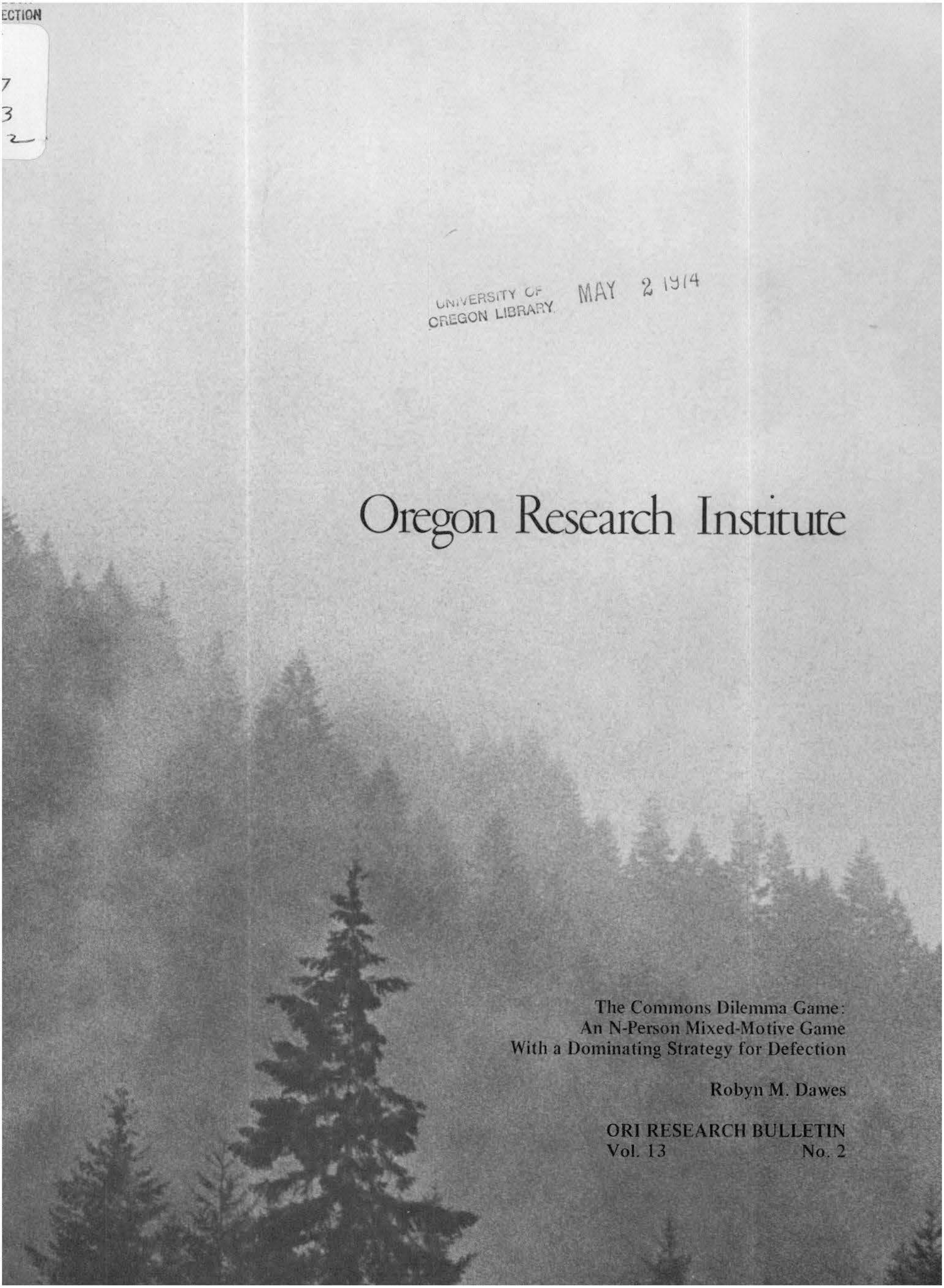

Oregon Research Institute

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ORI RESEARCH BULLETIN
Vol. 13 No. 2

OREGON RESEARCH INSTITUTE

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September 1973

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WITH A DOMINATING STRATEGY FOR DEFECTION[1]

Robyn M. Dawes

Oregon Research Institute and University of Oregon

Abstract

If individuals were to decide for themselves whether to buy anti-pollution devices for their cars, a _commons dilemma_ would result (Lloyd, 1833; Hardin, 1968). The money saved by not buying the device accrues directly to the individual while the harm done by the resulting pollution is shared equally by all. Moreover, the argument for not buying is independent of others' decisions --because if they do buy, the individual who does not makes no appreciable contribution to pollution, and if they don't the individual who does makes no appreciable contribution to reducing pollution. Yet everyone would prefer to have everyone buy. This paper presents an experimental _commons dilemma game_ that has all the properties of the commons dilemma and that reduces to a _prisoner's dilemma game_ when there are only two players.

[1]This research was supported, in part, by National Institute of Mental Health Grants Nos. MH-21216 and MH-12972, and by National Science Foundation Grant No. GS-32505.

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Hardin (1968), Olson (1965), Dawes, Delay and Chaplin (in press), and others have discussed the dilemma in which gain from antisocial behavior accrues directly to the individual while loss is spread out among all members of society. Thus, the decision to pollute by having additional children, or by not recycling , or by obtaining an automobile with high gas mileage but no pollution device, is of direct benefit to the person who makes that decision, while the harm is spread equally among all. Hence, the value of the decision for each individual considered singly is positive; but if all individuals reach the same decision, all suffer.

Olson (1965) discusses at some length the decision to join or not to join a labor union. He points out that as the potential union (implicit group) becomes large enough, the impact of any one individual's dues decreases --even though the cost to the individual of paying the dues remain constant. Thus, it is rational for each individual member of the potential union to refuse to join, because the union will probably either achieve or fail in its goals independently of the particular individual, and the individual both enjoys whatever benefits the union may obtain and saves his union dues by refusing to join. Olson argues that the logic of this situation demands the closed shop.

Hardin (1968) and Dawes, Delay and Chaplin (in press) were concerned with the problem of pollution--including that caused by having additional children. Again, the basic logic of the situation is the same. Whether other people pollute or do not pollute, each individual is better off polluting. The effect of this pollution is spread out among all the members of the "commons" or society, while the benefit accrues directly to the individual. Consider, for example (Lloyd, 1833), the situation in which each of 10 people owns one 1,000-lb. bull and all 10 bulls graze upon a common pasture that is capable of sustaining them all. Suppose further that the introduction of an additional bull would result in the weight of each bull decreasing to 900 lbs.; that is, with the introduction of an additional bull the pasture could support only 9,900 lbs. of cattle rather than 10,000. Any individual who introduces an additional bull has increased his wealth by 800 lbs., because he now has two 900-lb. bulls rather than one 1,000-lb. bull. But the total wealth has been reduced by 100 lbs., and if everyone acts according to the same "rationality" and introduces additional bulls, the commons will deteriorate completely and everyone will end up with nothing.

This commons dilemma, gain to self with loss shared by everyone, is ubiquitous--especially in large societies. In its most dramatic form, it may cause each single soldier to flee from a battle, because each reasons that his own participation makes little difference in the final outcome, yet it makes a great difference to him personally, and he thereby ensures rout and disaster for all the soldiers--including himself. In its mildest form, it may result in an academician obtaining a job offer at another institution only in order to achieve a better salary at his or her own institution. The adverse effect such a salary raise would have upon each colleague is negligible if the institution is large. Moreover, the motive for obtaining such an offer is present whether or not other people engage in the same behavior as well; if they do, then obtaining such offers is necessary in order to maintain "equity." If they don't, then there is still plenty of money to go around for regular raises. An intermediate form of the dilemma may be found in people's decisions to obtain unrealistically high payoffs from insurance companies because "after all, the company can afford it" (with the result that everyone's premiums skyrocket).

When the society consists of only two individuals, the well-known *prisoner's dilemma* (Rapoport & Chammah, 1965a) reflects the structure of the commons dilemma described above. The prisoner's dilemma is described by Coombs, Dawes and Tversky (1970) as follows:

"Two men rob a bank. They are apprehended by the local district attorney, who knows they have committed the robbery but who does not have sufficient evidence to convict them. The district attorney puts his two prisoners in separate rooms and makes an identical proposition to each. If either prisoner confesses and the other does not, the one who confesses will go free for supplying state's evidence and the other will be sent to jail for 10 years. If they both confess, they will both go to jail for 5 years. If neither confesses, they will both go to jail for a single year on some minor charge such as carrying a concealed weapon. The district attorney informs each prisoner that he has made this same proposition to the other, and he then leaves them in their separate rooms to think.

"Each prisoner, being rational, decides to figure out his best course of action for each course of action the other prisoner might take. If the other prisoner confesses, it is clearly better to confess than not to confess, because confession in this circumstance means going to jail for 5 years instead of 10. If the other prisoner does not confess, it is again clearly better to confess than not to confess, because confession in this circumstance means going free rather than going to jail for a year. Thus no matter what the other prisoner does, confession is a better course of action than nonconfession.

"The result of such reasoning is that both prisoners confess and go to jail for 5 years. Yet they would both clearly prefer the outcome in which neither confesses and they go to jail only for 1 year. Hence, the dilemma. Rationality dictates that they both adopt a course of action that leads to an outcome that is mutually undesirable.

"In general, a prisoner's dilemma game is one in which (1) each player has a strategy that dominates all others and (2) the outcome that occurs because each player chooses his dominant strategy is less preferred by all players than is some other outcome [pp. 242, 243]."

Rapoport and Chammah (1965b) give a mathematically precise definition as follows:

"The general form of Prisoner's Dilemma [Game] is given in Matrix 1. [Here, "Row player" chooses either Row 1 (C_1) or Row 2 (D_1); simultaneously Column player chooses either Column 1 (C_2) or Column 2 (D_2). The first entry in each cell indicates the payoff to Row player if that particular combination of row and column is chosen, while the second entry indicates the payoff to Column player.]

	C_2	D_2
C_1	R_1, R_2	S_1, T_2
D_1	T_1, S_2	P_1, P_2

Matrix 1

Here $S_i < P_i < R_i < T_i$ ...

. . . The 'dilemma' is a reflection of the fact that in the absence of an enforceable agreement, D_i $(i = 1,2)$ is the 'rational' choice for each of the players, in the sense that the payoff associated with D_i is larger than that associated with C_i, regardless of how the other player chooses, whereas the paired choice C_1C_2 is better for both players than D_1D_2 [p. 831]."

While there have been efforts to extend the prisoner's dilemma game to more than two people (Cf. Bixenstine, Levitt, & Wilson, 1966; Marwell & Schmitt, 1972; Meux, 1970), these have largely involved specific numbers of players with specific payoffs. (In one exception, Marwell & Schmitt carefully constructed a three-person game that was "equivalent" to a standard two-person game). The present paper outlines a general n-person game that has the following properties:

(i) each player has a choice between two strategies--a "defecting" strategy and a "cooperative" strategy.

(ii) the positive payoff for the defecting strategy accrues directly to the player who defects, while the negative payoff for the defecting strategy is shared among all players.

(iii) the total payoff to all players decreases with the number of players who defect.

(iv) the structure of the game remains invariant no matter how many players are involved.

(v) the defecting strategy is the dominating strategy no matter how many other players choose to cooperate or defect.

(vi) the degree to which the defecting strategy dominates the cooperative strategy increases with the number of players.

(vii) the game reduces to a prisoner's dilemma game when $n = 2$.

The game proposed will have two additional properties, which are not considered crucial but may be of some interest:

(viii) The degree to which the defecting strategy dominates the cooperative strategy is a constant irrespective of the number of the other players who choose to defect, and

(ix) for $n = 3$, the three-person prisoner's dilemma proposed by Marwell and Schmitt is a special case of the proposed game.

The common's dilemma game is defined as follows. Each player may choose a cooperating (C) strategy or a defecting (D) strategy. Each player who chooses the cooperating strategy receives a positive payoff of c. Each player who chooses a defecting strategy receives a positive payoff of c, plus an additional positive payoff of d, greater than $\frac{1}{n - 1}$. For each player who chooses a D strategy, a penalty of d + 1 is assessed to the group as a whole and is paid out equally by the n players (including the players who choose D). d, c, and +1 may all be subject to the same ratio transformation without changing the essential structure of the game.

The game as defined satisfies conditions (i) - (iv). To demonstrate most of the other properties, it is only necessary to consider the algebraic difference between choosing a D strategy when m other players in an n-person game have chosen D and choosing a C strategy in that situation. If a D strategy is chosen, the payoff to the individual choosing that strategy is

$$c + d - \frac{(m + 1)(d + 1)}{n} \tag{1}$$

If the C strategy is chosen, the payoff to that individual is

$$c - \frac{m(d + 1)}{n} \tag{2}$$

The algebraic difference of (1) - (2) is equal to Equation (3).

$$c + d - \frac{(m + 1)(d + 1)}{n} - [c - \frac{m(d + 1)}{n}] \tag{3}$$
$$= d + \frac{m(d + 1)}{n} - \frac{(m + 1)(d + 1)}{n}$$

$$= d - \frac{d + 1}{n} \tag{4}$$

$$= \frac{(n - 1)d - 1}{n} \tag{5}$$

This difference, as given in Equation (5), will always be a positive number (because $d > \frac{1}{n - 1}$ implies that $(n - 1)d - 1 > 0$); hence D is dominating (cindition (v)). Moreover, as can be seen from Equation (4), this difference increases with increasing n (condition (vi)). Finally, it is independent of m (condition (viii)).

A ratio transformation on c, d and 1 clearly does not effect conditions (i) - (iv), since these follow directly from the definition of the game. To demonstrate that it also has no effect on conditions (v), (vi), and (viii), substitute αc for c, αd for d and α for 1 in the payoff terms in Equations (1) and (2). ($\alpha > 0$.) Then, Equation (3) becomes

(3') $$\alpha c + \alpha d - \frac{(m + 1)(\alpha d + \alpha)}{n} - [\alpha c - \frac{m(\alpha d + \alpha)}{n}] \quad ,$$

which reduces to

(5') $$\frac{(n - 1)\ \alpha d - \alpha}{n} = \alpha[\frac{(n - 1)d - 1}{n}]$$

which because $\alpha > 0$ again is a positive number (condition (v)) increasing with n (condition(vi)) independent of m (condition (viii)).[2]

When n = 2, the common's dilemma game reduces to the prisoner's dilemma illustrated in Table 1.[3]

Insert Table 1 about here
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[2]Actually, the game is unaffected by linear transformations from x to $\alpha x + \beta$ in which β as well as α is greater than zero, but the structure of the game can be changed if $\beta < 0$.

[3]While it is true that the commons dilemma reduces to a prisoner's dilemma game when there are only two players, it is not true that all prisoner's dilemma games can be rephrased as commons dilemma games with n = 2. Further, not all n-person games in which defection is a dominating choice reducing total payoff are of the type described here.

Table 1

Player 2

		C	D
Player 1	C	c, c	$c - \frac{d+1}{2}$, $c + \frac{d-1}{2}$
	D	$c + \frac{d-1}{2}$, $c - \frac{d+1}{2}$	c - 1, c - 1

Note d > 1

Finally, the Marwell and Schmitt (1972) game may be described as one in which each of three players simultaneously plays two identical prisoner's dilemma games against the other two players. Each player must choose a D or C strategy for <u>both</u> of these games, and each player obtains the average (or sum) of his payoffs in each game. Thus, if the average is received, the two simultaneous games presented in Table 2a may be reduced for each individual to the single game in Table 2b.

Insert Table 2 about here

The Marwell and Schmitt game is equivalent to the commons dilemma game in which each individual receives 4 for a C choice, 8 for a D choice and the group as a whole is assessed 6 for each D choice. Thus it is not surprising--given condition (vi) of the commons dilemma--that Marwell and Schmitt find more D choices in their 3-person game than in their 2-person game.[4]

The point of constructing a formal commons dilemma game is to allow an <u>empirical</u> investigation of the commons dilemma. Suppose, for example, you are a subject in a psychological experiment consisting of a single play of a commons dilemma game in which each of 10 players receives \$20 for a cooperative choice, each receives an additional \$100 for a defecting choice, and a penalty of \$120 is shared among all 10 for each defecting choice. If all make the cooperative choice, all will receive \$20--while if all defect, all will receive nothing; nevertheless, you do a quick calculation of the type involved in Equations (1) through (5) and determine that you are \$88 better off by choosing a defecting choice irrespective

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[4]For the 2-person and 3-person games to be strictly equivalent within the framework of the commons dilemma, the payoffs in the CD cells of the 2-person game should be 5,1 rather than 6,0.

Table 2

		Other C	Other D
Player	C	4,4	0,6
	D	6,0	2,2

(a)

		Combination of Others CC	CD	DC	DD
Player	C	4	2	2	0
	D	6	4	4	2

(b)

of what the other players do. What would you do? What could the group do to assure that its members make the cooperative choice? Can the group do anything--short of coercion--to assure cooperation? It is hoped that the answers to questions such as these will have some bearing on the current dilemmas society is facing concerning such commons problems as overpopulation and pollution.

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