Organizational coordination: A game-theoretic view

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Abstract: While several areas of organizational research have benefited from the use of games to study interaction between individuals, one area that has not done so is the study of organizational coordination. This is in spite of the large game-theoretic literature on coordination games and solutions to coordination problems. This paper brings the two approaches together, showing how simple games can be used to represent different problems of organizational interdependence and how game-theoretic solutions to coordination problems are related to organizational solutions.

I. Introduction

Coordinating activity is an important problem faced by organizations (March and Simon, 1958; Thompson, 1967; Malone and Crowston, 1994). Organizational researchers have relied on several different approaches to study coordination problems. For instance, one approach consists of work aimed at identifying successful coordination practices in existing organizations by directly examining behavior in small samples of actual firms (Lawrence and Lorsch, 1967; Thompson, 1967) and by collecting data on practices across organizational units (Argote, 1982). As another example, more recent research uses computational models to explore interdependence between organizational units or practices, including in the models things such as turnover rates and environmental uncertainty (Carley and Lin, 1997; Carley, 1992). However, one approach that has been largely ignored in organizational research is the extensive game-theoretic literature, both experimental and theoretical, on coordination (see Cooper, 1999; Ochs, 1995).

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This paper is an attempt to bridge the gap between organizational and game-theoretic work on coordination. While many aspects of organizational coordination are not usefully captured by games, this does not eliminate the value of game theory as a tool for organizational research. On the contrary, representing complicated strategic situations in a very simple, abstract, and formal way provides useful insight into how behavior might change as the underlying structure of a situation changes and presents us with a common tool for analyzing seemingly different situations. The value of game theory for organizational research can be seen in the fact that other areas of organizational research benefited from this approach.[1] The goal of this paper is to make a similar case for using game theory as a tool for studying coordination in organizations. The goal is not to argue that the application of game theory to research on organizational coordination should replace other better-established approaches, but that instead that it is a useful complement to other approaches.

II. Game theory and organizational research

Game theory is an extension of decision theory to situations involving strategic interaction. Put simply, game theory is a way to derive and analyze very simplified, abstract representations of situations involving interaction in decisions or actions. Therefore, game theory can be applied to many of the same situations that are the focus of social psychology, network theory, and multi-agent complex systems modeling.

A game-theoretic representation of a situation has the following basic elements:[2]

1. A set of decision makers or players,
2. A set of actions available to each of the players,
3. A mapping from all combinations of actions into outcomes,
4. Preferences for each player over each of the outcomes,
5. The information and beliefs held by players at any point in the game

[1]This research is discussed in the next section.
[2] The representation here is general and contains, as special cases, different categories of games. For instance, information plays no role in one class of games (games of complete information)

Players. In standard game theory, players are usually thought of as extremely rational, self-interested, utility maximizing decision makers that efficiently use all available information. Therefore, traditional game theory ignores potential individual differences in things such as culture, intelligence, and possible motives other than self-interest. Typically, the only possible differences between players are in their preferences over outcomes.[3]

Actions. The actions are typically represented abstractly. For instance, if a player has three available choices, these might be represented as a_1, a_2, and a_3 and not otherwise distinguished. Therefore, traditional game theory ignores that the labels attached to actions may elicit norms or otherwise affect behavior (cf. Ross and Ward, 1996). Similarly, the information and beliefs held by players usually cover only abstract parameters of the game such as the values associated with certain outcomes. Traditional game theory ignores any possible context in information or beliefs, omitting the possibility that players' beliefs and information may be closely tied to things such as norms and affect.

Outcomes. The mapping of action combinations into outcomes represents the structure of the interaction. This mapping represents what the possible outcomes are and how players' actions interact to produce these outcomes.

Preferences. Players' preferences over each of the outcomes are represented by utility values. While these values are often used interchangeably with monetary values, they can also include other components that a player might value, such as social concerns (e.g., Rabin, 1993). Traditional game theory assumes that these values are stable, so that players' preferences over outcomes are not affected by what takes place in the game.

Information. The information held by players is typically represented by the extent to which they can distinguish between different states of the world. For instance, a player might not be aware of what action another player took previously, or a player might not be aware whether the other player places a high or a low value on a particular outcome.

[3] In games of incomplete information, it is possible to allow one player to have different potential values over outcomes and to have the actual values determined probabilistically. This is done by designating "nature" as a player and having nature "act" to determine the players' type. The information available to any of the players about the true type can then be varied. An organizational example of this type of problem might occur when prospective employees are either "hardworking" or "lazy" (which can be determined by their "cost" for working) and an employer knows that there is one true type but cannot observe it.

Once we have a game as defined above, we can apply a solution concept to predict behavior and outcomes. The most frequently used concept is Nash equilibrium. Put simply, an outcome is a *Nash equilibrium* if, at that outcome, no player wants to change his or her choice holding what others players are doing as fixed

To illustrate the concept of Nash equilibrium (often simply referred to as "equilibrium"), consider a familiar example: the Prisoner's Dilemma game (PD), represented by the matrix in Table 1. The game has two players (Player 1 and Player 2), each of whom has two actions (Cooperate (C) and Defect (D)). Each of the combinations of actions results in one of the four cells of the matrix, each of which represents an outcome. Preferences over outcomes are given by the utility values in each cell; the first number is the value for the first player, while the second number is the value for the second player.

		Player 2	
		Cooperate (C)	Defect (D)
Player 1	Cooperate (C)	2, 2	0, 3
	Defect (D)	3, 0	1, 1

Table 1. Prisoner's Dilemma (PD) Game

The unique Nash equilibrium for PD is the outcome in which both players choose D, resulting in a payoff of 1 for both. While there is another outcome (C, C) which both players prefer, it is not an equilibrium because each player could do better by switching her action to D.[4]

To lay the foundation for the game-theoretic analysis of coordination in the rest of the paper, it is useful to now present another representation of games, known as the "extensive" form (Figure 2). This representation allows us to take into account temporal aspects of the game, as well as any resulting limited information over prior moves of other players.

[4] Since D always yields a higher payoff – no matter what the other player does – it is a *dominant strategy*.

In Figure 2, the game represented is exactly the same game as in Table 1. Player 1 moves first, selecting C or D and then Player 2 selects similarly. The circle around Player 2's choices is important; it represents the fact that Player 2 does not know what choice Player 1 made prior to making her own choice. The circle identifies which "nodes" Player 2 is unable to distinguish between: if Player 2 could observe the choice made by Player 1, then the circle would be erased and Player 2 would know where in the game she is when making her choice (i.e., she would know what action Player 1 had taken). The players' values over outcomes are the numbers next to each of the outcomes – at the end of a "branch" – with the number on top corresponding to the value for Player 1. The values are the same as in Table 1.

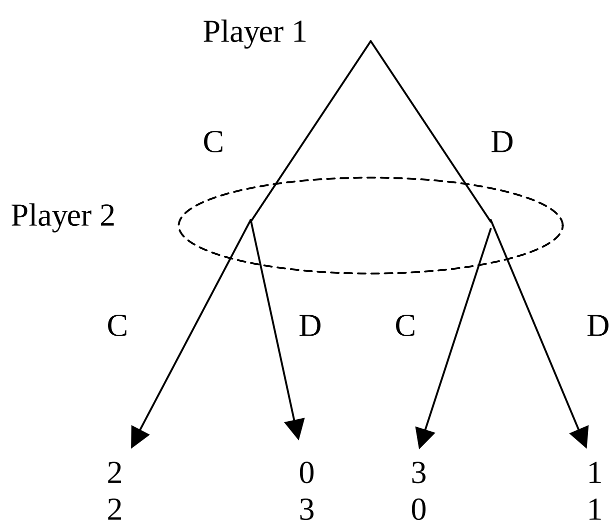

Figure 1. PD Game in extensive form

The unique Nash equilibrium is again (D, D). As before, defecting is a dominant strategy. The fact that the game is represented in extensive form does not imply any difference according to traditional game theory. In spite of the fact that one player now moves first, traditional analysis predicts no difference since players' information is unchanged.[5] However, for modeling coordination in organizations it will be useful to have a representation of situations in which players may act at different points in time.

The Prisoner's Dilemma represents situations where there is a cooperative outcome that is collectively optimal (C, C) but is not an equilibrium because players have individual incentives to select D – resulting in the only equilibrium being (D, D). However, several laboratory studies have shown that cooperation rates are typically high.[6] Therefore, while PD is one of the most commonly studied games – particularly in organizational research (e.g., Bettenhausen and Murnighan, 1991; Kogut and Zadner, 1996) – it is also one in which the equilibrium prediction is most often wrong.

The above description of game theory depicts in a theory that seems at first glance unsuitable for organizational research. It ignores many aspects of social interaction (in organizations or elsewhere) that are very likely to influence behavior and outcomes. It makes unrealistic predictions based on unreasonable assumptions about players, their preferences, and the decision concepts or rules they might use to guide their choices (as in PD). One might argue that these are the main reasons why, in spite of interest in coordination both among organizational researchers and game theorists, the two approaches are rarely combined.

However, organizational researchers have frequently used games to study organizational problems other than coordination. For instance, there is extensive organizational research in the area of social cooperation using Prisoner's Dilemma and public goods games (Bettenhausen and Murnighan, 1991; Kogut and Zadner, 1996; Dawes and Orbell, 1990), research in bargaining that uses ultimatum and other bargaining games (Messick, Moore and Bazerman, 1997; Blount, 1995; Blount, Thomas-Hunt and Neale 1996), and work on the emergence of organizational routines that uses simple games (Leavitt, 1960; Cohen and Bacdayan, 1994). Given the extent to which games are used to study the above organizational topics, they must have some value in organizational research, in spite of the many problems with game theory. There are two main reasons why dismissing the value of games for organizational research is wrong.

[5] There is research indicating that the extensive-strategic game form equivalence is violated behaviorally and that the temporal order of moves matters (Schotter, Weigelt and Wilson, 1994; Cooper, et al., 1993; Camerer, Weber and Knez, 2000).
[6] See, for instance, Roth (1995a).

First, while traditional game theory is incorrect in its predictions more often than not, behavioral game theory – which aims to improve the predictive value of the theory by taking into account many aspects of social interaction that are familiar to psychologists, sociologists, and researchers in other fields – has made advances in pursuit of a descriptively better theory. For instance, there is a substantial body of evidence indicating that the self-interested prediction of traditional game theory is wrong.[7] It is not surprising that subjects in experiments will frequently give up money in order to reward or punish others. Recent theoretical work recognizes this and extends traditional game theory to allow players to have concerns for how their outcomes compare to those of others (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) or for reciprocating positive or negative actions by others (Rabin, 1993).[8] To the extent that advances in behavioral game theory improve the predictions and real-world applicability of the theory, game theory becomes a more useful tool for studying problems in real settings such as organizations.

A second and perhaps more important reason, given the current limitations of game theory, is that there is value in formally describing the basic structure of a situation. Writing down and analyzing the most basic aspects of a social problem yields some important insights. It becomes possible to obtain a clear view of key elements of the situation and what exactly makes that situation unique from others. In addition, a formal representation allows us to compare and contrast apparently different or similar situations and to make comparative-static predictions about what will happen as one aspect of the situation changes. Once we can describe situations in a common language, it becomes very easy to make comparisons between these situations and to predict how behavior will change as any of the simple parameters describing the situation are changed.

This paper is concerned primarily with the second reason and its application to the study of organizational coordination. Therefore, the main part of the paper deals with

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[7] A large part of this evidence is in the extensive experimental literature on PD, bargaining, and public goods games. In experiments using both these types of games, the equilibrium prediction of self-interested behavior is frequently rejected (see Ledyard, 1995; Roth, 1995b).

[8] Further research in behavioral game theory relaxes assumptions concerning the rationality of players (McKelvey and Palfrey, 1995; Costa-Gomez, Crawford and Broseta, 1998), recognizes that things such as conventions and norms matter in determining outcomes (Bicchieri, in progress; Bacharach and Bernasconi, 1997; Knez and Camerer, 1995), and allows for the possibility that players construal or personal or social representation of the game may matter (Colin's mental models paper?).

representing and analyzing common organizational coordination problems game-theoretically. The next section defines coordination in both organizational and game-theoretic terms. As we will see below, two common problems in organizations that are often confused and treated interchangeably are actually quite different and this difference becomes clear when the problems are represented game-theoretically.

III. Organizational and game-theoretic coordination

In order to discuss coordination in both organizational and game-theoretic terms, it is first necessary to define it according to both approaches. Malone and Crowston (1994) summarize several definitions of organizational coordination problems, including: "managing dependencies between activities" (p. 90) and "the additional information processing performed when multiple, connected actors pursue goals that a single actor pursuing the same goals would not perform" (p. 112). Thompson (1967) discusses coordination as the solution to problems of interdependence, or problems that arise whenever outcomes depend on what is being done elsewhere in the organization. A final description arises from the organizational practice of specialization, which results in "goal decomposition" and the need to subsequently integrate the goals and activities of different units (Lawrence and Lorsch, 1967; Heath and Staudenmayer, 2000).

While each of the definitions differs slightly from the others, it is possible to synthesize a common construct based on their similarities. There are two aspects common to most definitions: 1) problems arise because of specialization and decomposition of activities and 2) these problems arise because these activities are interdependent or need to be integrated correctly to achieve the organizational goal. In addition, a large part of the discussion of coordination in the organizational literature points to problems that can be solved through increased communication, planning or the establishment of self-enforcing norms or routines (March and Simon, 1958; Thompson, 1967; Heath and Staudenmayer, 2000). Therefore, coordination problems are not those in which actors have goals that are not aligned, as in the Prisoner's Dilemma or problems of cooperation. We will return to this point later.

Coordination problems have also received attention from game-theorists. Schelling (1960) discusses the most basic form of coordination problems, or "matching" problems in which each decision maker's goal is to match what others are doing. In these common-interest problems the only source of difficulty is that all parties must arrive at a consensus of expectations about the correct choice.[9] These basic problems – in which, for instance, two people have to figure out where to meet without being able to communicate – capture the aspect of coordination that is essential to game-theorists: the presence of multiple equilibria (Ochs, 1995; Cooper, 1999) and *strategic uncertainty*, or uncertainty about what action others will take. The game in Table 2 represents the most basic form of the problem.

		Player 2: A	Player 2: B
Player 1	A	1, 1	0, 0
	B	0, 0	1, 1

Table 2. Pure Matching coordination game

In this game, as in the Prisoner's Dilemma, there are two players and each has two actions (in this case they are labeled "A" and "B"). Each player values positively only the outcomes in which both players make the same choice. This game has two pure-strategy equilibria: (A,A) and (B,B).[10] Players do not care which equilibrium is reached, but only that their actions coincide. Game theorists label this game a "pure coordination" game because the only problem is figuring out which of two equally valued equilibria will result.[11] The coordination problem arises because of the presence of two equilibria

[9] Problems of this kind have also received considerable attention in the linguistics literature (Lewis, 1969) and have been studied experimentally by Bacharach and Bernasconi (1997).
[10] Pure-strategy equilibria are those in which players select one of the available actions with probability 1. Many of the games in this paper also have mixed-strategy equilibria in which players choose actions probabilistically. However, since all the coordination games will have more than one pure-strategy equilibrium and these are the most commonly played empirically, the analysis will omit mixed strategies.
[11] Other types of coordination games can involve such things as mixed motives: assume instead that the equilibrium payoffs are different so that (A,A) now yields (2,1) and (B,B) yields (1,2). In this game, known as the "Battle-of-the-Sexes" game, players have an incentive to coordinate on one of the two equilibria (they're better off at either equilibria than at either of the out-of-equilibrium outcomes) but also

and uncertainty about which one should be played. The game therefore captures the aspect of a problem that makes it a coordination problem: strategic uncertainty. Strategic uncertainty results from uncertainty about what actions others will take. Once subjects are at an equilibrium, the strategic uncertainty (as well as the coordination problem) is resolved.

Given the interest of both organizational researchers and game theorists in coordination problems, it is surprising that the value of combining the two areas has not been realized. For instance, the organizational analogy of the game in game in Table 2 is a situation in which there are several possible "best" actions, but each action is the best only if others are taking it as well. Examples include the adoption of certain technologies that may only be beneficial if other parts of the organization are adopting the same technology (e.g., operating systems, accounting systems) (Milgrom and Roberts, 1992; Weber, 2000), or some software development in which there are several different programs that may work equally well but where the program will only work if all the components are designed coherently (Kraut and Streeter, 1995; Heath and Staudenmayer, 2000). As with other organizational coordination problems, the type of problem captured by this game can be resolved through things such as informal history and norms, communication, and formal rules governing which of the two actions should be played. Given the presence of problems of this kind in organizations, applying this and more complicated versions of the same game – for instance, with more actions or players, or with changing "environments" or sets of actions seems useful.

Another area in which game theory might help organizational research is in pointing out key differences between concepts that may often be treated interchangeably.

IV. Coordination vs. Cooperation

Organizational researchers often discuss problems of *coordination* and *cooperation*, and the two concepts are frequently treated interchangeably (Kogut and Zadner, 1996;

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care which of the two equilibria are reached (Cooper, et al., 1989 & 1993). Other examples coordination games will be discussed subsequently in this paper.

Williamson, 1991; Malone and Crowston, 1994; Murnighan, Kim, and Metzger, 1993). However, game theory provides a simple way to represent the two concepts and clearly define the difference between them.

To see exactly how a game theorist would distinguish coordination problems from cooperation problems, consider the difference between the Prisoner's Dilemma game in Table 1 and the Stag-Hunt game in Table 3.[12]

		Player 2	
		High (H)	Low (L)
Player 1	High (H)	2, 2	0, 1
	Low (L)	1, 0	1, 1

Table 3. Stag-Hunt Game

The game in Table 3 is similar to PD in the outcomes along the diagonal: both games have outcomes yielding (2,2) and (1,1). In addition, Stag-Hunt also has an equilibrium corresponding to the (1,1) outcome resulting when both players select L. However, the games are otherwise quite different.

The difference arises from the difference in payoffs for the off-diagonal outcomes. If one player chooses L in Stag-Hunt while the other player chooses H, this yields a payoff of 1 to the player choosing L and a payoff of 0 to the player choosing H. In PD, the corresponding outcome yields 3 for the player choosing D and 0 for the player choosing C. Therefore, unlike in PD where the action D is a dominant strategy, L is not a dominant strategy in the Stag-Hunt game. If the other player is choosing H, it is optimal to choose H as well, resulting in one other pure-strategy equilibrium (H, H).

Stag-Hunt has two (pure-strategy) equilibria and is therefore a coordination game. The coordination problem results from players' uncertainty about what others will do. If a player is certain that the other player will play H then she should play H as well, but if she believes that the other player will play L then she should play L. One of the

[12] This game has also been called the assurance game (Camerer and Knez, 1997) and the volunteer's dilemma (Murnighan, Kim, and Metzger, 1993). See also Weber (2000).

equilibria (H, H) gives both players a better payoff and should therefore be more desirable. The reason that players may find it difficult to reach this equilibrium is the problem of coordination. The reason it may be difficult to obtain the outcome (C, C) in PD is the problem of obtaining cooperation.

The Prisoner's Dilemma represents situations in which obtaining cooperation is difficult because of individual incentives to defect. Players realize that they would be better off if they both cooperated than if they both defected, but defecting is a dominant strategy. Therefore, organizational cooperation involves getting actors within an organization to work towards a common goal even if they have to give up personal incentives to shirk or defect.

Stag-Hunt represents situations in which coordination is difficult because of strategic uncertainty about what another will do. Unlike in PD, both players realize that they are best off if they successfully coordinate on (H, H), but do not want to select H if they think the other player will not do so as well. Therefore, organizational coordination involves getting actors within an organization to believe that others will work towards the common goal as well, in which case it is individually rational for everyone to do so.

The difference between Stag-Hunt and PD exactly captures the difference between problems of cooperation and coordination. In the former case, the problem arises from the fact that individual incentives are not aligned with group goals. Therefore, "solving" PD and other cooperation problems requires getting members of an organization to put their self-interested goals aside and work towards the good of the group. As Williamson (1975) and others have noted, organizations offer an advantage in this type of solution over market transactions. In Stag-Hunt, however, the main problem arises because of strategic uncertainty, even though the goals are aligned. Therefore, "solving" Stag-Hunt and other coordination problems requires getting members of an organization to believe that others will take the optimal action as well. Organizations help solve coordination problems by providing a group of actors with a group identity that reinforces the belief that others are likely to behave "optimally" and with a shared history that presents a natural coordinating device (Weber, Heath and Dietz, in progress; Weber, 2000).

Table 4 presents both games as special cases of the same general situation. The aspect of the situation that changes between the two cases is the value of x. When x is greater than or equal to 2, the game is a Prisoner's Dilemma, it becomes individually rational (a dominant strategy) to not pursue the common goal, and the unique equilibrium is (D/L, D/L).[13] When x is less than 2 and greater than or equal to 1, however, then there are two equilibria and the game becomes a Stag-Hunt coordination game. Finally, if x is less than 1, the game remains a coordination game, but at least part of the security associated with the action D/L in the Stag-Hunt game is lost.

		Player 2: Cooperate/ High	Player 2: Defect/ Low
Player 1	Cooperate/ High	2, 2	0, x
Player 1	Defect/ Low	x, 0	1, 1

Table 4. Prisoner's Dilemma ($x \geq 2$) and Stag-Hunt ($2 > x \geq 1$) Games

Another interesting thing happens as x varies. If the game is a PD, it becomes more costly – in terms of foregone incentives to defect – to work towards the common goal as x increases. Therefore, we would expect that cooperation should decrease as x becomes larger, or as the incentives to work towards individual – rather than group – goals become greater. Similarly, in Stag-Hunt the risk associated with choosing C/H becomes greater as x increases, since the amount to be gained, or "premium" for selecting C/H when the other player does so as well decreases. If x is only slightly less than 2, players gain almost nothing by choosing C/H if the other player does so as well (but the loss associated with selecting C/H when the other player selects D/L is unchanged).

[13] When x is exactly equal to 2, D/L is still a weakly dominant strategy, meaning that it always results in outcomes that are at least as good, as opposed to strictly dominant strategies which always result in outcomes that are always better. In this unique case, there are two equilibria, but eliminating weakly dominated strategies can eliminate one of them.

Therefore, we would expect that efficient coordination (on (C/H, C/H)) should decrease as x increases. This is true in laboratory studies (Battalio, Samuelson and Van Huyck, 1999). Finally, as x decreases, reaching zero and becoming negative, the action D/L becomes riskier and less attractive, though the outcome (D/L, D/L) remains an equilibrium.

While the problems of cooperation and coordination can be distinguished by examining Stag-Hunt and PD, one similarity between the two problems can also be seen from the comparison: as the value of not working towards the group goal decreases, players take actions towards the group goal more frequently. However, the similarity should not be extended too far. The source of this similarity between the two games is quite different. In PD, reducing x also reduces the benefits from taking advantage of or free riding on the group's effort. Decreasing x reduces the benefits from opportunism and reduces the value of the "best" outcome from an individual player's point of view: where she takes advantage of the effort or cooperation of the other player. In Stag-Hunt, however, reducing x does not change the best outcome from either player's point of view. The best outcome remains the one corresponding to efficient coordination. Instead, reducing x in Stag-Hunt leads the pursuit of this efficient coordination to potentially yield greater benefit and become less risky.

As we can see from the above analysis, using game theory allows us to clearly distinguish between and compare two concepts frequently discussed in organizational research. The next section extends this type of analysis by examining representations of and solutions for different types of coordination problems familiar to organizational researchers

V. Game-theoretic models of organizational coordination problems

Thompson (1967) discusses organizational coordination as the solution to problems arising from internal interdependence among organizational units. He identifies three such kinds of interdependence: pooled, sequential and reciprocal. However, his discussion of the three concepts is not formal, making it difficult to extract the key characteristics of each type of interdependence. This section attempts to do so in game-theoretic terms, identifying the key aspects of each type of interdependence and then presenting examples of game-theoretic representations for each one. Finally, we will analyze the game-theoretic representations for insights into how each type of coordination problem might be best approached.

1. Pooled interdependence

According to Thompson, pooled interdependence is the weakest form of interdependence. Organizational units may be interdependent only "in the sense that unless each performs adequately, the total organization is jeopardized: failure of any one can threaten the whole and thus the other parts" (p. 54). Therefore, he describes this form of interdependence as the situation "in which each part renders a discrete contribution to the whole and each is supported by the whole" (p. 54). Malone and Crowston (1994) provide another definition of pooled interdependence as "where the activities share or produce common resources but are otherwise independent" (p. 113).

There seem to be a few key elements to the above definitions of pooled interdependence. The main one, stressed both by Thompson and by Malone and Crowston is the lack of any direct interdependence between units. In both cases, pooled interdependence is described as creating only weak or indirect interdependence that arises only in the global functioning of the organization as a whole.[14] Another key aspect is the independence of action between organizational units. In both definitions, it seems clear that what one part does not directly affect the actions available to another part of the organization. The interdependence arises only when the actions are brought together at the organizational level. Finally, since the actions are independent, whether one part acts before or after another should not directly affect outcomes.

It is possible to describe pooled interdependence by three key elements:

1) Independence of action: The set of possible actions available to each organizational actor is not affected by what other actors do.

[14] One possible characterization of Thompson's definition is that pooled interdependence is really intended to refer to situations where there is no interdependence and each organizational unit is almost completely independent from the others. While Thompson's definition may leave this open as an interpretation, it seems rather uninteresting since a complete decomposability of tasks implies that there is no problem to be solved. The organization's best interests are served without any need for coordination.

2) Interdependence at the organizational level: The interdependence exists only at the level of the entire relevant group or organization. The actions of individual actors or units are linked only in how they affect the whole.
3) Interdependence not affected by anteriority: The time at which each unit takes its action has no effect on the problem.

One classic example of pooled interdependence is the relationship between different branches of the same bank. Each branch operates relatively independently of the other branches and the profitability of a particular branch is rarely affected by the actions of another branch. However, to the extent that all branches are affected by what happens to the organization as a whole they are interdependent. Since the branches share common resources – such as capital and reputation – the availability or quality of these resources affects all of them. The interdependence results because each branch can affect the availability of these resources to others. To the extent that every branch can affect whether the bank's reputation is tarnished or the ability of the organization to continue to exist, each branch needs to take into account what the others are doing. For instance, if another branch is going to take an action that will ruin the reputation of the bank as a whole, then it is no longer in the interest of any of the other branches to expend effort to protect the reputation.

		Player 2: Appropriately	Player 2: Inappropriately
Player 1	Appropriately	x+b-c, x+b-c	x-c, x
	Inappropriately	x , x-c	x, x

Table 5. Bank branch coordination game

As an example, consider the situation where a bank has two branches. Each branch can either act appropriately (take actions to protect the reputation of the bank) or act inappropriately (take actions that ruin the reputation of the bank). Each branch realizes some benefit (b) if the bank's reputation is untarnished, but acting to maintain the reputation involves some effort or cost (c). Assume that each branch's operations are otherwise independent and that both earn some fixed amount independently of whether they act appropriately or inappropriately (x). This situation, corresponding to pooled interdependence can be described by the game in Table 5. If we let x equal 1, b equal 2, and c equal 1, then the game in Table 5 is exactly the same as the Stag-Hunt game in Table 3.

The Stag-Hunt game also describes problems of pooled interdependence related to organizational change. Consider a situation in which two organizational units can decide whether to effectively implement a change in procedures (H) or not implement it (L).[15] Not implementing the change is less risky and guarantees a somewhat favorable outcome (the status quo). The ability of each unit to implement the change and the success within that particular unit is unaffected by what the other unit does. However, the operation of the organization as a whole is affected by whether or not both units implement the change successfully. Because of increased efficiency, the best outcome for the firm is where both units successfully implement the change. Therefore, there are indirect rewards to each unit if both successfully implement the change. However, there is risk associated with attempting to implement the change since – if the other unit does not do so as well – the resulting coordination failure will most affect the unit that attempted to implement the change. In this game, actions are independent, the interdependence only indirectly affects outcomes to each actor, and order of actions does not matter.

		Player 2	
		Technology A	Technology B
Player 1	Technology A	1 + y, 1 + y	1, 1
	Technology B	1, 1	1 + y, 1 + y

Table 6. Alternate Pure Matching coordination game

There are other games that capture problems of pooled interdependence. For instance, consider the version of the Pure Matching game in Table 6. Assume that each of the two players in the game in Table 5 represents one of two divisions of a firm and

[15] This example is from Nanda (1996).

that each division is choosing which of two information technologies to implement. Each division will be able to perform its particular task equally well with either of the two technologies, but the ability of the organization as a whole to perform optimally will be affected by whether or not both divisions adopt the same technology. This interdependence problem contains the three elements discussed above: each division can adopt one of the two technologies independently of what the other division is doing, the interdependence does not affect the functioning of the divisions with respect to their particular tasks but does affect the organization as a whole, and whether one division adopts its technology choice before or after the other is unlikely to have an effect. Therefore, each division receives some payoff (1) for selecting and correctly implementing either technology, but also receives an additional payoff ($y > 0$) if they implement the same technology as the other division. This game is the same as the game in Table 2 and traditional game theory makes no distinction between the two.[16]

Both the Pure Matching and Stag-Hunt games describe problems of pooled interdependence. In both cases, the interdependence only exists at the aggregate level when the actions of otherwise independent units are combined. However, situations in which there are only two organizational actors are infrequent and often uninteresting and the same can be said for situations in which these actors have only two possible decisions. For instance, the Stag-Hunt game might only have organizational relevance when if can be used to represent situations involving many people in a firm, each acting independently and where there are different degrees to which individuals can attempt to implement the desired changes. The Weak-Link game represented in Table 7 models exactly this type of situation (Nanda, 1996).[17]

The Weak-Link game extends the Stag-Hunt game to model situations in which there is more than one actor and each actor has more than two possible choices. The game represented in Table 7 allows for any number of players. While in this case each player has seven actions, the number of actions can be changed to any number (Van Huyck, Battalio and Rankin, 1996a).

[16] Traditional solution concepts such as Nash equilibrium are insensitive to linear transformations of players' payoffs (i.e., payoffs in the second game are equal to 1 plus y times the payoffs in the first game). More recent behavioral work has developed solution concepts that take into account the possible effects of such differences (e.g., McKelvey and Palfrey, 1995).
[17] The Pure Matching game can similarly be extended to include any number of players and actions.

The table represents payoffs a little differently than previous payoff tables. In this game, each player selects an action (1-7) independently of other players. The payoff to each player depends on her choice (indicated by row) and the minimum choice of all players (indicated by column). The number in each cell gives this payoff.[18] Each player faces the same payoff table and has values determined by her own action and the minimum of all other players' actions. The game is named the "Weak-Link" game because it is the weakest link or the lowest performing element of the group that determines the payoffs for all players. In this sense, the game exactly captures one important aspect of pooled interdependence discussed by Thompson: "unless each performs adequately, the total organization is jeopardized; failure of any one can threaten the whole and thus the other parts" (p. 54).

	Minimum of all players' choices						
Player's choice	7	6	5	4	3	2	1
7	90	70	50	30	10	-10	-30
6		80	60	40	20	0	-20
5			70	50	30	10	-10
4				60	40	20	0
3					50	30	10
2						40	20
1							30

Table 7. Weak-Link (Minimum-Effort) coordination game

Similarly to the Stag-Hunt game, the equilibria consist of all outcomes in which everyone is choosing the same action, resulting in seven pure-strategy equilibria. For instance, if all players are selecting action 1 and receiving a value of 30, then no player can do better off by increasing her choice since this would not affect the minimum and would lower her payoff. Similarly, if all players are selecting 7 and receiving a value of

[18] The cells below the diagonal are empty because a player's choice cannot be lower than the minimum of all choices.

90, a player can only do worse off by lowering her choice. Also as in the Stag-Hunt game, the equilibria are not all equally valued. In the Weak-Link game, players are better off if they can coordinate on the "efficient" equilibrium where everyone is selecting 7. However, selecting 7 is risky because it can also lead to the worst outcome for a player (with a value of -30) if at least one other player selects 1.

There are other games as well that capture the key elements of pooled interdependence (e.g., the Battle-of-the-Sexes game (Cooper, et al., 1989 & 1993)). We will return to problems of pooled interdependence in a discussion of solutions to interdependence problems. For now, we turn our attention to game-theoretic representations of the two other types of interdependence.

2. Sequential Interdependence

Thompson (1967) refers to sequential interdependence as a serial form of interdependence in which the outputs of one unit become the inputs for another. Therefore, in contrast with pooled, sequential interdependence has both a direct interdependence between units and a temporal aspect. Malone and Crowston (1994) concentrate on the ability of units to take action, defining sequential interdependence as "where some activities depend on the completion of others before beginning" (p. 113).

The above two definitions lead to key characteristics of situations involving sequential interdependence. First, as the name implies, there must be an element of time involved; it now matters when organizational actors take their actions. This is primarily because there is now interdependence in action: the possible actions available to each unit may depend on what others have already done. Finally, as Thompson argues, this results in a direct interdependence between organizational units. These three key characteristics – which contrast sequential with pooled interdependence – can be stated as:

1) <u>Temporal order matters</u>: Whether an actor takes an action before or after another actor impacts the nature of the interdependence.
2) <u>Interdependence in action</u>: The actions taken by a previous actor may affect the possible actions available to another actor.
3) <u>Direct interdependence between organizational actors</u>: The actions taken by one organizational actor directly affect the performance of others.

There are many non-coordination games that model situations with the above elements,[19] but when we limit the games to coordination games, these are less common. However, it is possible to find games that capture problems of sequential interdependence. For instance, consider the following organizational situation with four separate organizational units. The four units are responsible for different parts of the production of a good that, if completed, benefits all of them. However, in order for the good to be completed, each of the units must contribute to a particular part of the production process and each unit cannot begin working on their part of the production until the previous part is done. Finally, if at any point one of the units shelves the project, the good will not be completed, the effort of units that already did their part will be wasted and no one will realize the benefits of completing the project.

Situations of this kind are common to organizations. Moreover, the description precisely captures Thompson's (1967) example of a situation with sequential interdependence between two organizational units, the Keokuk plant and the Tucumcari assembly operation: "Keokuk must act properly before Tucumcari can act; and unless Tucumcari acts, Keokuk cannot solve its output problem" (p. 54). This situation is represented in the game in Figure 2.

The game in Figure 2 has four players. Each player corresponds to one of the organizational units. In the game, each player decides whether to act properly (Act) or not act properly (Quit) either by delaying or shelving the project. Acting properly imposes a cost on that unit (-5), but completing the project results in a positive net reward (10). As in Figure 1, the set of numbers next to each outcome provides the payoffs to every player. The first number is the value of the outcome to Player 1, the second the value to Player 2, and so on.

The game in Figure 2 captures the key elements of sequential interdependence described above. Position in the game matters: players would rather act later, after they've seen what others have done. There is interdependence in action in that actions by earlier players can determine what (if any) actions are available to subsequent players. In addition, the interdependence is direct since Player 1 can determine the outcomes to all players by selecting Quit initially.

[19] See, for instance, McKelvey and Palfrey (1992) on the centipede game.

This game does not have a “free-rider” problem in that the best outcome for all players is when everyone acts properly and the project is completed. In this case, no player has an incentive to not do their part since this leads to a strictly worse outcome for all players. Therefore, the game has an efficient equilibrium in which all players select Act.

Suppose instead, however, that Player 3 believes for some reason that player 4 is going to select Quit. In this case, it is now optimal for Player 3 to select Quit as well since this results in an outcome that yields 0 instead of –5. In this case, Player 2 would want to select Quit for the same reasons and so would Player 1. Therefore, there is another equilibrium in which Player 1 selects Quit because she (correctly) believes that at least one of the other players will select Quit. In this case, all four players end up with 0.

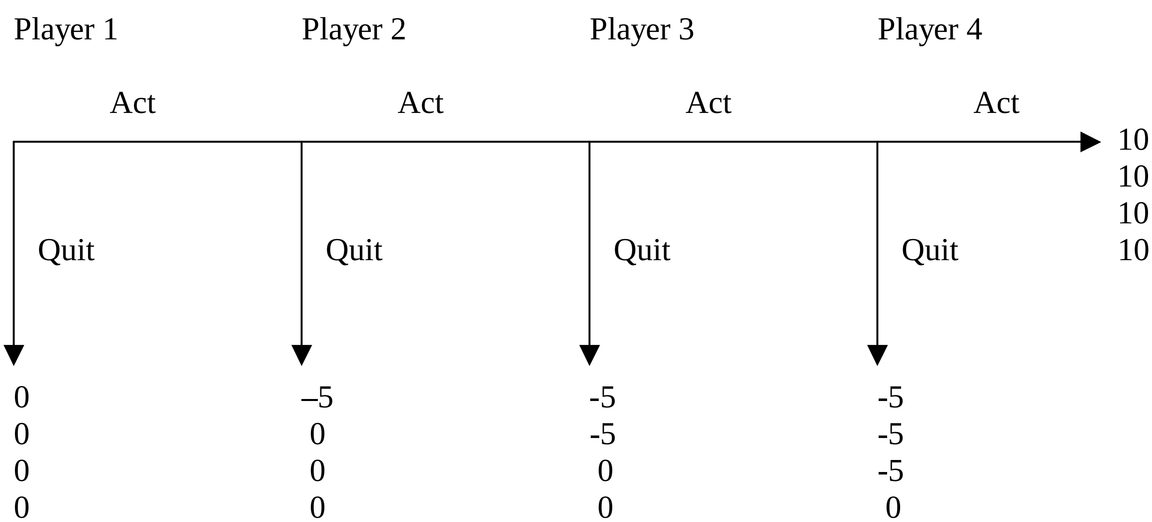

Figure 2. Sequential Coordination game

However, there is one problem with the inefficient equilibrium. In order for it to be an equilibrium, Player 1 has to believe that at least one other player will select Quit. In order for Player 2 to select Quit (conditional on having a choice), she has to believe that either Player 3 or 4 will select Quit and the same can be said for Player 3 with respect to his beliefs about what Player 4 will do. Note that conditional on having a choice, however, Player 4 should always select Act – if all previous players have done their part, then Player 4 can gain 10 by completing the project while shelving it at that point yields only 0. Therefore, Player 4 should always select Act (it is a dominant strategy), and by induction so should Players 3, 2, and 1. Thus, the efficient equilibrium is the only one to survive an equilibrium refinement known as "subgame-perfection" that assumes that players will only make reasonable choices whenever the game reaches them and that all players know this.

What should we expect to happen in this game? Traditional game theorist would predict that the efficient equilibrium in which everyone selects Act should always result. However, this is unlikely to always be the case for a couple of reasons familiar to behavioral game theorists. First, there is substantial evidence of people making "irrational" mistakes – violating dominance – across a wide variety of games (e.g., Stahl and Wilson, 1995; Nagel, 1995). If this is the case in this game, or even if some players believe others are likely to, the inefficient equilibrium may result. Second, there is ample evidence that people don't care only about individual outcomes, but also about how these compare relative to outcomes received by others (ultimatum game studies; Camerer and Thaler, 1995; see also Fehr and Scmhidt, 1999; Bolton and Oeckenfels, 2000). If Player 4 in the above game has a strong concern for relative standing, then she may prefer the outcome in which she receives 0 but the other player lose 5 to the outcome in which everyone receives 10. An organizational analogy of this is a situation in which the actor represented by Player 4 is not rewarded according to how the firm does as a whole but instead according to how that particular unit compares to others. If this is the case – or even if just other players believe it is so – then the inefficient equilibrium will likely result.

That the inefficient equilibrium might result can also become intuitively clear if the payoffs are changed. Assume instead that all of the outcomes yielding –5 now instead yield –5000. In this case the ordinal ranking of the outcomes is unchanged and so are the equilibrium predictions. It seems unlikely, however, that Player 1 would risk losing the much greater amount for the much smaller potential reward.

The Sequential Coordination game in Figure 2 represents a very simple case of sequential interdependence. It models the type of linked production problem described by Thompson. However, as with most game-theoretic representations, the description is too simple to directly correspond to actual organizational problems. It is unlikely that many sequential interdependence problems faced by real firms require actors to choose between only two actions. However, as with the games used to illustrate pooled interdependence, extending the game in Figure 2 to more complicated problems is simple. Adding more possible actions for each player involves simply adding branches to each of the nodes and then taking into account what actions will be available to subsequent players if the new branch is selected and how the payoffs will be affected. Therefore, given a sequential interdependence problem with a defined set of actors, possible actions, and possible outcomes with associated values, it is possible to construct a corresponding game.

3. Reciprocal Interdependence

The final type of interdependence is reciprocal. According to Thompson (1967), this type of interdependence occurs when the outputs of each unit become inputs for other organizational units. He considers the interaction between maintenance and operations units of an airline. The maintenance unit produces an output, an airplane prepared for flight, that serves as an input for the operations unit; the operations unit, meanwhile, produces airplanes in need of servicing, an input for the maintenance unit. Thompson states, “the distinguishing aspect is the reciprocity of the interdependence, with each unit posing contingency for the other” (p. 55). Malone and Crowston (1994) similarly define reciprocal interdependence as “where each activity requires inputs from the other” (p. 113).

According to the above definitions, reciprocal interdependence has several of the features of sequential interdependence. For instance, since in both cases the actions of actors are directly linked, there is interdependence in action and this interdependence is direct. In addition, the temporal order may matter in reciprocal interdependence as well since one actor may decide first and affect subsequent possible choices for others.

The unique aspect of reciprocal interdependence is the fact that actors can affect outcomes repeatedly and that, unlike in sequential interdependence, their role may not be completed once they have acted. Therefore, we can add the following feature to the three key elements of sequential interdependence to characterize reciprocal interdependence:

4) Multiple relevant moves by any actor: Each actor has more than one opportunity to take actions that directly affect others who will in turn be able to take actions that affect the actor. Moreover, every actor in the interdependent relationship contributes constantly or repeatedly so that no one acts only once.

With this added characteristic in mind, it is possible to modify the Sequential coordination game in Figure 2 to represent one type of situation involving reciprocal interdependence. This game is presented in Figure 3. As with the Sequential coordination game in Figure 2, players decide whether to Act or Quit in the completion of a project and acting imposes a cost of 5, while quitting imposes no cost but prevents the group from completing the project and receiving the associated rewards.

Unlike the Sequential coordination game, however, the game in Figure 3 has only two players and each player decides whether to Act or Quit twice. The situation represented by the game is one in which Player 1 decides whether or not to work towards the group goal, in which case he produces an output that Player 2 then has to build on or not work on. If Player 2 works towards completion, then he produces an output that returns to Player 1, and so on. Therefore, the game captures the key aspect of reciprocal interdependence: that each unit produces outputs that become inputs for the other units. As with the game in Figure 2, this game represents a simple description of one type of reciprocal interdependence. It is possible to extend the game by having more players (as long as each acts more than once) and having more actions available to all of the players.

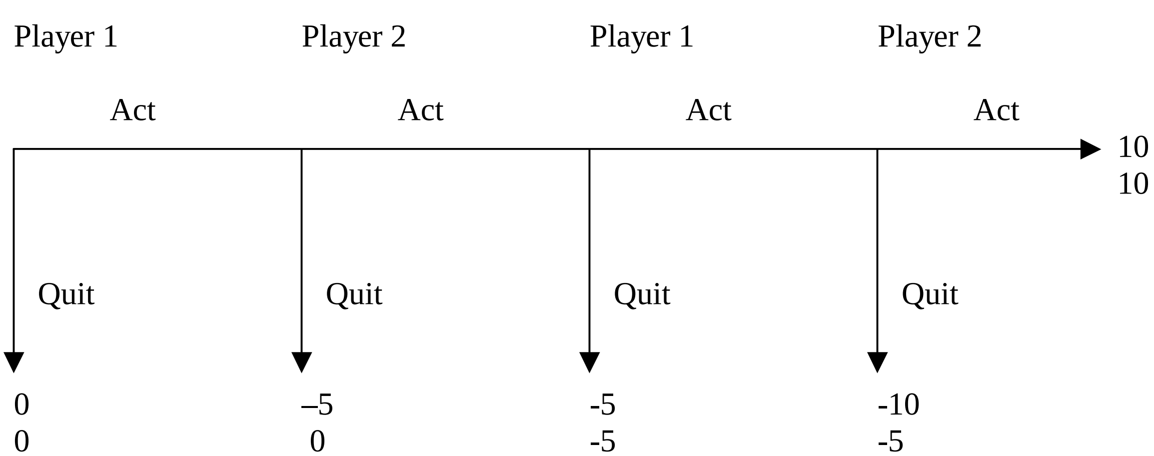

Figure 3. Reciprocal Coordination game

This game also has two equilibria. In the efficient equilibrium both players select Act both times and receive the payoff corresponding to their preferred outcome. In the inefficient equilibrium, Player 1 believes that Player 2 will opt to Quit at some time and therefore selects Quit in her first move.

As with the Sequential interdependence game, the efficient equilibrium is selected by the subgame-perfection equilibrium refinement. However, for the same reasons as in the Sequential Coordination game, individuals playing the game might end up at either equilibrium.

While the game in Figure 3 and its extensions represent one form of reciprocal interdependence, there exists another important category of games that capture some of the key elements of this type of problem: repeated games. When games are repeated, players' actions will directly affect the outcomes for other players, and each player will make several actions. There are repeated games in which it is optimal for players to coordinate and alternate between their two preferred outcomes (Dickhaut, McCabe and Mookherji, McCabe, 1999). The Prisoner's Dilemma game also becomes a coordination game (with multiple equilibria) when it is repeated infinitely. In addition, it is possible for repeated games to include the feature that actions available to players depend on what others did previously (interdependence of action). For instance, consider a repeated ultimatum bargaining game in which two players bargain over some fixed amount in every round (Figure 4).

In the ultimatum game, one player (the proposer) proposes some allocation of the fixed amount, or pie. The other player (the responder) then either accepts this allocation, in which case both players receive the proposed division, or rejects it in which case both players receive 0.[20] While there are many equilibria to this game, the traditional game-theoretic prediction (corresponding to the subgame-perfect equilibrium) is that proposers will propose to keep almost the entire amount and responders will grudgingly agree in order to receive whatever small amount the proposer offers instead of zero. Assume further that the role of proposer and responder alternates in every round so that if a player is the proposer in one round, she will be the responder in the next. Finally, assume that the amount that the responder receives in one round is tripled and this amount then

[20] For a discussion of research using the ultimatum game, see Camerer and Thaler (1995).

becomes the amount that this player will have to divide in the next round when she becomes the proposer. Figure 4 presents a round of this game, where one round corresponds to first Player 1 acting as the proposer and then Player 2.[21]

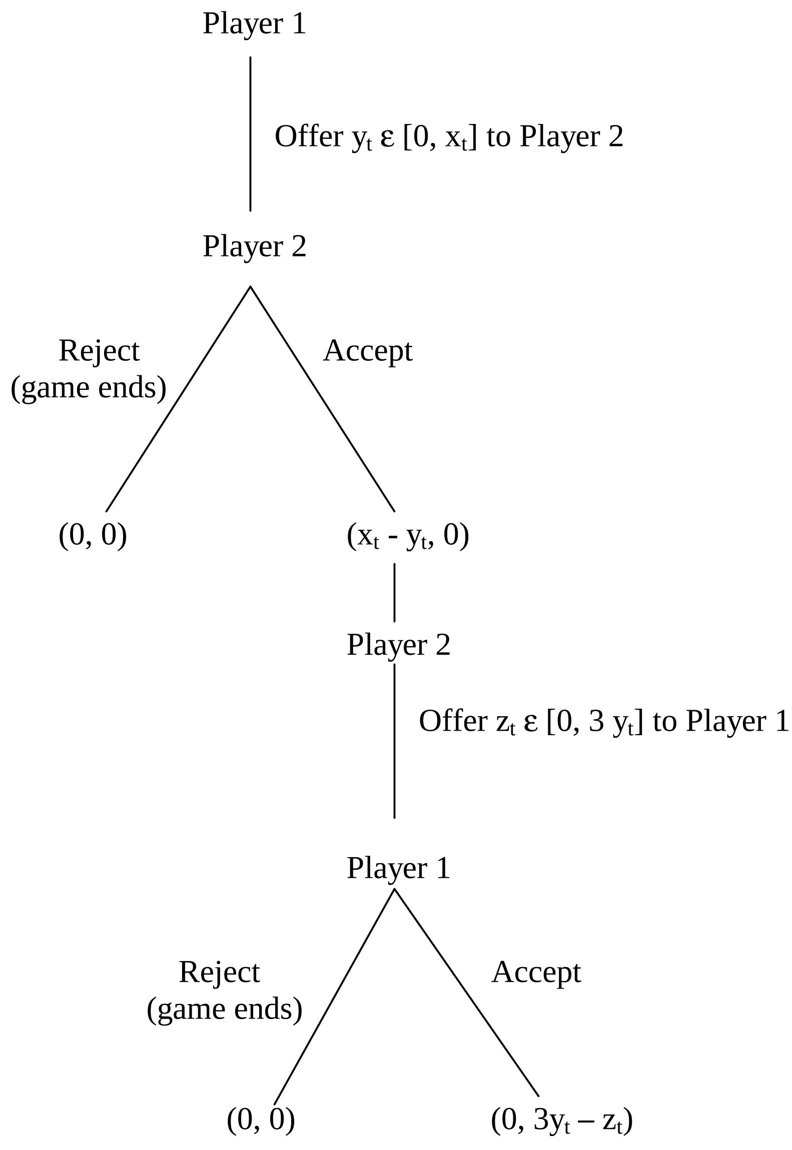

Figure 4. One round (t) of repeated ultimatum game

(Note: In every round, $t > 1$, $x_t = 3\ z_{t-1}$; in round 1, $x_t = 10$)

[21] This game is similar to the trust game in which players also leave some amount (which grows) for the other player to allocate (see Berg, Dickhaut and McCabe, 1995).

This repeated game also very closely captures the key elements of reciprocal interdependence discussed by Thompson. Each player produces an output: the offer to the other player that then serves as an input into that player's subsequent decision. While it is perfectly rational in any one round to keep the entire amount and not offer any to the other player (and this is also the subgame-perfect equilibrium prediction when the game is repeated for a finite number of rounds), players have a desire to coordinate on an efficient outcome where a positive – and large – amount gets passed to the next player in every round. Proposing offers greater than 1/3 of the available amount guarantees that the size of the available amount will grow.[22]

This game (which can be extended to more than two players) closely corresponds to organizational situations in which organizational members produce some output at a cost that becomes an input for others who in turn have the opportunity to produce a costly output that gets returned. Therefore, this game closely models the type of interdependence discussed by Thompson in his example of airline maintenance and operations teams.

VI. Organizational and game-theoretic solutions to coordination problems

After discussing different types of organizational interdependence in game-theoretic terms, we can now turn to a discussion of solutions for these types of problems. The goal is again to link the organizational and game-theoretic research.

1. Organizational solutions

Thompson (1967) discusses the following three solutions to problems of interdependence: standardization, plan, and mutual adjustment (see also March and Simon, 1958). Coordination by standardization can be accomplished by establishing rules or procedures that limit the actions of actors to those that help solve the

[22] This game is similar to the centipede game (McKelvey and Palfrey, 1992) but has the added organizational feature that players realize some earnings in every round and leave some amount to "grow".

interdependence problem. According to Thompson, this type of coordination applies best to stable, simple relationships. As its name suggests, coordination by plan involves addressing a particular interdependence problem by developing schedules and formal rules for action. Finally, coordination by mutual adjustment results from information and shared knowledge arising from repeated interaction.[23]

According to Thompson, there is a connection between the types of interdependence problems and the coordination solutions. Stable problems of pooled interdependence can be solved by standardization; providing indirectly interdependent units with informal rules and procedures concerning the appropriate behavior to be performed allows them to determine and follow the behavior that is best for the organization. Plans and schedules allow groups to solve problems of sequential interdependence by explicitly stating the correct behavior to be performed. Finally, problems of reciprocal interdependence involve repeated interaction between the same actors, so coordination by mutual feedback works best by allowing each to adjust their behavior to be in line with those of others through repeated shared experience.

2. Game-theoretic solutions

Game theorists similarly have a list of tools useful for obtaining successful coordination in groups. Among these are making certain actions salient or focal (Schelling, 1960; Bacharach and Bernasconi, 1997), using precedent to coordinate activity (Van Huyck, Battalio and Beil, 1991; Weber, 2000), decreasing the riskiness of attempting to coordinate (Battalio, Samuelson and Van Huyck, 1999), statements by people in authority positions (Van Huyck, Gillette and Battalio, 1992), communication between players (Cooper, et al., 1989; Dickhaut, McCabe and Mookherji, 1999), and repeated interaction (Van Huyck, Battalio and Rankin, 1996b; Van Huyck, 1997).

Salience and focality. As Schelling (1960) recognized, one way of solving coordination problems tacitly (where communication is difficult or impossible) is by

[23] Coordination can also be divided into programmed and non-programmed coordination mechanisms (March and Simon, 1958). Programmed coordination mechanisms involve formal rules and procedures (such as coordination by standardization and plan) while non-programmed mechanisms involve coordination through interaction between members of the organization (such as coordination by mutual adjustment). Programmed coordination works best when there is low uncertainty in the environment, while non-programmed works best in environments with high uncertainty (Van De Ven, Delbecq and Koenig, 1976; Argote, 1982).

providing everyone "with some clue for coordinating behavior, some focal point for each person's expectation of what the other expects him to expect to be expected to do" (p. 57). Thus, one way of solving coordination problems like the Pure Matching game in Table 2 is to add some element to the labeling of the possible actions that makes one salient or focal to all of the actors. Recall the organizational example modeled by this game where any of two equally good but complementary technologies can be adopted. Salience in this example might be achieved by having an unwritten rule in the organization that "the lowest cost technology is always the one to go with" or "always go with the in-house product."

Precedent. One way of establishing salience is through precedent. There is ample evidence in experiments on coordination games that what a group did previously is likely to become a self-reinforcing norm about what to expect in the future (Weber, 2000; Van Huyck, Battalio and Rankin, 1996b). Therefore, in the above example, if the organization is one in which the lowest cost alternative has always been selected in the past, then this will be a focal choice every time a similar problem arises. Game theorists have also recognized that organizational culture is one way in which this precedent helps select an equilibrium (Kreps, 1990; see also, Hermailin, 1994).

Decreased risk. Another way to improve coordination is to modify the value of outcomes to players. As previously mentioned, modifying one payoff parameter in the Stag-Hunt game (Table 4) can lead to different behavior. By changing the payoffs in a Stag-Hunt game (and a Weak-Link coordination game) to reduce the riskiness of efficient action, it is possible to obtain more efficient coordination without changing the basic nature of the game. Therefore, with a temporary change in payoffs it is possible to increase successful coordination (see Battalio, Samuelson and Van Huyck, 1999) and since precedent plays an important role in coordination games this successful coordination is likely to persist even after the decreased risk is eliminated.

Authority. There is also evidence that statements by people in positions of authority affect behavior in coordination games. Simply having the authority suggest or recommend a particular action, leads players to take it more frequently (Van Huyck, Gillette and Battalio, 1992). Therefore, one way to improve coordination is to have leaders who state the action that everyone should be taking.[24] In addition, since actual leadership in real situations often has the power to directly influence or coerce action, this is likely to be an even more effective tool in real organizations.

Communication. Communication creates shared expectations about what equilibrium others expect to see. These expectations are self-reinforcing since players then take the actions corresponding to this equilibrium – which is a best response based on the beliefs created by communication. However, communication is not always effective – it is most effective when all parties communicate their intended action and when they use the same language (Cooper, et al, 1992; Heath and Staudenmayer, 2000).

Repeated interaction. Finally, dynamic adjustment can help a group reach a coordinated equilibrium (Van Huyck, Battalio and Rankin, 1996b). Even when not initially coordinated, by repeatedly playing the same game and observing what others did players can reach an equilibrium by adjusting their actions to be aligned with those of others. This can be true even when they are myopically best responding to the actions of the other players and not really thinking about adjustment (Erev and Rapoport, 1998). By simply adjusting their behavior in the direction of the equilibrium that most others tried to get to, players can achieve successful coordination (Crawford, 1995).

3. Combining the two approaches to solutions

There is a parallel between the types of coordination outlined by Thompson and the above game-theoretic solutions to coordination problems. Standardization is very similar to precedent and salience in that it creates successful coordination by tacitly indicating the correct action to be performed. In these cases, there are some unwritten rules, procedures, or aspects of how things are done in the organization that point to the appropriate action. Both standardization and salience work best in repeated and stable environments in which the same simple, general rules can be applied to problems repeatedly.

Coordination by plan often requires an organizational authority to modify a problem or limit the actions of decision makers to achieve successful coordination. In this sense, it works in a manner similar to statements by leadership and modifications of

[24] See also Foss (1999). For a situation in which leadership is ineffective, see Weber, et al. (1999).

the game: an authority position is responsible for implementing the correct plan, or set of actions (either by changing the problem or by decreeing which action everyone should take).[25]

Finally, coordination by mutual adjustment is very similar to the process by which players can coordinate through repeated play and communication. By adjusting their behavior to coincide with what others have done or said, players in a game can reach equilibrium in much the same way as members of an organization can coordinate action successfully by adjusting their behavior to what others have done. Mutual adjustment – like communication and dynamic adjustment – is most necessary in changing environments where the same informal or formal rules cannot be applied repeatedly across situations. In cases where the coordination problem has changed substantially, following previously effective rules may not help achieve coordination. For instance, suppose precedent and standardization previously resulted in members of an organization taking an action that resulted in efficient coordination, but because of some change in the organization's environment this action is no longer optimal. However, if this action is still available, then it may be selected because of the strength of precedent as a selection principle (Nanda, 1996; see also Van Huyck, Battalio and Beil, 1990). Therefore, the coordination problem may be worse than if precedent could not be applied – for instance, if the actions were relabeled. Therefore, standardization may result in inefficiency if used in a dynamic environment; making the ability to obtain successful coordination worse than if no solution had been attempted. In these cases, the coordination problem would be much easier to solve through communication or mutual adjustment.

[25] The exact solution associated with coordination by plan – that an authority creates a plan which decision makers have to implement – has not received attention from game theorists because if the plan is binding, the resulting problem is not a game and therefore theoretically less interesting. For instance, if in the Stag-Hunt game (Figure 3) both players are restricted to play the action H, then both players will and the "good" equilibrium will result. However, this is no longer a coordination problem since the loss of agency removes any strategic uncertainty. When such plans are implemented in organizations, it seems unlikely that the authority will be able to completely bind the actions of all actors, resulting in at least some strategic uncertainty. Therefore, when modeling coordination by plan in game-theoretic terms it might be interesting to look at a game where the authority's choice is binding only with some probability less than 1.

VII. Conclusion

Game theory is a useful tool for organizational research. Some of the benefits of this interdisciplinary approach have been realized, but one area of organizational research where it has been largely ignored is coordination. The purpose of this paper has been to argue that a game-theoretic approach to organizational coordination can serve as a useful complement to the other approaches used by organizational researchers. Game theoretic models allow us to both explore precise definitions of coordination problems and classify their sources. It is possible to represent coordination problems as organizational researchers have discussed them in simple game-theoretic terms and from this exercise gain insights into how they might be solved.

While there are relatively few examples of existing studies using games to study coordination in organizations, some instances do exist. For instance, Weber, et al., (2000) examine the ability of large and small groups to coordinate efficiently in the Weak-Link game in Table 7 under a simple form of leadership. Previous studies using this game have shown a consistent group size effect: small groups almost always coordinate successfully while large groups never do (Van Huyck, et al, 1990). Weber, et al, examined whether simple leadership in the form of one subject addressing the group and urging them to coordinate efficiently would improve the ability of large groups to coordinate. The experiments reveal that the leadership manipulation is not sufficiently strong to overcome the group size effect; large groups are unable to coordinate efficiently even after being addressed by a leader. However, one interesting result of subjects' ratings of leadership quality is that leaders were blamed for the poor performance in large groups – even though they had no control over the bad outcome and even though the leaders in groups of both sizes were rated equally able immediately after their speeches.

Since large groups almost never coordinate in the Weak-Link game, an interesting question is how firms are able to successfully grow while avoiding coordination problems associated with size. In another laboratory study using the Weak-Link game, Weber (2000) explored one way in which firms might overcome similar coordination problems associated with size: the growth process itself. Starting off with successfully coordinated small groups and adding new players slowly resulted in more successful coordination in large groups, providing evidence that they way in which growth is managed is an important tool for solving coordination problems related to organizational size.

In another application of Weak-Link games to organizations, Knez and Camerer (1995) examined the effect of precedent on norm formation in coordination games and Prisoner's Dilemma games. They found that norms established in one type of game transfer to situations represented by another type of game, even when the underlying problem is quite different.

Weber, Heath and Dietz (in progress) use simple coordination games to examine the effect of group identity on the ability of groups to solve different types of problems, arguing that one of the principal benefits created by organizations is this group identity. In the experiments, even simple group identity manipulations help groups solve problems like coordination and trust.[26]

Finally, some studies have examined how groups coordinate when faced repeatedly with complicated tasks. Some of these studies have examined how procedures and routines emerge that are suited to solving these tasks (Leavitt, 1962; Cohen and Bacdayan, 1994). More recent research (Weber and Camerer, 2001) similarly explores how groups arrive at solutions to complicated language formation tasks, but then also examines what happens when the groups are altered or merged. These experiments use a version of "sender-receiver" coordination games (first studied experimentally by Blume, et al., 1998) in which groups of subjects have to develop a rich verbal internal language in order to solve a complicated coordination task. This language shares several characteristics of organizational cultures (e.g., it arises through shared history, it is idiosyncratic to a specific group, and it provides an efficiency advantage).

As this paper and the above examples indicate, research on organizational coordination can benefit from the application of game theory. While there are several problems with traditional game theory, this does not rule it out as a useful tool. Organizational researchers can only benefit by adding the benefits of one more tool – a tool designed to study the type of strategic interaction that occurs regularly in organizations – to their arsenal.

[26] See also Kogut and Zadner (1996).

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