisoner's Dilemma (Exploiter), Chicken (Martyr), Leader, and Hero. Alternatively, in research on psychological processes prevalent in conflict and negotiation, Halevy and colleagues (Halevy et al. 2012, Halevy and Katz 2013) found that study participants usually described situations that fit four symmetric archetypal games: Prisoner's Dilemma, Chicken, Stag Hunt, and Maximum Difference (Concord). Molho and Balliet (2017) suggest that experiments and meta-analysis could compare interdependence theory with analysis based on a small set of prototypical games. Such comparative analysis could extend to include the topology of 2x2 games and the game coordinate systems proposed by Saari and colleagues (Jessie and Saari 2019, Guisasola and Saari 2020) as further alternative or complementary approaches for modeling and analyzing behavior in social situations.

11. Limitations and extensions: understanding complexity in payoff space

If "my mask protects you and your mask protects me" and I care about what happens to you, this transforms the situation so that I prefer to wear a mask, whatever you do. This changes the game from Primal Exchange into Concord, as in Figure 3. Indifference changes into higher ranks for outcomes where I wear a mask. A similar change could also occur if it turns out that wearing a mask also gives me some protection, if norms shift so I am concerned about my neighbors' approval, or if not wearing a mask risks penalties for violating a government rule. Additional considerations could include inconvenience of mask-wearing, different beliefs about risks and benefits, and politicization of mask wearing as some kind of signal or expression of identity. All these changes could occur asymmetrically, for one but not the other, creating a variety of possible payoff structures. Simple models such as the archetypes discussed in this paper may sometimes offer useful insights, but are only tools for trying to understand and act in a complex world. Pejó and Biczók (2020) offer an example and discussion of early efforts to apply game theory models to the challenges posed by Covid-19.

Archetypal games offer highly simplified models that illustrate and help analyze some important aspects of social situations. However, problems and solutions often depend on specific details of history and context. The transformations by making and breaking ties in primal archetypes described in this paper are a useful starting point, but trace only a few of the vast number of possible pathways through the topology of payoff swaps that connect 2x2 games (Robinson et al. 2007). Empirical changes are not limited to those that would make or break ties in a single pair of payoffs, or only follow a pathway of symmetric changes in payoffs.

For payoffs not restricted to ordinal ranks, normalized payoffs can be mapped onto a continuous version of the topology (Bruns 2015). However, the actual payoff values may still contain crucial information, such as when benefits or risks are very high for one outcome or one actor. As discussed above, individual preferences and choice behavior may be stochastic and dynamic, influenced by multiple external and internal processes. Information may be incomplete in a variety of ways. The topology of games can extend beyond 2x2 games to include situations with multiple actors and help understand the potential for endogenous evolution of situations to achieve better results (Frey and Atkisson 2020). Archetypal games could help expand the menu of models considered in research, including efforts to understand how cooperation is affected by different rules and other conditions (Taylor and Ward 1982, Nowak 2006, Taylor 2006, Van Lange et al. 2014, Balliet et al. 2017), such as common knowledge (Schelling 1960, Chwe 2013), repeated interaction (Axelrod 1984), communication (Ostrom et al. 1994), and negotiation, including with intelligent agents (Crandall et al. 2018).

The ways in which simple archetypes generate more diverse situations offer tools for understanding similarity and diversity in interdependence in social-ecological situations. Archetypes and their relationships may thereby contribute to the potential role of game theory as a part of a unifying language for behavioral and evolutionary science (Gintis 2007, Cronk and Leech 2013). Archetypes provide simple building blocks for understanding social-ecological systems that may also contribute to the quest to understand more complex systems, as stated by Elinor Ostrom (2010):

> We should continue to use simple models where they capture enough of the core underlying structure and incentives that they usefully predict outcomes. When the world we are trying to explain and improve, however, is not well described by a simple model, we must continue to improve our frameworks and theories so as to be able to understand complexity and not simply reject it.

Literature cited

Axelrod, R. 1984. *The evolution of cooperation*. Basic Books, New York, USA.

Balliet, D., J. M. Tybur, and P. A. Van Lange. 2017. Functional interdependence theory: an evolutionary account of social situations. *Personality and Social Psychology Review* 21(4):361–388.

Berlin, I. 2012. *The proper study of mankind: an anthology of essays*. Random House.

Bruns, B. 2010. Transmuting Samaritan's Dilemmas in irrigation aid: an application of the topology of 2x2 games. Page *Capturing the Complexity of the Commons: International Association for the Study of Commons 2010 North American Regional Meeting*. Tempe, AZ, USA.

Bruns, B. 2015. Names for games: locating 2 × 2 games. *Games* 6(4):495–520.

Caragiannis, I., D. Kurokawa, and A. D. Procaccia. 2014. Biased games. Pages 609–615 *Proceedings of the Twenty-Eighth AAAI Conference on Artificial Intelligence*.

Chwe, M. S.-Y. 2013. *Rational ritual: culture, coordination, and common knowledge*. Princeton University Press, Princeton, N.J, USA.

Crandall, J. W., M. Oudah, F. Ishowo-Oloko, S. Abdallah, J.-F. Bonnefon, M. Cebrian, A. Shariff, M. A. Goodrich, and I. Rahwan. 2018. Cooperating with machines. *Nature Communications* 9(1):233.

Cronk, L., and B. L. Leech. 2013. *Meeting at Grand Central: understanding the social and evolutionary roots of cooperation*. Princeton University Press.

Frey, S., and C. Atkisson. 2020. A dynamic over games drives selfish agents to win–win outcomes. *Proceedings of the Royal Society B: Biological Sciences* 287(1941):20202630.

Gintis, H. 2007. A framework for the unification of the behavioral sciences. *Behavioral and Brain Sciences* 30(1):1–16.

Goforth, D., and D. Robinson. 2012. Effective choice in all the symmetric 2x2 games. *Synthese* 187(2):579–605.

Guisasola, S., and D. Saari. 2020. With potential games, which outcome is better? *Games* 11(3):33.

Halevy, N., E. Y. Chou, and J. K. Murnighan. 2012. Mind games: the mental representation of conflict. *Journal of Personality and Social Psychology* 102(1):132.

Halevy, N., and J. J. Katz. 2013. Conflict templates: thinking through interdependence. *Current Directions in Psychological Science* 22(3):217–224.
Hasenclever, A., P. Mayer, and V. Rittberger. 1997. *Theories of international regimes*. Cambridge University Press, Cambridge, UK.
Heilig, S. 2012. When prisoners enter battle: natural connections in 2 X 2 symmetric games. Honor's Thesis, Saint Peter's College, Jersey City, NJ, USA.
Holzinger, K. 2003. *The problems of collective action: a new approach*. Preprints aus der Max-Planck-Projektgruppe Recht der Gemeinschaftsgüter, Max-Planck-Projektgruppe Recht der Gemeinschaftsgüter, Bonn, Germany.
Hopkins, B. 2014. Expanding the Robinson-Goforth system for 2x2 games. Pages 177–187 *in* Crisman, Karl-Dieter and Jones, Michael A, editors. *The Mathematics of decisions, elections, and games*. American Mathematical Society, Providence, RI, USA.
Huertas-Rosero, Á. F. 2003. A cartography for 2x2 symmetric games. *arXiv preprint cs/0312005*.
Jessie, D. T., and D. G. Saari. 2019. *Coordinate systems for games*. Springer Nature, Switzerland.
Kauffman, S. 1995. *At home in the universe: the search for laws of self-organization and oomplexity*. Oxford University Press, New York.
Kelley, H. H., J. G. Holmes, N. L. Kerr, H. T. Reis, C. E. Rusbult, and P. A. M. Van Lange. 2003. *An atlas of interpersonal situations*. Cambridge University Press, Cambridge, UK.
Kelley, H. H., and J. W. Thibaut. 1978. *Interpersonal relations: a theory of interdependence*. John Wiley & Sons Inc, New York, USA.
Martin, L. L. 1992. Interests, power, and multilateralism. *International Organization* 46(4):765–792.
Molho, C., and D. Balliet. 2017. Navigating interdependent social situations. Pages 1–30 *in* J. F. Rauthmann, R. A. Sherman, and D. C. Funder, editors. *The Oxford handbook of psychological situations*. Oxford University Press, Oxford, UK.
Nowak, M. A. 2006. Five rules for the evolution of cooperation. *Science* 314(5805):1560–1563.
Ostrom, E. 2010. Beyond markets and states: polycentric governance of complex economic systems. *American Economic Review* 100(3):641–72.
Ostrom, E., R. Gardner, and J. Walker. 1994. *Rules, games and common-pool resources*. University of Michigan Press, Ann Arbor, MI, USA.
Pejó, B., and G. Biczók. 2020. Corona games: masks, social distancing and mechanism design. Pages 24–31 *Proceedings of the 1st ACM SIGSPATIAL International Workshop on Modeling and Understanding the Spread of COVID-19*.
Ragin, C. C. 2009. *Redesigning social inquiry: fuzzy sets and beyond*. University of Chicago Press, Chicago, USA.
Rapoport, A. 1967. Exploiter, leader, hero, and martyr: the four archetypes of the 2 times 2 game. *Behavioral Science* 12(2):81.
Rapoport, A., M. J. Guyer, and D. G. Gordon. 1976. *The 2 x 2 game*. University of Michigan Press, Ann Arbor, USA.
Robinson, D., and D. Goforth. 2005. *The topology of the 2x2 games: a new periodic table*. Routledge, London, UK.
Robinson, D., D. Goforth, and M. Cargill. 2007. Toward a topological treatment of the non-strictly ordered 2x2 games. *Working Paper*.
Schelling, T. C. 1960. *The strategy of conflict*. Harvard University Press, Cambridge, MA.
Simon, H. 1990. Bounded Rationality. Pages 15–18 *in* John Eatwell, Murray Milgate, and Peter K. Newman, editors. *The New Palgrave: Utility and Probability*. Norton, New York, NY, USA.

Simpson, J. 2010. Simulating strategic rationality. Ph.D. Dissertation, University of Alberta, Edmonton.
Strogatz, S. H. 2018. *Nonlinear dynamics and chaos with student solutions manual: with applications to physics, biology, chemistry, and engineering*. CRC Press.
Symmonds, M., and R. J. Dolan. 2012. The neurobiology of preferences. Pages 3–31 *Neuroscience of preference and choice*. Elsevier, Amsterdam, Netherlands.
Taylor, M. 2006. *Rationality and the ideology of disconnection*. Cambridge University Press.
Taylor, M., and H. Ward. 1982. Chickens, Whales, and Lumpy Goods: Alternative Models of Public Goods Provision. *Political Studies* 30(3):350–370.
Van Lange, P. A., D. P. Balliet, C. D. Parks, and M. van Vugt. 2014. *Social dilemmas: understanding human cooperation*. Oxford University Press, Oxford, UK.
Zürn, M. 1993. Problematic social situations and international institutions: on the use of game theory in international politics. Pages 63–84 *International relations and pan-Europe: theoretical approaches and empirical findings; publication of the proceedings of the Inaugural Pan-European Conference in International Relations, Heidelberg, Germany, September 16-22, 1992*. Verlag, Hamburg, Germany.