INTENTIONS AND GAME THEORY

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Intentions and the holding of intentions are defined separately, so that the former is an abstract object and the latter a mental state. This definition allows both individual and collective intentions to be described independently of (i) the beliefs of any individual about the intentions held by any other individual and (ii) the deliberative process by which the intentions are formed. This facilitates their use as objects of analysis in game theory, the formal study of strategic interaction.

KEYWORDS: intentions, collectivism, game theory, agency.

1. INTRODUCTION

The goal of this essay is to draw some connections between intentions, as they are discussed by philosophers, and game theory, the formal study of strategic interaction. To do this, I build on the discussion of intentions in Searle (1980), together with the approach of Bratman (1993) to intentions that some collective activity occur. In particular, the latter paper provides the useful conceptual distinction between intentional attitudes of the form (i) "I intend that we J" and those of the form (ii) "We intend that we J", where J is some collective action.

Here, I take the conceptual separation between the subject and the object of the intentional attitude a step further by stating the content of an intention independently of whoever holds it. That is, the intentions considered here are not mental states per se, but rather abstract objects that induce mental states when they are held. An intention is collective insofar as its conditions of satisfaction, the actions which must occur in order for it to be successfully carried out, depend on the intentional actions of multiple individuals.[1,2] An intention can be held by an individual, and may be simultaneously held by multiple individuals. When an individual holds an intention he will act, to the best

[1]Consider expressions (i) and (ii) from the opening paragraph. (i) is an individually held intention that a collective action take place. Bratman (1993) gives four definitions of (ii), each stronger than the previous one. Three of these definitions (Views 2-4, pp103-6, op.cit.) involve infinite hierarchies of beliefs of the participants about one another's intentions. The definition of collective intention used here is closest to the simplest and most naive definition (View 1, pp103, op.cit.). According to this definition, "We intend that we J if and only if I intend that we J and you intend that we J." This weak definition is still stronger than the definition of a collective intention used here. A collective intention according to the definition used here could be of the form "Rowena and Colin J by way of this intention being carried out". If, in addition, Rowena holds this intention and Colin holds this intention, then according to View 1 of Bratman (1993) it can be said that "Rowena and Colin intend that we J".

[2]There is no agreement in the literature on what makes collective intentions distinctively collective, with discussion in the literature covering belief structures, collective goals and the reasoning by which the intention was formed (Bardsley, 2007; Bratman, 1992, 1993; Butterfill, 2012; Gilbert, 1990; Gold and Sugden, 2007; Searle, 1990; Tuomela and Miller, 1988; Velleman, 1997). I take no position on this, merely using "collective intention" as a convenient label for intentions whose conditions of satisfaction require action by more than one individual.

of his abilities, towards ensuring the conditions of satisfaction of the intention. Importantly, this conceptual framework allows collective intentions to be held by individuals without the necessity of any restriction on the beliefs of one individual about the intentions held by other individuals, although certain restrictions on such beliefs will make sense in given contexts.

This parsimonious content-based definition of intentions is a pragmatic one and allows the use of intentions in game theory in a way that should be accessible to practitioners in other fields such as economics, sociology and anthropology. Unlike much of the previous literature, I take no position on what truly defines or distinguishes a collective intention, but am merely interested in being able to use these objects to make interesting statements about the type of situations that are modeled in game theory. An alternative to a content-based definition of a collective intention is that of Gold and Sugden (2007), who also consider game theory in their analysis and argue that what makes an intention collective is the deliberative process by which it comes to be held. However, for the purposes of the current paper, it is essential that the properties of intentions can be considered independently of such deliberation. Section 2 describes the approach. Section 3 discusses it with reference to beliefs, optimization and the deliberation by which collective intentions may come to be held. Section 4 applies the approach to equilibrium reasoning in games.

2. MODEL

We shall consider intentions as they are held prior to their being carried out. Searle (1980) refers to these as *prior* intentions and gives an example of the *representative content* of such an intention as follows:

(2.1)   (I perform the action of raising my arm

                  by way of carrying out this intention.)

Our first step is to separate the representative content of intentions from the holder or holders of the intentions. Rewrite the representative content of (2.1) as

(2.2)   (The holder of this intention performs the action of raising his or her arm

                  by way of this intention being carried out.)

Under this latter formulation, the intention can be considered independently of who holds it. In its most basic form, we have

(2.3)   (X by way of this intention being carried out.),

where X are the *conditions of satisfaction* of the intention. If such an object forms part of the mental state of a given individual and causes the individual to act, consistently with some model of the world (which need not be accurate), towards a state in which X pertains, then we say that the intention is *held* by that individual.

		Colin	
		S_C	H_C
Rowena	S_R	3, 3	0, 2
	H_R	2, 0	2, 2

FIGURE 1.— Stag hunt game. For each combination of strategies, entries give payoffs for Rowena and Colin respectively.

Note that reference can be made to specific agents as part of the conditions of satisfaction. For example,

(2.4)   (Alice raises her arm by way of this intention being carried out.)

Such an intention can still, in the abstract, be held by anyone. For example, Bob may intend to cause Alice to raise her arm by means of administering an electric shock.

An intention can be collective in that it includes the actions of multiple individuals in its conditions of satisfaction. For example,

(2.5)   (Alice and Bob raise their arms by way of this intention being carried out.)

Such an intention could be held by both Alice and Bob, by only one of them or by neither of them.[3,4]

Consider the Stag Hunt game in Figure 1, which we will use as an example. There are two individuals, Rowena (for rows) and Colin (for columns). Rowena has two *strategies* available to her, either she hunts hare (H_R) or she hunts stag (S_R). Colin can also hunt hare (H_C) or stag (S_C). If Rowena hunts hare, then she catches a hare for sure and gets a payoff of 2. If Rowena hunts stag and Colin also hunts stag, then Rowena obtains a

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[3] To give sense to the idea of one individual intending the action of another individual, Bratman refers to the idea of building an "influence condition" (of a kind later formalized by Bardsley, 2007) into the intention, that "for me to intend that we J I need to see your playing your role in our J-ing as in some way affected by me." For the purposes of the current paper, such conditioning is unnecessary, and even awkward, in that it introduces necessary dependence of the intentions held by a given individual on the intentions held by others. Furthermore, from an aesthetic point of view, it introduces an awkward discontinuity. If even the tiniest influence of my action on your action is enough for "me to intend that we J", then continuity suggests that no influence may likewise be satisfactory. This is the approach taken here. Specifically, we allow Alice to hold intention (2.5), violating what Bardsley calls "the uncontroversial constraint that one may only try to bring about one's own actions".

[4] Consider the contrast to the approach of Bardsley (2007). By incorporating conditionality into the content of intentions so that the actions of one individual can be conditional on the intention held by another individual, Bardsley introduces collectivity into both the conditions of satisfaction of the intention and the causal relation between intention and action. The current approach only includes collective considerations in the conditions of satisfaction. This enables the separation of the causal aspect of intentions from beliefs about the intentions of other players. For example, our formulation allows the possibility of Alice holding intention (2.5) and having an incorrect belief that Bob also holds intention (2.5). Note, however, that inconsistency between the current approach and that of Bardsley (2007) is not necessarily as great as it first appears, as he deals with *intentions-in-action* (intentions held at the time of action, see Searle, 1980) whereas we deal with prior intentions. It may be more reasonable for prior intentions (particularly under the planning conception of Bratman, 1993) to violate the "uncontroversial constraint" than it would be for intentions-in-action to do so.

payoff of 3. However, if Rowena hunts stag and Colin hunts hare, then the stag escapes and Rowena obtains a payoff of 0. Colin's payoffs are similar to Rowena's.

Now, we can consider intentions with representative content given by these strategies. For example, the intention that Rowena hunt hare has the representative content

$$(2.6) \qquad (H_R \text{ by way of this intention being carried out.}).$$

Such an intention will be successfully carried out if Rowena holds this intention and does indeed play H_R. However, we can also consider intentions such as the collective intention that Rowena and Colin both hunt hare. This has the representative content

$$(2.7) \qquad (H_R \text{ and } H_C \text{ by way of this intention being carried out.}).$$

Such an intention will be successfully carried out if Rowena and Colin hold this intention and do indeed play *strategy profile* (H_R, H_C).

Assume that Rowena holds the intention with representative content given by (2.7). If she observes Colin play S_C and she has sufficient reasoning ability, then she will know that the intention has not been successfully carried out. If she observes Colin play H_C, then it may be that the intention has been successfully carried out. However, it may be otherwise. For example Colin could have held the intention

$$(2.8) \qquad (H_C \text{ by way of this intention being carried out.}),$$

or even held the intention

$$(2.9) \qquad (S_C \text{ by way of this intention being carried out.}),$$

but due to his short sightedness, mistaken a hare for a stag and instead played H_C.

3. DISCUSSION

3.1. *Circumstances beyond one's control*

From following the exposition above, it might seem that a difference between individual and collective intentions is that if Rowena holds a collective intention, then she holds an intention with conditions of satisfaction which include something over which she has no control, namely the strategy of Colin. However, this is less of a distinction than it may at first seem, as even individual intentions are often contingent upon events over which the holder of the intention has no control or no knowledge.

Consider, for example, the intention to raise one's arm with the representative content given by (2.2). This intention can be held by Rowena even if she cannot raise her arm for some reason, for example due to an injury, but does not know this fact. In such cases, it is traditional in game theory to think of 'Nature' as a player whose choices resolve uncertainty. The role of Nature and of Colin in the conditions of satisfaction of an intention held by Rowena are therefore similar.

This similarity between the actions of Nature and the actions of other individuals is also noted by Bardsley (2007, pp151-2), the difference being that Bardsley (2007)

wishes to exclude individuals from holding intentions over actions or circumstances over which they have no control. His response is to restrict the domain of the intentions in question to when specific circumstances prevail. For example, Rowena could hold an intention with representative content

(3.1)   (Under the circumstances that Rowena is not injured,

               Rowena raises her arm by way of this intention being carried out).

But what of circumstances that Rowena cannot foresee? We could define an intention with representative content

(3.2)   (Unless prevented by circumstances beyond her control,

               Rowena raises her arm by way of this intention being carried out),

but then, if Rowena holds the intention (3.2), it is impossible for its conditions of satisfaction not to be satisfied. Such tautological propositional content seems to defeat the point of considering such an object in the first place. By allowing individuals to hold intentions over actions or circumstances over which they have no control (in the words of Bratman (1993), to hold an 'intention that X' rather than an 'intention to X'), the current work avoids such complications.

3.2. *Beliefs*

In the presentation above, no restrictions are placed on the beliefs of Rowena and Colin about one another's intentions, or indeed whether they even have any such beliefs. This is consistent with evidence that humans develop the ability to undertake collectively intentional action prior to sophisticated logical inference and the ability to articulate hierarchical beliefs (Tomasello and Rakoczy, 2003, and citations therein). Of course, it may be that either the reasoning that Rowena follows, or her discussions with Colin when she decides to hold an intention, lead her to form some beliefs about the intentions held by Colin. For example, if Rowena and Colin deliberate and agree that they should hold a collective intention with representative content

(3.3)   (S_R and S_C by way of this intention being carried out.),

then it seems natural that, following such deliberation, they should both hold such an intention and also believe that the other holds such an intention.

Although such beliefs seem sensible, they are not necessary under the formulation of intentions used here. To see this, consider the following situation. Rowena and Colin deliberate and agree that they should hold a collective intention with representative content given by (3.3); consequently both Rowena and Colin hold such an intention; yet Rowena believes that

  (i) Colin is a coward who will always intend to play H_C, and

  (ii) Rowena has magical powers over Colin's behavior, such that any strategy played by Rowena is perfectly mirrored by Colin.

In this situation, Colin will try to play S_C to carry out (3.3). Rowena will also play S_R to carry out (3.3), and further holds the erroneous beliefs that (i) Colin intends to choose H_C, but (ii) by choosing S_R she is causing Colin to act against this intention so that the strategy profile (S_R, S_C) is played. The intention represented by (3.3) will, assuming that Colin and Rowena have perfect control over their own strategy choices, be successfully carried out.[5]

Of course if Rowena did not in fact hold the intention given by (3.3), but instead held a more precise intention:

(3.4)   (Rowena shall use her magical powers to cause (S_R, S_C)

             by way of this intention being carried out.),

then this intention would not be successfully carried out, although Rowena may believe that it has been. In fact, it is possible that Rowena holds both the intentions given by (3.3) and by (3.4), acts towards the carrying out of both of them, and believes that both have been successfully carried out, even though in fact only (3.3) has been. Note that, similarly to (3.3), almost all intentions omit some intermediate causal details. For example, when I intend to stir my coffee, I do not care about the precise trajectories that the milk molecules will take in disseminating themselves amongst the water molecules.

3.3. *Deliberation and optimization*

Gold and Sugden (2007) argue that what makes collective intentions distinctively collective is how they are formed and that "an analysis that focuses on the intentions themselves will miss the feature that makes collective intentions collective." Although the current treatment does not take this approach, it may be instructive to consider the relationship between the deliberative process by which intentions come to be held and the intentions themselves.

Collective deliberation does not imply that every intention formed as a consequence of such deliberation is collective. It is possible that Rowena and Colin will discuss the game in Figure 1 and conclude that, given surrounding uncertainties and their lack of trust in one another's competence, that they do not wish to collaboratively decide upon which intentions to hold. Subsequently, they may come to hold individual intentions to choose Hare so that Rowena holds the intention given by (2.6) and Colin holds the intention given by (2.8).

Conversely, under the current formulation, collective deliberation is not necessary for collective intentions to be held and carried out. Consider a situation where both Rowena and Colin erroneously think that their strategy choice will be perfectly mirrored by the strategy choice of the other individual. From Rowena's perspective, she

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[5]This is analogous to the example in Bratman (1993, pp103-4), in which two individuals intend to go to New York together, but one of these individuals intends to go by kidnapping the other individual. Bratman argues that for an intention to be truly 'shared' by two individuals, the individuals must each intend that the intended actions are carried out in part due to the intentions of the other individual. Here, we remain silent on which intentions can be said to be truly 'collective' or truly 'shared'.

can then either play H_R, inducing the strategy profile (H_R, H_C) to obtain a payoff of 2, or she can play S_R, inducing the strategy profile (S_R, S_C) to obtain a payoff of 3. By individual reasoning she can determine that it is optimal for her to choose S_R. Colin can reason similarly. Consequently, it is possible that both Rowena and Colin hold (3.3), strategy profile (S_R, S_C) is played and the intention successfully carried out without any deliberation at a collective level. Note that by ascribing erroneous beliefs to the individuals, this example reduces their decision problems to individual decision problems. That this is possible illustrates how the approach of the current paper provides insight into the problem of collective intentions precisely because it does not attempt to seek distinctions between individual and collective intentions, but rather draws the simple distinction between the holding of an intention and the intention itself.

Despite the above, the author agrees with Gold and Sugden (2007) that there is a close relationship between collective intentions and deliberation with collective considerations. Such deliberation could be explicit discussion between individuals or 'team reasoning' by individuals who reason from the perspective of a collective (Bacharach, 1999; Sugden, 1993, 2003). It is possible to consider the implications of this deliberation for any collective intentions that come to be held as a consequence. One possible implication of deliberation is optimality. If Rowena and Colin consider possible collective intentions over strategy profiles, then there are four possibilities for the X in expression (2.3). These are strategy profiles (H_R, H_C), (S_R, H_C), (H_R, S_C), (S_R, S_C). All of these profiles except for (S_R, S_C) are Pareto dominated in terms of payoffs. That is, for any such intention other than that given by (3.3), higher payoffs for both individuals could be obtained by successfully carrying out (3.3) so that (S_R, S_C) is played.

Thus the nature of deliberation is that it is not only a way to share information, beliefs and argument, but it also affects the objects over which intentional behavior can be optimized. By asking the question 'what should we do?', rather than asking 'what should I do?', rational well-informed groups of individuals can come to hold optimal collective intentions. Through deliberation, the individuals can behave as a single agent, acting to optimize a vector of strategies. In short,

(3.5)   Collective intentions + Optimization = Collective agency.

Note that it is common amongst users of game theory to describe a strategy as a 'plan' or, if one wishes, a 'complete contingent plan'. Our exposition up to this point shows that this cannot be the case. Any plan should include its conditions of satisfaction and, in that sense, plans are like intentions. However, conditions of satisfaction may differ across sets of intentions that induce the same strategy profile. For example, assuming that individuals can perfectly control the strategy they play, individual intention (2.6) held by Rowena together with individual intention (2.8) held by Colin will lead to the strategy profile (H_R, H_C) being played. Collective intention (2.7) held by Rowena and Colin will likewise lead to (H_R, H_C) being played. However, these intentions differ in their conditions of satisfaction. Should it occur that strategy profile (H_R, S_C) is played, then in the case of individual intentions, the intention held by Rowena to play H_R will have been successfully carried out. In the case of the collective intention that (H_R, H_C)

		Colin	
		D_C	V_C
	D_R	$2,2$	$0,3$
Rowena	V_R	$3,0$	$-5,-5$

FIGURE 2.— Hawk-Dove game. For each combination of strategies, entries give payoffs for Rowena and Colin respectively.

be played being held by Rowena, the intention will not have been successfully carried out and Rowena will be able to infer this. Hence, if game theorists wish to talk about optimal plans, then they should consider optimization over objects like the intentions of the current work, which are one step removed from strategies.

4. EQUILIBRIUM IN INTENTIONS

Assume that Rowena and Colin each hold an intention over the strategies to be played in a game. Rowena can either hold an intention regarding her own strategy, or a collective intention regarding strategies for her and Colin. Similarly for Colin. The intention held by Rowena determines the strategy she plays, and the intention held by Colin determines the strategy he plays. For example, if Rowena holds intention (2.6) and Colin holds intention (3.3), then Rowena will play H_R and Colin will play S_C.[6] We call the intentions held by Rowena and Colin an *equilibrium in intentions* if (i) any intentions held by Rowena or Colin will be successfully carried out, (ii) any intentions held by Rowena or Colin will be optimal according to some deliberative process of evaluation.

Condition (i) states that in equilibrium no intention will be held that is not successfully carried out. The idea here is that there is something inherently unstable about an intention that is doomed to fail. This condition tells us, for example, that the intentions described in the preceding paragraph cannot be an equilibrium in intentions, as Colin holds collective intention (3.3) that (S_R, S_C) be played, but Rowena does not hold this intention so the intention is not successfully carried out.[7]

Condition (ii) is deliberately vague. What constitutes an equilibrium in intentions for a given situation will depend on the deliberative process followed by the individuals concerned. There are many possible deliberative processes. We shall consider five of them in the context of the hawk-dove game of Figure 2. Rowena has two strategies, Hawk (V_R) and Dove (D_R). Colin can likewise choose Hawk (V_C) or Dove (D_C). We conduct an equilibrium analysis of this game.

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[6]It will be apparent to the reader that the concept is readily extendable to more complex situations with more than two players.

[7]Recall that even if (S_R, S_C) is in fact played, for example due to Rowena holding an individual intention to play S_R, this would not make it that (3.3) is successfully carried out, as for this to be the case, (S_R, S_C) must come to be played by way of the intention being held by the relevant participants.

4.1. *Optimal individual intentions given correct inference*

Consider a deliberative process in which Rowena can correctly infer the intention held by Colin, and given Colin's intention, holds an individual intention that does not lead to a lower payoff than some other intention that she might hold. Similarly for Colin. This is the logic of Nash equilibrium, only over intentions instead of directly over strategies. For the hawk-dove game of Figure 2, this rules out cases in which Rowena and Colin intend to play the same strategy. For example, if Rowena held the intention with representative content

(4.1)   (D_R by way of this intention being carried out.),

and Colin held the intention with representative content

(4.2)   (D_C by way of this intention being carried out.),

then Rowena and Colin would each obtain a payoff of 2. But then, holding fixed Rowena's intention at (4.1), Colin could obtain a higher payoff of 3 by instead holding the intention with representative content

(4.3)   (V_C by way of this intention being carried out.).

Alternatively, holding fixed Colin's intention at (4.2), the best intention that Rowena can hold is

(4.4)   (V_R by way of this intention being carried out.).

In equilibrium in intentions, either Rowena holds (4.1) and Colin holds (4.3), or Rowena holds (4.4) and Colin holds (4.2). These equilibria in intentions lead, respectively, to the Nash equilibrium strategy profiles (D_R, V_C) and (V_R, D_C) of the hawk-dove game.

4.2. *Optimal collective intentions given correct inference*

Consider a deliberative process such that Rowena and Colin come to hold a collective intention (e.g. by explicit discussion or by team reasoning) that does not lead to a lower payoff for both of them than they might obtain from some other collective intention. For example, if Rowena and Colin both hold the intention with representative content

(4.5)   (V_R and V_C by way of this intention being carried out.),

then they each obtain a payoff of −5, so this cannot be an equilibrium in intentions, as if Rowena and Colin instead held

(4.6)   (D_R and D_C by way of this intention being carried out.),

then they would each obtain a payoff of 2. Such payoffs cannot be improved upon for both players, so Rowena and Colin both holding (4.6) is an equilibrium in intentions. Further equilibria in intentions are Rowena and Colin both holding

(4.7)   (D_R and V_C by way of this intention being carried out.),

and Rowena and Colin both holding

(4.8)   (V_R and D_C by way of this intention being carried out.).

These equilibria in intentions lead, respectively, to strategy profiles (D_R, D_C), (D_R, V_C) and (V_R, D_C), the Pareto efficient strategy profiles of the hawk-dove game.

4.3. *Optimal intentions (individual or collective) given correct inference*

Consider a deliberative process in which Rowena can correctly infer the intention held by Colin, and vice versa, and Rowena and Colin come to hold intentions (individual or collective) such that no set of individuals could hold a different intention and obtain a higher payoff for all of its members, holding fixed the intentions held by individuals outside of the set.

As such a set could be a single individual (i.e. Rowena or Colin), this excludes any intentions excluded by the deliberative process of Section 4.1. Furthermore, as such a set could comprise both individuals (i.e. Rowena and Colin), this excludes any intentions excluded by the deliberative process of Section 4.2.

The remaining candidates for an equilibrium in individual intentions are when Rowena holds (4.1) and Colin holds (4.3), or Rowena holds (4.4) and Colin holds (4.2). For both of these sets of intentions, we already know that no single individual would wish to adjust his or her intention. To verify that either of these sets is an equilibrium in intentions, it remains to check that there is no collective intention that could be held by Rowena and Colin that would give them both higher payoffs. This is indeed the case, so either of these sets of intentions is an equilibrium in intentions.

The remaining candidates for an equilibrium in collective intentions are when both Rowena and Colin hold one of (4.6), (4.7) or (4.8). For each of these intentions, we already know that there is no collective intention that would give both Rowena and Colin higher payoffs. To verify that any given one of these intentions is an equilibrium in intentions, it remains to check that there is no single individual who could obtain a higher payoff by holding a different intention. This is indeed the case for (4.7) and (4.8). However, when Rowena and Colin both hold (4.6), they both obtain a payoff of 2, and holding fixed the intention held by Colin, Rowena could obtain a higher payoff of 3 by instead holding intention (4.4).

In summary, there are four equilibria in intentions under this deliberative process. Two of them are when Rowena and Colin hold individual intentions that lead to strategy profiles (D_R, V_C) and (V_R, D_C), and two of them are when Rowena and Colin hold collective intentions to play the same strategy profiles. That is, either of the strategy profiles that is a (Pareto efficient) Nash equilibrium of the hawk-dove game can be played due to either an equilibrium in individual intentions or an equilibrium in collective intentions.

4.4. *Optimal individual intentions given partially pessimistic inference*

Consider a deliberative process in which Rowena and Colin still try to choose optimal intentions, but where Rowena can correctly infer the intention held by Colin only when she holds a collective intention together with Colin. In all other cases, Rowena is pessimistic about Colin's intentions in the sense that Rowena evaluates each possible intention that she could hold according to the worst possible outcome for her if she holds that intention. Similarly for Colin.

The lowest payoff Rowena can obtain when she holds intention (4.1) is 0 and the lowest payoff she can obtain when she holds intention (4.4) is −5. Consequently, if Rowena is pessimistic about Colin's intentions, then she would hold intention (4.1). Similarly, if Colin is pessimistic about Rowena's intentions, then he would hold intention (4.2). So, without the possibility of collective intentions, the unique equilibrium in intentions is for Rowena to hold (4.1) and Colin to hold (4.2), leading to the strategy profile (D_R, D_C). Note that (D_R, D_C) is not a Nash equilibrium of the hawk-dove game.

4.5. *Optimal intentions given partially pessimistic inference*

Although individual intentions given by (4.1), (4.2) lead to payoffs of 2 for each of Rowena and Colin, their evaluation of the intentions under pessimistic inference is as if these intentions will lead to a payoff of 0. Thus, when collective intentions are possible, (4.1), (4.2) is not an equilibrium as Rowena and Colin could hold the collective intention (4.6) to play (D_R, D_C), which they would evaluate as providing each of them with a payoff of 2. That is, although each of these sets of intentions lead to the same strategy profile and payoffs, they are evaluated differently due to the pessimistic inference of individuals regarding the intentions of those with whom they do not share an intention.

However, Rowena and Colin holding (4.6) is also not an equilibrium. In this situation, as Rowena holds a collective intention with Colin, she correctly infers that he holds this intention. Given the inference that Colin holds (4.6), Rowena can evaluate that if, instead of holding (4.6), she were to hold (4.4), then she would obtain a higher payoff of 3. A similar argument shows that Rowena and Colin holding (4.5) is also not an equilibrium in intentions.

Finally, consider Rowena and Colin holding either (4.7) or (4.8). In either of these cases, Rowena and Colin hold the same collective intention and draw correct inferences about the intention held by the other individual. Given this, there is no individual intention which Rowena (respectively, Colin) could hold that she (respectively, he) would evaluate as leading to a higher payoff. Furthermore, there is no collective intention that would lead to both Rowena and Colin obtaining higher payoffs. Therefore, Rowena and Colin holding either (4.7) or (4.8) is an equilibrium in intentions. These intentions lead to strategy profiles (D_R, V_C) and (V_R, D_C) respectively, the Nash equilibria of the hawk-dove game. In this low information environment with pessimistic inference, collective intentions are necessary for equilibria in intentions to lead to the play of Nash equilibrium strategies.

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