A Study of Non-logical Inference Structure: Q- and R-implicatures[1]

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Conversational implicatures, whether they are quantity-based or relation-based, depend critically on features of the context. They have been largely considered as defying any formalistic treatment in logical semantics. The interaction between speaker and hearer has seemed to be beyond any mathematical theorizing and the task has been thrown away into a pragmatic "waste-basket." Even in pragmatics, those who follow the functional approach, e.g. Dinsmore (1979) and Leech (1983), cast doubt on any formalistic account of conversational implicatures. In fact, with some exceptions such as Gazdar (1979), Atlas and Levinson (1981) and Horn (1989), conversational implicatures and the explicating processes have been informally stated, due to the recalcitrant nature of the notion of the speaker's intention. However, as Parikh (1991) shows in the case of ambiguity, game theory provides a means of dealing with such a task. Following Parikh's assumption that communication is an interactive, strategic process that involves interplay of inferences about the participants' intentions, I attempt to show that the structure of non-logical inferences is subject to a mathematical game-theoretic analysis.

1. Goal

The goal of this paper is to establish a relationship between the so-called non-logical, pragmatic inferences involving conversational implicatures and the theory of games of strategy. It is argued that the relationship is more than analogical, but that the typical problems of communicative processes are strictly identical with the mathematical notions of suitable games of strategy.

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2. Non-logical Inferences

One way of defining an inference from the viewpoint of linguistic communication is that it is a statement about the unuttered made on the basis of the uttered. Inferences can be classified into two types. First, there are some inferences such as the one in (1c) from the sentences (1a) and (1b), which can be characterized in terms of traditional logical rules:

(1) a. Lima is the capital of Peru or Lima is the capital of Chile.
b. Lima is not the capital of Chile.
c. Lima is the capital of Peru.

Logicians have developed an inferential system, or deduction system, based on a set of well-defined "inference rules" such as Disjunction Elimination to account for reasoning processes like the one we have just seen. What is important here is that formal logic investigates the structure of deductive inference by abstracting meaning from sentences and dealing only with their logical form. Inference schemata formulated in sentential logic apply only to reasoning the validity of which depends upon the logical form of the sentences in question.

On the other hand, there is a different type of reasoning or inference processes the validity of which depends not only upon the logical form of the sentences but also upon the contextual knowledge between the interlocutors. For example, in a normal situation, we can equally 'infer' the speaker's intention (3) upon hearing the utterance of (2):

(2) Do you know the time?
(3) If you know the time, please tell me what it is.

This type of inference is clearly different from what we saw in (1). The truth conditional meaning of sentence (2) alone, no matter how it is represented formally, is not enough to explain how the hearer extracts (3) from the utterance of (2). Instead, we need to concentrate not so much on the abstract meaning of the sentences, as on the speaker's intention or the illocutionary force of the utterance, which does not come within the realm of truth-conditional semantics. Therefore, we are required either to extend the domain of traditional logic to incorporate such aspects of context-dependent, non-logical inference, or to establish a system of conversational inferences on the basis of an entirely different set of rules or principles of communication. This study is in the spirit of the latter. More specifically, we attempt to explore the structures of those non-logical inferences within the framework of game theory and the neo-Gricean model of pragmatics.

3. Communication as Strategic Games

3.1. Previous Approaches[2]

Traditionally in most of the orthodox linguistic philosophy and logical semantics the very relations that connect language with reality are left static and unanalyzed. Wittgenstein (1958) provides an exception to this tradition by discussing rather informally the 'language-games'--rule-governed activities connecting language with the world. They are supposed to give the expressions of language their meanings, but these games have scarcely been related to any systematic logical or linguistic theory with a few occasional exceptions in the seventies and the eighties.

Since von Neumann and Morgenstern (1944) laid the foundations for the mathematical theory of games, a special game theoretic approach to logic has been proposed by Hintikka (1973).[3] It turns Tarskian formal semantics directly into a game in such a way that two players, Myself and Nature, try to vindicate respectively the claims of truth and falsehood of a certain proposition A in some interpretation I. Although it examines a certain aspects of the dynamics of the representative relationships between language and reality, the primary goal is to define truth of a proposition A in a dialogue by introducing the notion of game into logical reasoning.

There are crucial differences between Hintikka's game and what I call 'communication game.' First, Hintikka adheres to Tarskian formal semantics as a base on which to build a game theoretic model, whereas the present analysis is built on the basis of Gricean pragmatics. This will guarantee a further freedom to deal with context-dependent aspects of implicatures, because the Gricean model provides us with an easier access to non-truth-

[2] Non-logical inferences are basically "strategic," in the sense that they involve a complex interplay of interactions trying to figure out speaker's and addressee's intentions.

[3] For its relation to Wittgenstein's language games, see Tennant (1979).

functional, contextual aspects of meaning in general.

Second, the players in Hintikka's game are Myself and Nature. There is only one agent in this game who decides the moves and his counterpart is basically unconcerned with the outcome of the game. In contrast, the players in our model are the direct participants in a conversation, i.e. speaker and hearer. Moreover Hintikka's dialogue game is one special case of two-person zero sum games, while our communication game is not, which we will return to later in section 4. Finally, while Hintikka's game may involve elements of chance like the card dealt in poker games, no appeal to chance is involved in our communication game. On the contrary, the strategic interaction between the interlocutors is responsible for the outcome in our game. Therefore, our game is a type of matrix game, as we will see in the following sections.

3.2. Game Theory and Implicature

We will first examine in which way the game theory can be brought into relationship with pragmatic inference and what their common elements are. This can be done best by stating briefly the nature of some fundamental pragmatic problems so that the common elements will be seen clearly. It will then become apparent that there is not only nothing artificial in establishing the relationship but that on the contrary the game theory is the proper instrument with which to develop a theory of communication.

In the pragmatics literature it has often been noticed that there are two antithetical forces operating in every conversation. They are the 'Force of Unification,' or Speaker's Economy, and the 'Force of Diversification,' or Hearer's Economy. First, the Force of Unification urges the speaker to simplify or minimize what she has to express.[4] This is a correlate of the Principle of Least Effort proposed by Zipf (1949). For instance, the speaker would prefer to say (4) rather than (5), unless she feels it necessary to be more specific about what she is talking about:

(4) Some of my friends live in Boston.
(5) Some of my friends live in Boston and others do not.

On the other hand, the hearer-oriented counterforce of diversification

[4] We will use 'she' for the speaker and 'he' for the addressee.

tends towards maximization or expansion of informational content being expressed. In other words, the hearer prefers, all other things being equal, to reduce the number of steps that need to be taken to get to the inferred proposition. Therefore, as Horn (1989: 192) points out, "the Speaker's Economy places an upper bound on the form of the message, while the Hearer's Economy places a lower bound on its informational content."

The existence of these antithetical forces brings about a game-like situation in pragmatic inference. Both the speaker and the hearer desire to obtain a maximum of utility or satisfaction. To achieve that goal, they adhere to their own economy. In other words, all other things being equal, the speaker tries to say as little as possible, making her contribution only necessary, while the addressee tries to process the speaker's utterance without stretching his imagination to the point that he thinks he pays more than he has to in an ordinary situation. Yet, this does not mean that they refuse to cooperate when they are engaged in a conversation. Normally, they expect each other to cooperate for the purpose of their conversation, but they want to fulfill it with least effort on each side. Parikh (1991) argues convincingly that the efforts made by the speaker and the hearer centering around an ambiguous sentence lay a foundation for a mathematical game-theoretic model of communication. He proposed to "combine ideas from two quite different disciplines," viz. theory of communication and theory of information flow, "in order to develop tools for studying the various problems connected with the concept of communication (Parikh 1991: 512)." The same idea can be applied to conversational implicatures.

4. A Game Theoretic Analysis of Implicatures

In this section, a game-theoretic analysis of a special type of conversational implicatures is presented. The notion of game adopted here is entirely different from that of either Hintikka (1973) or Wittgenstein (1958). I will focus on how an implicature is explicated and what kind of game such communication game is.

First, suppose someone says a sentence Ψ in (6) to her friend:

(6) Ψ: John broke a finger yesterday.

Among the possible readings of the sentence, we have the following two interpretations p and p':

(7) p: John broke his own finger yesterday.
p': John broke a finger yesterday and the finger was not his.

The normal interpretation of Ψ is p in (7). However, with some stretch of imagination, the hearer may find the interpretation p' more suitable. Suppose the speaker was referring to a law-enforcer named John confronting with an unruly mob and he happened to break one of the fingers of those who resisted to disperse violently. Then in a situation like this the hearer may choose p' as a preferred reading of (6). Then, how do we formalize such a common-sensical explication of implicatures? We will turn to this question in the following section.

4.1. An Abstraction of Explication of Implicatures

There are two ways a game can be represented. First, there is a normal form that represents a game in terms of mathematical devices including characteristic function. It presents a simple method of analyzing a game but it is more or less hard to follow without considerable background in mathematics. On the other hand, an extensive form uses a game tree, which shows in a step-by-step fashion the procedures of a game. The game tree enables us to understand the structure of a game in an easy manner, and therefore we will use the extensive form throughout the paper.[5]

A game tree, an example of which is given in Fig. 1 below, consists of a set of decision nodes such as ①, ②, ③ and branches that connect the nodes. The nodes (or vertices) represent each state and occur at each point at which a player has to make a move or decision (that is an admissible transformation). The branches lead to the next decision nodes which can be reached from the current state. Let us consider the case we have seen in the previous section in terms of game tree.

Following established tradition in game theory all trees are drawn with their roots at the top. The intial node labeled as ① represents a situation

[5] It is generally assumed that there are four elements of game: 1) players, 2) strategy, 3) payoff, 4) coalition. However, we are not concerned with the fourth element of coalition in this paper and this factor is not directly represented in a game tree. Instead, following Grice (1975), we assume that participants in a discourse are rational agents who are being co-operative.

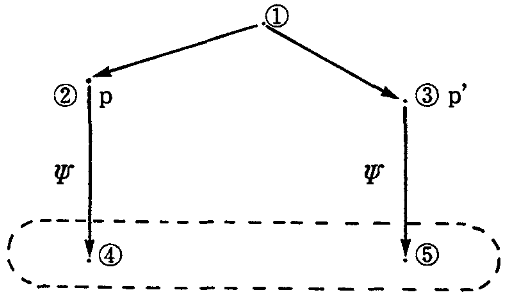

Fig. 1

or state before an utterance is made. This is where the speaker pauses to consider speaking something that she believes is relevant. Depending on the speaker's decision about what to say, we move on to one of the next nodes ② or ③: in ② we have the speaker intending to communicate p, and in ③ we have her intending to communicate p', p and p' being the two possible readings of the sentence Ψ in (6). So, ② and ③ are the choice nodes representing the two possible ways of settling the issue of whether the speaker's intention is to communicate p or p'.

A game tree can reproduce not only the actual moves that the players have chosen, but also each possible state, together with the possible decisions leading from it. Suppose that the speaker wants to communicate p rather than p' to the hearer. Then the speaker proceeds to the node ②. Once the sentence Ψ is uttered, all that the hearer knows is that the speaker could be either at ② or ③, because he cannot tell the speaker's intention. In general, the rules of any game must specify in advance which moves are indistinguishable to the players--the set we have enclosed in dotted lines. This set indicates that the hearer cannot distinguish the speaker's move and is called an "information set" for the hearer.[6]

After the sentence is uttered, it is the addressee's turn to choose a correct interpretation. Not knowing his counterpart's intention, he has the two choices p or p' at ④ and ⑤. This situation is modelled by the tree in Fig. 2.

On the hearer's part, he does not have knowledge as to which of ④ and ⑤ is factual only by hearing the sentence Ψ. If he were to choose p, then he would get a correct interpretation and so a certain amount of satisfaction,

[6] However, after the speaker has uttered the sentence , it is common knowledge between the speaker and the hearer that p V p' is available to the hearer.

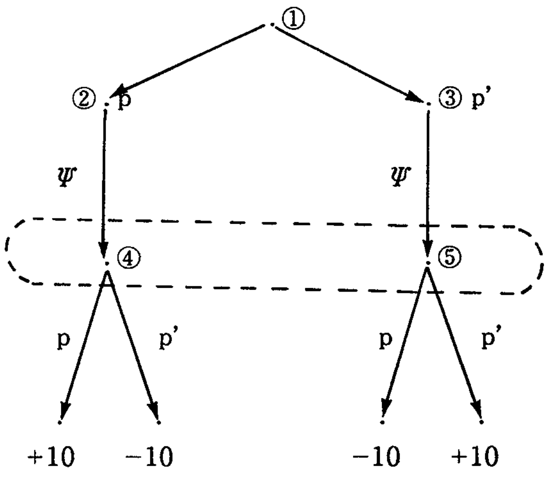

Fig. 2

only if the situation he was in turned out to be ④.[7] In game theory the term "payoff" is used for satisfaction the players may get at the end of the game. All payoffs can be interpreted as numbers and they are given at each terminal state.[8] For the ease of exposition, let's assume that the payoff is +10, when the hearer makes a correct guess about the speaker's intention by taking p as the appropriate interpretation. But if ⑤ were factual, the communicative interaction would end up with a false interpretation and so less satisfaction on both sides, say a payoff of −10.

There are, of course, a number of ways for the speaker to express the same situation, but the sentence Ψ in (6), i.e. 'John broke a finger yesterday' is the one that the speaker chose in this case. However, she could also have chosen a different sentence μ: John broke a finger yesterday and the finger was his own. Unlike Ψ, the only possible reading of μ is p, if we restrict our attention to the interpretation of the object noun phrase. It is

[7] In the economic literature the term 'utility' is often used instead of 'satisfaction.' The notion of satisfaction in our communication game is the same as that of utility. Both speaker and hearer seek to maximize their payoffs and employ their own strategies. However, the payoff as an end result of their interaction is shared by them all.

[8] There have been proposed various ways of measuring the payoff of a game. One of them is a 'von Neumann-Morgenstern utility function' in von Neumann and Morgenstern (1944). We will not be concerned with the details of how the exact values of payoff are determined in this paper.

obvious that to say μ would cost more than to say Ψ. Nevertheless, the speaker may choose to say μ instead of Ψ in order to describe the same state-of-affairs, because the cost of a more complex utterance should be much smaller than the possible dissatisfaction she may get when she fails to get her message through the hearer by saying Ψ.

Similarly, if the speaker finds herself in state ③, she may think that it is more appropriate to say μ': John broke a finger yesterday and the finger was not his finger, rather than to say Ψ. While the meaning of μ' is straightforward and has no danger of misinterpretation, it is much more complex and verbose than Ψ. This fact will be reflected in the payoff, which will be lower, say 7, than in the case of the best possible moves between the interlocutors.[9] Note that the speaker may still choose to say Ψ in state ③, running the risk of the addressee's misinterpretating it as conveying p. In that case, if the addressee correctly interprets it as conveying p', then the payoff will be a positive one, meaning that the talk exchange will be a successful one. On the other hand, if the hearer mistakes the utterance of Ψ in ③ to mean p, the conversation will turn out to be a total failure with the lowest payoff. This situation is represented in Fig. 3.

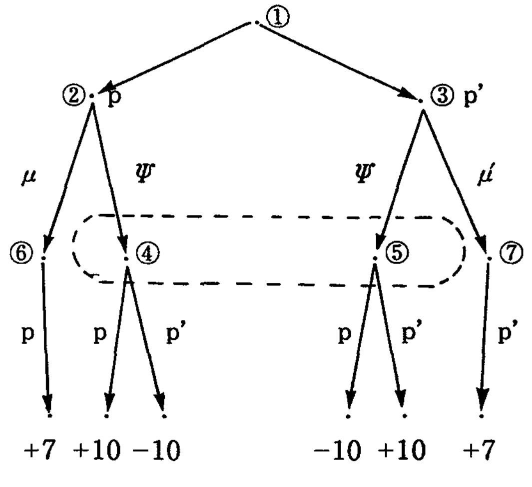

Fig. 3

[9] The value of the payoff depends largely on how you estimate the cost and satisfaction and convert them quantitatively into numerical values. The payoff values assumed here are meant to be only relative values without any further significance.

Note that the nodes ⑥ and ⑦ are not in the information set for the hearer, because the hearer can distinguish them when he has heard the sentence Ψ. The next step is to see how the players interact to reach a correct solution of this communication game.

4.2. Strategic Game

The kind of game we are looking at is a strategic game which is described by a set of rules. We may think of a strategy of a player as a set of instructions for playing the game. Conversely, each different way that a player may play a game is a strategy of that player. Following Parikh (1991), we assume that a strategy is a function from the set of all the decision nodes to a set of actions. In the game represented in Fig. 3, the speaker has the following four strategies:

(8) S1. ② $\longrightarrow \Psi$, ③ $\longrightarrow \mu'$
S2. ② $\longrightarrow \Psi$, ③ $\longrightarrow \Psi$
S3. ② $\longrightarrow \mu$, ③ $\longrightarrow \Psi$
S4. ② $\longrightarrow \mu$, ③ $\longrightarrow \mu'$

For the sake of simplicity, let us abbreviate each strategy in (8) as follows.

(9) S1. $< \Psi, \mu' >$
S2. $< \Psi, \Psi >$
S3. $< \mu, \Psi >$
S4. $< \mu, \mu' >$

On the other hand, the hearer's strategies are more restricted because there is the information set for him. Among the four choice nodes (i.e., ⑥, ④, ⑤, ⑦) for the hearer, ④ and ⑤ are in the same information set. Therefore, he cannot distinguish between them and his strategies are narrowed down as follows:

(10) H1. ⑥ $\longrightarrow$ p, ④, ⑤ $\longrightarrow$ p, ⑦ $\longrightarrow$ p'
H2. ⑥ $\longrightarrow$ p, ④, ⑤ $\longrightarrow$ p', ⑦ $\longrightarrow$ p'

The strategies in (10) show that the hearer has no alternative at the choice nodes ⑥ and ⑦, but that the only domain for his strategy is the information set.

Taking one strategy from each of the speaker's and hearer's strategy sets, we have the following matrix of all the strategies available in Table 1. Let's call the pair of the speaker's strategy and the hearer's strategy, i.e. <Sn, Hn>, a joint strategy Jn.

(11) Table 1: Matrix of Strategies

$$\begin{array}{cc} & \begin{array}{cccc} S1 & S2 & S3 & S4 \end{array} \\ \begin{array}{c} H1 \\ H2 \end{array} & \begin{bmatrix} J1 & J2 & J3 & J4 \\ J5 & J6 & J7 & J8 \end{bmatrix} \end{array}$$

Our task now is to show how one of the eight possible joint strategies dominates the others and proves to be the winning strategy in this game.

4.3. Solving the Equilibrium

To find a winning strategy in a game is to solve the multiple equilibrium problem. The most widely used solution concept is the Nash criterion proposed by Nash (1950). A strategy is called a Nash equilibrium if no player has a positive incentive for a unilateral change of this strategy, keeping the strategies of other players fixed. Take the joint strategy J4 in Table 1 as an example. With the speaker's strategy fixed as S4, the hearer has no incentive to deviate from p to p', because the choice nodes ④ and ⑤ are not to be considered as a result of the speaker's strategy. In contrast, if the speaker unilaterally deviates from S4 to S1, then obviously the speaker does better. Since the speaker has an incentive to deviate unilaterally, J4 is not a Nash equilibrium. In this way we find that only J1 and J7 in the matrix are Nash equilibria.

Then, which of the two equilibria is the intuitively plausible winning strategy? To solve this, we will apply the Pareto criterion, a criterion that can be applied to the Nash equilibria to determine the strategy that guarantees the optimal payoff. Before applying the Pareto criterion, we assume that the reading p, i.e. John broke his own finger, is more likely than the reading p', John broke a finger and it was not John's finger. We further assume that the speaker and the hearer think that it is common knowledge between them that the state described by p is more common, more probable than the state described by p'. This knowledge can be represented by the probabilities, say 0.8 and 0.2, respectively.[10] In other words, a situation where one broke one's own finger is four times as probable as a situation where one broke someone else's finger. One may argue that the probability of the first situation is only slightly higher than the second. Then the result would be reflected in the values of the payoff--the narrower the probability difference is, the smaller the payoff difference is. It can be sometimes even too close to call which state is more common. In an extreme case of ambiguity or implicature, the probabilities of each one of the two possible states may be even, i.e. 0.5 each. Then there can be two payoffs of an equal value.

Now in each case of J1 and J7, the expected payoff is determined as follows:

(12) a. payoff of J1 $= 0.8 \times 10 + 0.2 \times 7 = 9.4$
  b. payoff of J7 $= 0.8 \times 7 + 0.2 \times 10 = 7.6$

Therefore, J1 "Pareto-dominates" J7, which implies that both players find J1, viz <S1, H1>, the winning strategy for the game. In other words, the speaker is most likely to say Ψ if she is in state ② and μ' if she is in state ③, and the hearer is likely to choose p if he hears Ψ and to choose p' if he hears μ' as the best interpretation for each. Hence, the explication of implicature is completed.

This result depends crucially on the values of the probabilities. They come from the shared knowledge that ② is more likely than ③.

5. Principles of Inference and Game Theory

5.1. Horn's Q and R

In a dualistic theory of conversational implicature, Horn (1984, 1989) postulates two antinomic principles operating in pragmatic inference. They are the "Q-principle" and the "R-principle". First, the Q-principle is basically a hearer-based sufficiency condition, telling us "say as much as you can," or "make your contribution sufficient." It collects Grice's Quantity 1 maxim (Make your contribution as informative as is required), Manner 1

[10] Note that the probabilities are not pre-determined independently of the games, but are internally given according to the likelihood of the event described by the utterance. Therefore, the values may vary.

maxim (Avoid obscurity of expression) and Manner 2 maxim (Avoid ambiguity). The Q-principle dictates that the speaker must provide as much information as she can, given the circumstances. In the example we have seen so far, the speaker is expected to avoid the sentence Ψ, because it is the least verbose and ambiguous, if not obscure.

However, the result of a game theoretic analysis of the example shows that the speaker does not always avoid saying Ψ. This suggests that the Q-principle is not the only principle operating in communication. In fact, Horn (1984, 1989) suggests that there is a countervailing R-principle. It is a speaker-based necessity condition, telling us "say no more than you must," or "make your contribution necessary." Covering Grice's Quantity 2 maxim (Do not make your contribution more informative than is required), Relation maxim (Be relevant), Manner 3 maxim (Be brief) and Manner 4 maxim (Be orderly), the R-principle tells the speaker to let the circumstances speak and give out as little information as possible.

Given the R-principle, the speaker is expected to prefer the sentence Ψ to the more verbose sentences. This expectation again fails to prove itself, because the winning strategy is for the speaker to choose μ' rather than Ψ in some situation. Therefore, as Horn (1989) says, the two principles interact in explicating the implicatures: they sometimes clash, or one of them is overridden by the other, or one of them constrains the power of the other. [11] However, Horn does not go into the details of how the orderings between the two principles of pragmatic inference are determined. [12] In this respect, the game theoretic approach to implicatures may complement the neo-Gricean model of pragmatic inference.

5.2. MiniMax Theorem

There is an important theorem called the MiniMax Theorem in game the-

[11] An example from Stern (1931: 257-258) is especially relevant to the last case here.

[12] Horn (1984: 17) says that "pragmatic competence often differs across cultures... in accordance with the assignment of relative weightings to different maxims or principles." He does not mention, however, how the weightings are determined. except that "sex of speaker, and significance and accessibility of the information contributed, are other variables influencing the relative weights of Q-based and R-based principles."

ory. It was first proposed and proved by von Neumann (1928):

(13) MiniMax Theorem

In a matrix game <I, M, N, A>, such that I is the set of the players, M is the set of the first player's strategies $i_1, i_2, \cdots, i_n$, N is the set of the other player's strategies $j_1, j_2, \cdots, j_n$, A is the payoff matrix consisting of every payoff aij, $\langle i, j \rangle \in M \times N$, if there exist strategies i_*, j_*, and the real number v, such that $a_{i_* j_*} = \text{MaxiMin} a_{ij} = \text{MiniMax} a_{ij} = v$, the game is said to have a saddle point at i_* and j_*. The v of the saddle point is the value of the game and the i_* and j_* are the optimal strategy of the player 1 and 2, respectively.

The precise statement of the theorem would lead us too far, but the basic idea is that the players in a zero-sum game try to find an entry in the matrix of game called "saddle point" that will give them a security level of payoffs. Having this in mind, let us construct the payoff matrix of the game we saw in section 4.

(14) Values of Strategies

	S1	S2	S3	S4	Row Min
H1	9.4	6.0	3.6	7.0	3.6→MaxiMin
H2	−6.6	−6.0	7.6	7.0	−6.6
Column Max	9.4	6.0	7.6	7.0	
		↓ MiniMax			

In this matrix each speaker's strategy is represented by a column; each hearer's strategy is represented by a row. The speaker wishes to obtain the highest possible of the payoff entries. If he chooses S1, the hearer may choose either H1 or H2. If H1 is chosen by the hearer, they will obtain the highest payoff possible, 9.4. But then again, she also knows that there is a pitfall that the hearer chooses H2. If he does, the worst thing (payoff of minus 6.6) happens that they end up with a total miscommunication. On the other hand, if the speaker chooses S2 and the hearer decides to choose H1, the payoff will be 6.0, much less than the joint strategy J1 will yield, but certainly much higher than <S1, H2>. In this way the speaker considers every passible strategy and finds the smallest value of all maximum payoffs. This is the payoff called MiniMax for the speaker.

On the hearer's part, if he chooses H2, he may lose the game by having -6.6 as the payoff. Instead if he chooses H1, he may obtain at least 3.6 as the payoff, no matter what the speaker's strategy is. So, the value 3.6 is the least security level for the hearer and is called MaxiMin of the game.

Note that the MaxiMin is not equal to the MiniMax, which means that there is no saddle point in this game. Since the MiniMax theorem holds for strictly competitive, zero-sum games with a finite number of pure strategies, the result leads us to the conclusion that this kind of communication game is not a strictly determined zero-sum game and that the strategies that the players use in inference game are not the pure ones but the mixed ones. [13]

5.3. Communication Mixup in Game Theory

In discussing the cases where the competing pragmatic principles Q and R are weighted differently depending on one's communicative goals and constraints, Horn (1984) takes the communication mixup example from Tannen (1975):

(15) Conversational breakdowns and marital breakups (Tannen 1975)

First exchange:

Wife: Bob's having a party. You wanna go?

Husband: OK.

Second exchange (later):

Wife: Are you sure you want to go?

Husband: OK. Let's not go. I'm tired anyway.

Post-mortem:

Wife: We didn't go to the party because you didn't want to.

Husband: I wanted to. You didn't want to.

According to Tannen's gloss of this interchange, the wife is operating on

[13] A zero-sum game is a game of pure conflict with payoffs of strictly opposed values. At its opposite end lies a game of pure coordination, a game in which the players have the same interests. Most games, including the communication game of pragmatic inference, are found between these two extremes. They are called "mixed-motive" games since their payoffs are determined by the mix of conflict and coordination.

a direct strategy utilizing "Rule 3: Be friendly," one of the rules of politeness suggested by Lakoff (1973). The rule says "if one had meant more, she or he would (and should) have said it." In terms of Horn's taxonomy of pragmatic inference, the wife is operating on a Q-based inference pattern. Her partner, on the other hand, is employing an indirect, hint-seeking strategy which emanates from Lakoff's "Rule 1 politeness," requiring the speaker to "avoid saying too much when you can get it across by hints." This corresponds roughly to Horn's R-based inference pattern. Their different inference patterns lead them to a total miscommunication and the consequent, devastating breakup.

This kind of maxim clash is accounted for by referring to the concept of the winning strategy in terms of game theory of communication: communication mixup takes place when the speaker and the hearer have failed, unilaterally or bilaterally, to find the Pareto-Nash equilibrium. The failure to find the winning strategy may take place either wittingly or unwittingly. The interlocutors must pay higher costs and obtain lower payoffs when a communication mixup occurs. As a result, the fact that rational participants in a conversation are expected to avoid such a mixup is accounted for in terms of game theory of communication.

6. Conclusion

Pragmatic inference is not so much a matter of logic as a matter of information flow. Devlin (1990: 5) argues that "classical logic is inadequate to capture ordinary, everyday, 'people logic'." This inadequacy stems largely from the fact that, as Mey (1993: 57) argues, communication is not a matter "of what I say, but of what I can say, given the circumstances, and of what I must say, given my partner's expectations." It is believed that such a gap between logic and pragmatic inference can be filled, at least in part, by the game-theoretic model of communication, since the model enables us to analyze communication as an action by means of concepts such as 'strategy,' 'interaction,' 'payoff', etc.[14] The inferencing activity requires

[14] As Devlin (1991) says, inference can be regarded as "an ACTIVITY whereby certain facts (items of information) about the world are used in order to extract additional information (information that is in some sense implicit in those facts)." [Emphasis is mine.]

more than static logical rules, because it involves a series of understanding the intentions or strategies of both the speaker and the hearer under the circumstances. One aspect of this dynamic process has been analyzed in this paper adopting the concepts and tools of game theory.

We showed that an implicature-solving process is a process of finding out the unique Pareto-Nash equilibrium. We examined a precise method for determining conversational implicatures. We also showed that a communication game is not a strictly competitive zero-sum game involving pure strategies, because there is no saddle point and the MiniMax Theorem does not hold for strategic inference.

A conversation takes place felicitously when the two factors in communication, i.e. 'cognitive effect' and 'processing effect', strike the balance, if we use the terminology of the Relevance theory of pragmatics. In other words, only when the amount and importance of information contained in an inferred proposition for a particular participant in a particular situation is balanced against the number of steps that need to be taken to get to the inferred proposition, do we have a successful information flow. Such an information flow can be fruitfully analyzed mathematically by marrying the theory of strategic games and Gricean pragmatics.

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