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Meaningful Talk

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Natural language is a shared social convention that allows hearers to understand speakers. We model this using two steps. First, an encoding-decoding step where the sender transmits verbal information to the receiver. Second, an inferential step where the receiver may either believe the literal meaning of the message or disregard it in updating priors. These epistemic steps sharply restrict the beliefs that may be entertained on and off the equilibrium path. When there are credible messages, natural language is a powerful means to select equilibria.

JEL classification codes: D83, C72

Key words: cheap talk, signs, linguistic symbols, literal meaning, equilibrium meaning

> Director [in Japanese to interpreter]: The translation is very important, okay? The translation.
> Interpreter [in Japanese to the director]: Yes, of course. I understand.
> Director [in Japanese to Bob]: You're sitting quietly in your study. And there is a bottle of Suntory whiskey on the table. You understand, right? With wholehearted feeling, slowly, look at the camera, and as if you were meeting old friends, say the words — as if you were Bogie in Casablanca saying "Here's looking at you, kid" — "Suntory time!"
> Interpreter: He wants you to turn, look in camera. Okay?
> Bob: That's all he said?
> Interpreter: Yes, turn to camera.
> Motoko Rich, "What else was lost in translation", *New York Times*, 21.9.2003, and Wordreference Forum (http://forum.wordreference.com/showthread.php?t=65052).

I. Introduction

Talk is not a move like burning the bridges behind us, which can communicate to the enemy that our troops are not retreating. As Thomas Schelling (1960: 117) puts it, "Moves

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can in some way alter the game, by incurring manifest costs, risks, or a reduced range of subsequent choice; they have an information content, or *evidence* content, of a different character from that of speech. Talk can be cheap, when moves are not." Vincent Crawford and Joel Sobel (1982), in their pioneering study of the maximal amount of information an expert (the informed party) may offer the decision maker (the uninformed party) when there are incentives to misrepresent information, provide a game-theoretic representation of verbal communication between a sender and a receiver as cheap talk. Cheap talk sets language apart from signals: while signals may be credible because choices are differentially costly, words are not because they have no direct payoff consequences (see, e.g., Robert Gibbons 1992: 210).

The view that talk is not a move, while powerful, has ultimately led to treat language not only as cheap, but also as meaningless. Cheap-talk models concentrate on beliefs induced in equilibrium, not on equilibrium messages, even when senders are unbiased (Hefei Wang 2009). Our concern is that the only information which is actually added to the common priors — verbal communication — is not taken into consideration. We keep the feature that talk is cheap, in the sense that the sender may say whatever it feels like at no cost. However, receivers must be able to decode the messages transmitted by senders, a fact that has implications for all verbal communication games.

Navin Kartik, Marco Ottaviani, and Francesco Squintani (2007) point out that misrepresentation costs of senders transform language from cheap talk into a costly signal, a result which Steven Callander and Simon Wilkie (2007) reach in the specific context of political campaigns. The meaning correspondence in Stefano Demichelis and Jörgen Weibull (2008), who add lexicographic preferences of the sender for honesty, is particularly close to our focus.[1] However, costly talk for the sender is not sufficient to capture the informative role of natural language, because misrepresentation costs do not eliminate implausible informative equilibria where words have an equilibrium meaning completely unrelated to their literal meaning — what we call *unnatural language equilibria*. Instead, the decoding process of the receiver must be taken into account.

[1] The meaning correspondence is the relation between the announced message and the intended action. Demichelis and Weibull (2008) also introduce honesty, while we concentrate instead on the issues of credibility, truth, and belief.

Our model of verbal communication specifically relies on a pre-existing language that is shared by all the players (we later relate this to Roger Myerson 1989). Without a common language, there is no way for the speaker to verbally communicate meaning, either true or false, because there is no way for the hearer to understand the messages. In this connection, Bill Murray's character in *Lost in translation* illustrates the problems of comprehension in an unfamiliar language.

Our approach draws on Joseph Farrell's (1993: 515) deep insight that, credible or not, natural language has a comprehensible meaning, to which we add the inverse proposition, that the hearer will not be able to understand the speaker unless a common language is used. Inspired by the distinction between comprehensibility and credibility, we model an epistemic process where there is first an encoding-decoding step in which the sender transmits verbal information to the receiver, followed by an inferential step where the receiver must evaluate the credibility of the message. In the inferential step we restrict Bayesian updating so that the receiver may either believe the literal content of the message or disregard it. This forces beliefs to be formed taking into account the priors of the game without communication, and the verbal information that is actually communicated in the game. Our epistemic approach shares some features of the ostensive-inferential model of communication in Dan Sperber and Deirdre Wilson (1995).[2]

What type of information does natural language provide? Natural language is neither a move nor a type, but rather what in semiotics is called "symbolic information", i.e., words that point to moves or types. We use words to write papers that readers take seriously, and to organize seminars where people actually show up. Language is so ubiquitous that, in book I, chapter 2, of the *Wealth of Nations*, Adam Smith relates markets and exchange to our "faculties of reason and speech" (see also Ángel Alonso-Cortés 2008).

Section II conceptually describes our approach to symbolic communication. We motivate it with the George Akerlof (1970) market for lemons. Since this is a decentralized market, in Section III we ask how the seller and the buyer get together. This is a pure coordination game with a surplus from trade. Natural language allows the players to use explicit coordination, providing an alternative equilibrium selection mechanism to Thomas

[2] Our approach does not contribute to epistemic game theory. Rather, it tries to capture the informative role of natural language. The common understandings embodied in natural language nevertheless restrict the beliefs that players may entertain in response to verbal communication.

Schelling's (1960) tacit coordination through focal points salient to all the players. Section IV shows that within the market for lemons, where all equilibria are uninformative, it is nonetheless possible to rule out messages like “This is a lemon.” Section V formally defines natural language equilibria. Section VI relates our ideas to the literature on philosophy of language. The final section contains the closing remarks.

II. A Semiotic-Inferential Approach to Language

Language can be looked at as a convention and as a means of communication. This roughly corresponds to the distinction Ludwig Wittgenstein (1953) traces between a grammar, i.e., norms for meaningful language, and language games, i.e., activities where language is used (Anat Biletzki and Anat Matar 2009).

A. Language as a Shared Social Convention

Words, sentences, and language as a whole, are in a sense arbitrary, but in another they are not: we are born into them. For instance, in English the words “left” and “right” describe the moves left and right, in Spanish “izquierda” and “derecha” describe that. So while a language is an arbitrary set of conventions to communicate meaning, it is a set of shared social conventions. The idea of natural language as a social convention, i.e., as something both ordinary and artificial, harks back to Plato, Aristotle, and David Hume, while David Lewis (1975) constitutes the standard modern reference (Michael Rescorla 2010). For Hume, social conventions arise without need for either an explicit covenant (as in Hobbes) or a tacit agreement (as in Locke). Hume’s approach is described by Friedrich Hayek (1963) as an evolutionary view according to which institutions evolve spontaneously as the result of human actions, not of human design.

Linguistic conventions are an element of culture. For Gary Becker (1996: 16-18), culture is a kind of social capital that affects choices through its effects on an extended utility function that incorporates both personal and social capital. In the channel we explore, culture instead affects payoffs indirectly through its role in information transmission and equilibrium selection. For Clifford Geertz (1966: 3), culture “denotes an historically transmitted pattern of meanings embodied in symbols, a system of inherited conceptions expressed in symbolic forms by means of which men communicate, perpetuate, and develop their knowledge about and attitudes toward life".[3] In this regard, linguistic symbols are an additional source of information that has not been duly recognized in economics. Returning to Geertz (1966: 5-6),

> So far as culture patterns, that is, systems of complexes of symbols, are concerned, the generic trait which is of the first importance for us here is that they are extrinsic sources of information. By 'extrinsic,' I mean only that — unlike genes, for example — they lie outside the boundaries of the individual organism as such in that intersubjective world of common understandings into which all human individuals are born, in which they pursue their separate careers, and which they leave persisting behind them after they die. By 'sources of information,' I mean only that — like genes — they provide a blueprint or template in terms of which processes external to themselves can be given a definite form. ...it is precisely because of the fact that genetically programmed processes are so highly generalized in men, as compared with lower animals, that culturally programmed ones are so important; only because human behavior is so loosely determined by intrinsic sources of information that extrinsic sources are so vital.

Talk is not empty once we incorporate the cultural character of language.[4] The conventional feature which is specific to natural language can be described resorting to the categories used in semiotics. Signs point to something else.[5] The basic distinction, which appears in John Poinsot's 1632 *Treatise on signs*, is between conventional signs like the word "fire" or an image of a flame, and natural signs like smoke (Ricardo Crespo 2012). Charles S. Peirce introduces a three-fold distinction between symbols, icons and indices (Daniel Chandler 1994). This subdivides conventional signs into symbols which are purely conventional, such as the word "fire", and icons which resemble their subject matter, such

[3] Culture is a central concept in anthropology. Akerlof (1989: 2) quotes precisely this passage to define culture. Becker (1996: 16) uses a slightly different definition, also from Geertz.

[4] Ken Binmore (1994: 3) recognizes the importance of common understandings. Beyond common knowledge of rationality, he points out that common knowledge of this historical data helps to predict the equilibrium on which members of a society will coordinate in a specific game, but he does not explore further the role of, for example, sharing French as a common language, in sustaining an equilibrium (Binmore 1994: 140–143).

[5] Self-reference adds nothing in the games we analyze. More generally, self-reference can lead to contradictions, like the semantic paradox "This sentence is not true."

as an image of a flame. Indices are natural signs such as smoke, footprints, or medical symptoms, which are linked to some antecedent cause.

Ferdinand de Saussure introduced a dyadic model of signs composed of signifier and signified, while Charles S. Peirce proposed instead a triadic model that is closer to the modern representation of signs as composed of three elements (Chandler 1994). In the specific case of linguistic symbols, the components are:

(i) The signifier (sign vehicle): a sequence of letters or sounds "w", e.g., “This car is in great shape.”

(ii) The signified (intension/connotation): the concept $\hat{w}$ we think about when we read or hear the signifier.

(iii) The referent (extension/ denotation): the actual object w a signifier refers to, e.g., the used car they are trying to sell us.

We concentrate here on full sentences that can express statements, not on isolated words as they appear in a dictionary. Though the signifier "w" is only a part of the whole, it is also customary to refer to the signifier as the symbol.

B. Language Games

Sperber and Wilson (1995: 43) point out that communication is an asymmetric process: “It is left to the communicator to make correct assumptions about the codes and contextual information that the audience will have accessible and be likely to use in the comprehension process.” We leave out contextual information which allows to interpret utterances like “The door’s open” (Sperber and Wilson 1995: 20), since reference assignment and other pragmatic problems are issues that we do not touch upon here. We concentrate on using common codes, and their interpretation given the strategic context. In the spirit of Farrell’s (1993: 515) distinction between comprehensibility and credibility of messages, we formulate two steps in the epistemic process of using language to communicate meaning in concrete situations.

In regard to comprehensibility of messages, we characterize this as the encoding-decoding step. This relies on the linguistic conventions and can be described through de Saussure's dyadic model of linguistic symbols, i.e., signifier and signified. Speakers do not randomly use any word in the dictionary to name something. Rather, when there is asymmetric information, they rely on ordinary words to convey meaning to the hearer. A natural language shared by the speakers is the set "$\mathbf{M}$" comprised of all the messages "m" that can potentially be formed to utter comprehensible statements. As long as messages stick to the shared conventions in "$\mathbf{M}$", they may be anything, including lies, fiction, and economic models. As Wittgenstein (1953: 19) puts it, "Excalibur has a sharp blade" makes perfect sense, whether or not King Arthur's sword exists. The signified is crucial for the meaning of signifiers, de Saussure's point as a linguist. It is also crucial in asymmetric information games.

The semiotic representation of language, which concentrates on the process of coding and decoding messages, is the first step in our epistemic process of communication. This representation is denominated by Sperber and Wilson (1995:2) the "code model" of communication, which they trace back to Aristotle. In the encoding stage, the sender S uses the signifier "w^S" to express the signified $\widehat{w}^S$. In the decoding stage, the receiver R uses the signifier "m^R" to recover the signified $\widehat{m}^R$. Since thoughts are interior processes, only the signifier is manifest. We depict the coding-decoding process by a bijective function (statements, however, might be expressed in more than one way if there are equivalent expressions):

(1) $$"w^S" = e(\widehat{w}^S),$$

(2) $$\widehat{m}^R = e^{-1}("m^R").$$

We assume throughout our discussion that "m^R" $=$ "m^S", so the message that is heard by the receiver coincides with the message uttered by the sender. We implicitly rule out errors of perception. Communication is fully effective when $w^S = m^R$, where w^S is the referent that corresponds to "w^S", and m^R is the referent that corresponds to "m^R". In our examples, the referent w^S is either a move or a type. The issue we analyze here is that not all the information may be revealed due to willful distortions of the sender, i.e., "m^S" $\neq$ "w^S".

In regard to credibility, the key issue is whether the statement implied by the message is true or not. We characterize this as the inferential step. Here the point of view of Peirce and other logicians comes to the fore: the referent of the message must be taken into account. In the triadic model of linguistic symbols, the signifier, signified, and referent form a semantic triangle. Combining two semantic triangles, we can model unilateral communication between a sender and a receiver in the following diagram in Figure 1 that describes the word-to-fit-world and the world-to-fit-word sequences (this adapts the ordering in Kyung-Youn Park 1975). While one might do the analysis solely in terms of the referent w and the signifier "w", the signified $\widehat{w}$ is essential in asymmetric information games: the receiver uses the signified to ascertain the type or the intended action, because the referent is unobservable from the receiver's vantage point; otherwise, there would not be asymmetric information in the first place.

[Insert Figure 1 Here]

Sperber and Wilson (1995) contrast the semiotic model to the "inferential model" proposed by Paul Grice and David Lewis, where the hearer must infer the speaker's intention from the verbal information that is uttered. They develop this second model into an "ostensive-inferential model" where the hearer must take into account that the speaker has manifestly pointed out the verbal information being uttered (Sperber and Wilson 1995: 50–54). Sperber and Wilson (1995:175–6) thus describe verbal communication as a two-step process: the verbal information ostensively provided by the sender is the first step in the communication process, which is then used by the receiver to try to infer what the sender means.

Our approach is similar, though we restrict ourselves to purely linguistic symbols.[6] First comes the encoding-decoding sequence, as described by the semiotic model. Then, an inferential step by which the receiver must decide what inference to draw from the verbal information provided by the sender. We specifically assume that the receiver may either

[6] The approach in Sperber and Wilson (1995: 9-11) also takes into account contextual information that goes beyond the strategic setup, as well as natural signs like intonation and body language.

believe the literal meaning of the message, or disregard it when updating priors, motivating this with the problem of how the buyer and seller of a used car get together.

III. How Do Buyer and Seller Get Together?

Our ideas on natural language as a vehicle for conveying symbolic information developed from considering the coordination game. This game has played an important role in the philosophy of language (see Section VI). Our analysis is specifically motivated by the market for lemons, a decentralized market. We analyze it as a two-stage game where the negotiation stage is preceded by a coordination stage. This section analyzes the first stage game. Both parties are playing *rendez-vous*: if they successfully meet, in the second stage they can share the expected gains from trade. The following information must be transmitted before buyer and seller get together: the seller must post an ad saying that a car is for sale, indicating the quality of the car and a phone number; the buyer must call the phone number listed in the ad: and the seller must announce the place and time of meeting. In this stage we ignore the issue of quality, since the incentives for misrepresentation are addressed in the second stage. This leaves four pieces of information that must be conveyed from the seller (the sender) to the buyer (the receiver): that what is for sale is a car, the seller's phone number, the meeting time, and the meeting place.

Since the conceptual problem of communication is the same for each piece of information, we focus on the meeting place. We first describe the game without communication. We then model communication using three approaches: cheap talk, where anything may be said; costly talk, where there are misrepresentation costs; and meaningful talk, where the receiver's decoding process is introduced.

A. Game without Communication

Without loss of generality, let the expected payoffs for buyer and seller from meeting be normalized to 1, and, from not meeting, to 0.[7] Table 1 represents a game where the seller may only adopt two actions with positive probability in equilibrium, meeting left (L) or right (R) at noon. We relax this later.

[7] If the second stage of the market for lemons, which is discussed later on, implies market breakdown, high-quality sellers will not participate in the first stage. The coordination problem for sellers and buyers of lemons still remains.

[Insert Table 1 Here]

In this game, there are two pure strategy Nash equilibria, (L, L) and (R, R), as well as a mixed strategy Nash equilibrium that is Pareto dominated where each pure strategy is played with probability one half. The priors are that any strategy is equally likely. If, instead, any of the pure strategy equilibria were expected by both players, there would be no point in engaging in explicit communication.

B. Cheap Talk

Following the use/mention distinction, we distinguish between the world w and messages about the world $"w"$ using quotes. Though any messages are possible, Figure 2 only represents the minimal messages required, $"L"$ ("meet left") and $"R"$ ("meet right"). Any of the Nash equilibria in Table 1 subsist as outcomes when communication is explicitly modeled in this game through cheap talk.

[Insert Figure 2 Here]

An equilibrium is *informative* if the receiver changes beliefs after some message on the equilibrium path (Sobel 2011: 5). Otherwise, the equilibrium is *uninformative* (or *babbling*). There are uninformative cheap-talk equilibria where the seller plays both strategies with equal probability, and neither seller nor buyer pay attention to the equilibrium messages because they are not conditional on the actual choice of location. There is also an informative equilibrium where words are used in their conventional sense, so $"L"$ refers to L and $"R"$ to R. However, Figure 2 represents the *unnatural* informative equilibrium where words are not used that way. L is played with probability p, and R with probability $1 - p$. If the sender plays a pure strategy, the outcome corresponds to a Nash equilibrium, either (L, L) or (R, R). If the sender plays a mixed strategy, the payoffs correspond to a correlated equilibrium (Robert Aumann 1974). Though a public correlating device is not used, language allows both players to coordinate actions. We now explore different arguments to rule out unnatural informative equilibria.

C. Costly Talk

The setup where all sellers are charlatans that are willing to say anything can be modified by introducing a cost of misrepresentation. This nice idea was formalized by Kartik, Ottaviani, and Squintani (2007), and Callander and Wilkie (2007), with misrepresentation costs that depend on the extent of the distortion.[8] Our specific assumption is that disutility depends on the action of misrepresentation itself, because of the costs of making something up, so sellers have an infinitesimal but constant cost ε from thinking about saying something different from their true intentions.[9]

[Insert Figure 3 Here]

Costs of misrepresentation eliminate babbling equilibria in pure coordination games: if buyers ignore all messages, a seller would rather say the truth because it is the lowest cost message; given that, buyers have an incentive to heed the messages. However, costs of misrepresentation alone are not enough to do away with the excess of informative equilibria. Figure 3 shows that costs of misrepresentation do not destroy the unnatural language equilibrium of Figure 2, because if the sender deviates from the equilibrium message its payoff will fall from $1-\varepsilon$ to 0. This setup implicitly introduces some standard or norm to say things, otherwise senders would not be able to experience a cost of misrepresentation. We now extend this idea of norms to receivers.

D. Meaningful Talk

Though moral codes are important, we now turn to the most basic feature of language, the fact that we are brought up with a shared social convention that applies both to senders and receivers. Let the conventional expression for meeting at location L be "L", and at location R, "R". In the encoding stage, the sender's announcement "L" may coincide with the actual choice L (a truthful announcement) or not (a false announcement). In the decoding stage, the receiver's conventional interpretation of message "L" is action L. The

8 Unlike Kartik, Ottaviani, and Squintani (2007), Callander and Wilkie (2007) assume that inconsequential lies imply no costs, because misrepresentation costs are only borne by the winning political candidates, not by the losers.

9 This follows Streb and Torrens (2012). This approach resembles the heterogenous honesty costs in Demichelis and Weibull (2008), though there honesty only enters lexicographically to break ties in material gains.

semiotic process is followed by an inferential step, where the buyer can either believe messages literally, interpreting that "L" refers to L, or instead continue to have beliefs given by the priors that any move is equally likely. There is no salient interpretation if the words are not used in their conventional sense, because there is no way for the buyer to interpret the direction of the bias. Though talk does not affect the utility of the sender directly, Figure 4 shows this is no longer a cheap-talk game.

[Insert Figure 4 Here]

The best responses to message "L" will depend on the buyer's beliefs. If the message is not believed, there are as usual babbling equilibria where the sender's messages are not conditional on the actual location chosen, and the players use mixed strategies where any location is picked with equal probability. In this equilibrium, each player gets an expected payoff of 1/2. Furthermore, once second-guessing is ruled out by the inferential step, there are no informative unnatural language equilibria where words are not used in their ordinary sense. The only informative equilibrium is a *natural language* equilibrium where "L" refers to L and "R" to R, and each player gets a payoff of 1. The buyer will have clear expectations about the seller's move if the message is believed, and will be willing to play the pure strategy singled out by the seller's verbal message.

E. Truthfulness and Belief

Up to now, we have assumed that the meeting place may be communicated by one of two messages. Once we allow any kind of verbal messages, countless informative unnatural language equilibria crop up in cheap-talk games. Moreover, Figures 2, 3 and 4 are artificial in their assumption that, of all the potential moves, the seller will choose in equilibrium between only two meeting places at noon. Schelling's (1960: 55-56) famous example of tacit coordination involves two people who have to meet in an unspecified spot of New York, at an unspecified hour. In many coordination games, the number of meeting times and places are thus unbounded.

Instead of tacit coordination, one might think that talking beforehand over the phone is a much more trivial method of coordination. Think of the message "Meet me at noon at the information booth in Grand Central Station." This is a game of imperfect information, since the receiver does not see the actual move of the sender; however, verbal information about its stated intention is available. The key stumbling block with cheap talk turns out to be that the possible messages, or interpretations, are countless. Farrell (1993: 515) points out that meaning cannot be learned from introspection in cheap-talk models, so any permutation of messages across meanings gives another equilibrium. This double combination, countless times and places, plus unlimited messages for each one, compounds the original problem of tacit coordination discussed by Schelling (1960). Think what would happen if, additionally, the seven digits of the true phone number were randomly scrambled in the newspaper ad, or the ad was not listed in the section on car sales, but rather in a section such as movies playing at the theater. The sheer multiplicity of informative equilibria leaves us where Schelling (1960) left us: focal points. Selection arguments suggest that the only focal point is the informative equilibrium where natural language is used in its literal sense.

Our arguments provide an alternative reason for why the only informative equilibria are those in which language is used in its literal sense, namely, because otherwise the receiver will not be able to decode the message correctly. Consider specifically what happens when N locations are available and the priors are that any location is equally likely.[10] This is a game of imperfect information, though there is another kind of information: verbal information. A simple way of graphically representing how intentions are communicated that captures the gist of the matter is to completely ignore the specific moves and messages. After all, neither party is particularly interested in these details. We thus represent communication in a setup that is stripped down to its bare essentials, concentrating on whether the messages uttered by the seller in a common language are believed by the buyer. In Figure 5, the seller may reveal the truth about the intended meeting place or choose instead a misleading message. Mixed strategies defined over the two pure strategies of being either truthful or misleading allow all intermediate degrees of truthfulness, which range from stating the plain truth to being deceitful; the dividing line between helpful and misleading messages is when the seller says the truth $1/N$th of the time, which implies that messages are uninformative. As for the buyer, the inferential step introduces a restriction to the beliefs that may be entertained, which range from literally believing the seller's

[10] There are N pure-strategy and many mixed-strategy Nash equilibria. We focus on the least informative mixed-strategy Nash equilibrium, but communication makes sense as long as priors are not given by a pure-strategy equilibriium.

message to disregarding it. Mixed strategies allow intermediate degrees of belief, but not beliefs where the message is interpreted to mean something else than its face value when it is considered misleading. This might seem like a lack of imagination, but we interpret it otherwise below.

[Insert Figure 5 Here]

If the buyer expects the seller to say the truth more than $1/N$th of the time, the best response is to believe the message, which implies that the seller will always want to be truthful. When the seller reveals its true intentions, and the buyer believes the message, this can be characterized as an optimistic equilibrium. Optimism is blind, like faith: though the receiver cannot observe the action of the sender, only the utterance, the very fact that the receiver believes the message of the sender makes the sender willing to mean what it says. The semantic content of natural language can be understood as the result of the shared commitment by individuals of using and interpreting words according to accepted social conventions.

On the other hand, the usual babbling equilibria where strategies are not conditional on types are represented here as an equilibrium in mixed strategies where the seller says the truth with probability $1/N$, while the buyer disregards the message.[11] What is novel in our setup is that there are also babbling equilibria where the seller says the truth less than $1/N$ of the time, because the buyer cannot reinterpret the messages beyond what is implied by the priors. All these can be characterized as pessimistic equilibria, that hold once the probability of the sender being truthful is $1/N$ or lower. Both parties will be unable to coordinate a meeting by verbal means alone when shared conventions are not used, destroying the possibility of using talk as a cheap coordination device.

We are analyzing intended actions. If the sender had already chosen a location, it would instead be an incomplete information game where locations would be types that are given from the pre-play game without communication. Though the nature of the incomplete information game is slightly different, it can be represented by Figure 5 if the priors are that

[11] The receiver is just indifferent between disregarding or believing the message. It is not an equilibrium for the receiver to believe the message, because then the sender will always want to say the truth.

any location is equally likely. Natural language also allows selecting Pareto-optimal equilibria in this setup.

IV. The Market for Lemons

Akerlof (1970) introduces a model of asymmetric information where dishonesty may drive legitimate sellers out of business. Another consequence is that language becomes cheap. Though meaningful talk does not lead to disclosure, it may allow ruling out the message "This is a lemon" in equilibrium.

We consider two types of quality, $\theta_i \in \{\theta_L, \theta_H\}$, where $\theta_L < \theta_H$. The quality is known to the seller, but not to the buyer, at purchase time. The opportunity cost of a seller is $\alpha\theta_i$, with $\alpha < 1$, and $\alpha\theta_H > \theta_L$, so market breakdown is possible. Since buyers are willing to pay θ_i for a quality i product and sellers are willing to sell it at $\alpha\theta_i$, there is a potential gain from trade of $(1-\alpha)\theta_i > 0$. The product is high quality with probability $0 < q < 1$ and low quality with probability $1-q$. To abstract from the bargaining problem, we follow standard practice by assuming buyers are risk neutral and willing to pay the average quality offered on the market, $\mathbf{E}[\theta] = (1-q)\theta_L + q\theta_L$. Hence, sellers reap the whole surplus from trade.

The sequence is that the seller states quality, the buyer then makes a price offer, and the seller finally accepts it or not. Given our previous discussion of the coordination game stage, we concentrate on misrepresenting quality.[12] Though the seller can state anything, the minimal messages required are $"\theta_i" \in \{"\theta_L", "\theta_H"\}$, namely that the product is either low or high quality. Buyers can pay any price in the interval $[\theta_L, \theta_H]$, but it suffices to consider the price offers $p_i \in \{\theta_L, \mathbf{E}[\theta], \theta_H\}$, where $\mathbf{E}[\theta]$ corresponds to the priors of the game without communication. High-quality sellers will be willing to accept a price equal to the expected quality if and only if the following condition holds:

$$\mathbf{E}[\theta] > \alpha\theta_H. \tag{3}$$

[12] In the other steps there is no conflict of interest, so we assume people use natural language in the ordinary sense (alternatively, the bid and the sale could be speech acts which are legally binding for the speaker).

If condition (3) is not satisfied, only lemons are left on the market, so there is no point in talking about quality. If condition (3) is satisfied, one can rule out separating cheap-talk equilibria because sellers of lemons always have an incentive to mimic sellers of high-quality products. A babbling equilibrium in pure strategies exists in which all sellers pool on the same message, stating for example that they have a high quality product, "θ_H".[13] Though sellers could also pool on message "θ_L", that does not correspond to our experience with this market. Sellers who want to cheat buyers do not pick the message “This car is a lemon”, but rather “This car is in great shape”. Why?

Once we take into account the process of decoding messages, we can be more specific. When receivers disregard all messages, anything goes, just like in cheap-talk games. Figure 6 depicts instead an optimistic equilibrium where buyers do not doubt the message "θ_L", which is credible because quality is always at least that high (the alternative is to keep the priors that expected quality is $\mathbf{E}[\theta]$, which implies a higher price). If beliefs in response to "θ_L" are θ_L, sellers have an incentive to say "θ_H". The only rational response of buyers is not to believe this message and keep the priors.

[Insert Figure 6 Here]

The only prediction of the model is in fact about what might not be said in equilibrium. What happens with messages other than "θ_L" or "θ_H"? Though they do not correspond to any quality actually on the market, in our formal setup they work just as well as "θ_H". If there were instead a continuum of qualities, sellers would have an incentive to make claims greater than or equal to average quality $\mathbf{E}[\theta]$. In a sense the problem of misrepresentation is simpler in the market for lemons, because there is an incentive to inflate claims, whereas in the coordination stage there is no expected direction for misrepresentation (Kartik, Ottaviani and Squintani 2007 already derive inflated claims with costly talk).

[13] For the proposed message to be part of a perfect Bayesian Nash equilibrium, the reaction to any other announcement has to be a low price, so the conditional probability of high quality products must be smaller than or equal to $(\alpha\theta_H - \theta_L)/(\theta_H - \theta_L)$.

V. Natural Language Equilibria

To formalize the contribution of symbolic information to strategic games, we build on the Crawford and Sobel (1982) framework of strategic information transmission in unilateral communication games, where a sender S transmits a verbal message to a receiver R. Since anything can be said, and it does not directly affect the utility of the sender, talk is cheap in this sense — however, since talk effectively uttered affects the potential payoffs in the game, it is no longer cheap in the standard sense, as Figures 4 and 5 for the pure coordination game show.

Our approach is influenced by Farrell (1993) insight that natural language has a comprehensible meaning, whether or not it is credible. However, Farrell's focus is on refinements of beliefs in response to out-of-equilibrium messages, so he only applies this insight to the interpretation of out-of-equilibrium messages. Furthermore, since Farrell's self-signaling neologisms may refine away all the cheap-talk equilibria, they do not solve the problem of selecting cheap-talk equilibria (Sobel 2011: 11-12).

In the spirit of Farrell (1993), we assume that if a common pre-existing natural language is used, the receiver will be able to understand the different words the sender utters. Our addition in the decoding step is the inverse proposition: if a common language is not used, the receiver will not be able to understand the sender's meaning. We thus divide the epistemic process of communication in two steps: first, an encoding-decoding step where words have a literal meaning; second, an inferential step where the receiver must interpret the equilibrium meaning. Unlike Farrell (1993), and like Myerson (1989), we restrict the interpretation of messages not only out of equilibrium but also in equilibrium.

A. Priors

Before tackling the communication game, we characterize the equilibrium of the game without communication, which is key to define the priors. In incomplete information games, the priors in the game without communication are given exogenously, as is standard. We extend this idea to imperfect information games, where we single out the least-informative Nash equilibrium to determine the priors.

Let the set of possible worlds the receiver might face be given by $\mathbf{W} = \{w_1, \dots, w_W\}$. The possible worlds are the possible types in incomplete information games, $\mathbf{W} = \mathbf{T}$, and the possible moves of the sender in imperfect information games, $\mathbf{W} = \mathbf{A}^S$. The priors $\mathbf{P} = \{p_1, \dots, p_W\}$ are a probability distribution over the possible worlds.

Following the standard approach in the literature, in an incomplete information game the priors $p(w) \in \mathbf{P}$ involve exogenous beliefs about the sender's type, which, in the absence of any new information, determine the optimal response of the receiver in the Bayesian Nash equilibria of the game. In an imperfect information game, the common priors correspond to the strategy σ^S of the sender in the least informative mixed-strategy Nash equilibria of the game (or any one of them, should there be multiple equilibria), and the corresponding strategy σ^R of the receiver in that equilibrium.[14] In our examples there is a unique least informative Nash equilibrium.

B. Epistemic Steps: Comprehension and Belief

The information that natural language conveys is symbolic information. The messages "m" $\in$ "$\mathbf{M}$" can be anything at all. Though players may communicate in terms of precise statements "w" that point to a specific state of the world w, more generally natural language allows talking about different partitions of $\mathbf{W}$, with statements "$\mathbf{S}$" that point to a subset of moves or types $\mathbf{S} \subset \mathbf{W}$. The finest partition identifies individual elements through singleton sets {"m"}. Coarser partitions imply more imprecise statements. Additionally, incomprehensible and irrelevant messages refer to the null set, vacuous messages to the whole set. Consequently, *natural language* is a bijection over the powerset of $\widehat{\mathbf{W}}$**,** $e: \mathbf{P}(\widehat{\mathbf{W}}) \rightarrow$ "$\mathbf{M}$". One direction, "$\mathbf{S}$" $= e(\widehat{\mathbf{S}})$, denotes the encoding step by which the sender describes in words a perceived state of the world (an intended action or type). The other direction, $\widehat{\mathbf{S}} = e^{-1}($"$\mathbf{S}$"$)$, denotes the decoding step by which words are interpreted by the receiver in terms of an actual state of the world.

[14] If there were instead specific priors or ad-hoc information shared by all players, such as Schelling's (1960) focal points, the default equilibrium without communication would instead be something more informative.

ASSUMPTION 1: In the encoding-decoding step, the receiver can recover the literal meaning $\widehat{m}^R = e^{-1}("m^S")$ that is being provided verbally if and only if the sender uses a shared language to utter the symbolic information $"m^S"$.

In the asymmetric information games we consider, the receiver only has the literal meaning of the utterance to act upon. These common understandings are crucial in understanding the whole process, and this is why words can be informative despite the fact that they do not provide direct evidence either of moves or of types. The definitions of truthfulness and belief build on the social conventions shared by the players in their common language. Without these conventions, they can't be defined. While truth and belief are simple to characterize, untruthfulness and disbelief are manifold.

With a two-valued logic, the sender may be either truthful or not. A sender's *truth-function* is a two-valued function T^S: $"\mathbf{M}"\mathrm{x}\mathbf{W} \rightarrow \{\mathbf{0}, \mathbf{1}\}$, where $T^S("m", \mathbf{S}) = 1$ if and only if $"m" = "\mathbf{S}"$, $T^S("m", \mathbf{S}) = 0$ otherwise. There are many ways of being untruthful, but any degree of informativeness is potentially possible if we define mixed strategies over the polar cases of a fully informative and a perfectly misleading message, as in Figure 5 above.

The receiver may either believe the literal meaning of the sender's message or not. A receiver's *belief-function* is a two-valued function B^R: $"\mathbf{M}" \rightarrow \{\mathbf{0}, \mathbf{1}\}$, where $B^R("m") = 1$ if message $"m"$ is believed and $B^R("m") = 0$ if not. As with untruthfulness, there are many ways of not believing something. Mixed strategies can again lead to intermediate degrees of belief when defined on either wholly trusted or distrusted messages. However, we impose a restrictive response in case of disbelief. We limit disbelief to considering a message uninformative, i.e., as informative as the common priors. We thus rule out reinterpretations of the message, like interpreting $"L"$ to refer to R and $"R"$ to L in Figures 2 and 3 above. This leads to the second key element in our conceptualization, the assumption that the following inferential step is satisfied.

ASSUMPTION 2: In the inferential step, the receiver may either believe the message's literal meaning recovered from the decoding step ($B^R("m") = 1$) and update its priors accordingly, or not believe it ($B^R("m") = 0$), ignoring the message and not updating its priors.

The assumption that, when the message is believed, the message is considered informative, and beliefs are updated according to its literal meaning, simply reflects the fact that messages that are believed in equilibrium are so because they are considered truthful.

In case of disbelief, instead of assuming that the receiver considers the message uninformative in regard to the priors, the receiver could alternatively interpret the message to be misleading and assign it an interpretation that differs from what is literally stated. The snag we encounter here is that there is no way for coordinating alternative interpretations of the receiver with different misrepresentations the sender may fabricate, at least no way that goes beyond the common priors of the game before communication. In the market for lemons, for instance, there is a strategic incentive of owners of lemons to inflate their claims, and the priors indeed lead the receiver to interpret that all types of senders will claim “This car is in great shape” regardless of quality. In the pure coordination game, on the other hand, if the message “Meet me at noon at the information booth in Grand Central Station” is not believed, the receiver returns to its diffuse priors that any place and time is equally likely, instead of second-guessing whether this message might instead mean something else, like “Meet me at 9 a.m. in the lobby of the Chrysler Building.” Here there is no strategic incentive for the sender to distort a message in any which way.

Beliefs are thus determined by the receiver's decoding step, coupled with the receiver's inferential step. For example, the buyer will not be able to extract information from incomprehensible messages such as “RTL8029AS”, though an extended zip code with delivery point might work. The same happens with irrelevant information like “April Fool’s day to you”: the buyer has no way of deducing a location from that. If they are in New York, ``Meet me at the north side of the Golden Gate Bridge'' will not help either. To be relevant is maxim 3 of Grice's (1975:45–47) cooperative principle. We get back to Grice's maxims in Section VI, since they can be seen as an optimistic equilibrium of pure coordination games. The following lemma characterizes the consequences of Assumptions 1 and 2.

LEMMA 1: *If a statement "m" is incomprehensible, irrelevant, vacuous, or not believed by the receiver, beliefs are not updated.*

PROOF: *The result for incomprehensible messages follows from the assumption in the decoding step that a message must be understood before the receiver can decide if it* *believes the message or not. Incomprehensible messages do not qualify as symbolic information. As to irrelevant messages, this follows from the assumption in the inferential step by which a message may either be believed literally or disregarded; if the information is not relevant to the choice at hand, the receiver cannot infer anything from it in relation to the set* $\mathbf{W}$. *As to messages that are vacuous, e.g., messages like "I will not reveal anything" or messages that are trivially true because they refer to the whole set* $\mathbf{W}$, *these messages do not add new information whether they are believed or not. The last statement follows directly from the inferential step, since the receiver does not incorporate any new information in case of disbelief.*

Since players are fully rational, our definition of credible messages resembles Myerson's (1989) credibility criterion, where messages have a preexisting meaning, and credible messages must correspond to an equilibrium of the underlying game.

DEFINITION 1: A *credible* message is a comprehensible and relevant message that, if believed by the receiver, is either on the equilibrium path and true, or else off the equilibrium path.

When credible messages are believed in incomplete information games, only the true sender types want to send these messages, while in imperfect information games the sender wants to send the message and choose the corresponding move.[15]

Unlike Farrell (1993), where credible messages are always believed by receivers, here credibility and belief are two distinct concepts.[16] Though credible messages are believable, receivers may believe them or not. There are two polar cases.

DEFINITION 2: An *optimistic* equilibrium is an equilibrium where $B^R(''m'') = 1$ for all credible messages $"m" \in "\mathbf{M}"$ such that $"m" \neq "\mathbf{M}"$.

DEFINITION 3: A *pessimistic* equilibrium is an equilibrium where $B^R("m") = 0$ for all messages $"m" \in "\mathbf{M}"$.

To avoid a vacuous optimistic equilibrium with statements that are perfectly true but add no new information, we consider strict subsets of $"\mathbf{M}"$. The set of optimistic equilibria is

[15] Credible messages on the equilibrium path of imperfect information games identify the most preferred actions of the sender that are part of an equilibrium. Demichelis and Weibull (2008: 1304) call these messages *self-committing*, because the sender has an incentive to carry out the strategy when the receiver believes the respective message.

[16] Demichelis and Weibull (2008: 1305) interpret Farrell (1993) in the sense that credibility is a property of the message and the game in question. The same happens here.

broader than the set of informative equilibria because the messages that are believed by the receiver may be off the equilibrium path. Optimistic equilibria that are uninformative only predict what messages will not be said, as the example from the market for lemons in Section IV. The set of pessimistic equilibria is a subset of the babbling equilibria where all messages, both on and off the equilibrium path, are disregarded, i.e., interpreted in terms of the common priors of the game without communication.

C. Equilibria with Imperfect Information

In a meaningful-talk game with imperfect information, $\mathbf{W} = \mathbf{A}^{\mathrm{S}}$. The sequence is as follows. First, the priors $p(a^S) \in \mathbf{P}$ about the possible moves $a^S \in \mathbf{A}^{\mathrm{S}}$ are given by the least informative, or the default, equilibrium of the game without communication. Second, the sender S sends a message $"m" \in " \mathbf{M}"$. Third, the receiver R updates its priors; unlike standard cheap-talk games, we decompose this into the decoding and inferential steps. Fourth, the receiver picks $a^R \in \mathbf{A}^{\mathrm{R}}$ and the sender picks $a^S \in \mathbf{A}^{\mathrm{S}}$. Finally, $v^l{:}\, \mathbf{W}\mathrm{x}\mathbf{A}^l \rightarrow \boldsymbol{\mathcal{R}}$ is the utility function of player $l = S, R$. Strategies and beliefs are given by $(\omega^S, \sigma^S, \sigma^S, \mu)$, where:

- A strategy for the sender is a vector of probabilities $\sigma^S = (\sigma^S(w_1), \dots, \sigma^S(w_W))$, where for each $w \in \mathbf{W} = \mathbf{A}^S$, $\sigma^S(w) \in [0,1]$ and $\sum_{\mathrm{w} \in \mathbf{W}} \sigma^S(w) = 1$; and a vector of probability distributions $\omega^S = (\omega^S(w_1), \dots, \omega^S(w_W))$, where for each $w \in \mathbf{W}$, $\omega^S(w) = (\omega^S(w)("m_1"), \dots, \omega^S(w)("m_M"))$ is a probability distribution on $"\,\mathbf{M}"$, i.e., $\omega^S(w)("m") \in [0,1]$ and $\sum_{"m" \in "\mathbf{M}"} \omega^S(w)("m") = 1$.
- A strategy for the receiver is a vector of probability distributions $\sigma^R = (\sigma^R("m_1"), \dots, \sigma^R("m_M"))$, where for each $"m" \in "\mathbf{M}"$, $\sigma^R("m") = (\sigma^R("m")(a_1^R), \dots, \sigma^R("m")(a_W^R))$ is a probability distribution on $\mathbf{A}^R$, i.e., $\sigma^R("m")(a^R) \in [0,1]$ and $\sum_{a^R \in \mathbf{A}^R} \sigma^R("m")(a^R) = 1$.
- A belief for the receiver is a vector of probability distributions $\mu = (\mu("m_1"), \dots, \mu("m_M"))$, where for each $"m" \in "\mathbf{M}"$, $\mu("m") = \big(\mu("m")(w_1), \dots, \omega^S("m")(w_W)\big)$ is a probability distribution on $\mathbf{W}$, i.e., $\mu("m")(w) \in [0,1]$ and $\sum_{\mathrm{w} \in \mathbf{W}} \mu("m")(w) = 1$.

Because the equilibria of cheap-talk games are a key building block of the natural language equilibria we subsequently define, we start by defining them. This also helps to clarify our critique of unnatural informative equilibria.

DEFINITION 4: In a cheap-talk game with imperfect information, a perfect Bayesian Nash equilibrium satisfies conditions (1) through (5):

(1) For each $w \in \mathbf{W}$,

$\tilde{\omega}^S(w) = \arg\max_{\omega^S(w)} \sum_{"m"} \omega^S(w)("m") \sum_{a^R} v^S(w, a^R)\tilde{\sigma}^R("m")(a^R)$.

(2) $\tilde{\sigma}^S = \arg\max_{\sigma^S} \sum_w \sigma^S(w) \sum_{"m"} \tilde{\omega}^S(w)("m") \sum_{a^R} v^S(w, a^R)\tilde{\sigma}^R("m")(a^R)$.

(3) For each $"m" \in "\mathbf{M}"$,

$\tilde{\sigma}^R("m") = \arg\max_{\sigma^R("m")} \sum_{a^R} \sigma^R("m")(a^R) \sum_w v^R(w, a^R)\tilde{\mu}(\mathrm{m})(w).$

(4) If for a message $"m" \in "\mathbf{M}"$, there exists a $w \in \mathbf{W}$ such that $\tilde{\omega}^S(w)("m") > 0$, then $\tilde{\mu}(\mathrm{m})(w) = \frac{\tilde{\omega}^S(w)("m")\tilde{\sigma}^S(w)}{\sum_w \tilde{\omega}^S(w)("m")\tilde{\sigma}^S(w)}$.

(5) If for a message $"m" \in "\mathbf{M}"$, $\tilde{\omega}^S(w)("m") = 0$ for all $w \in \mathbf{W}$, then $\tilde{\mu}(\mathrm{m})(w) \in [0,1]$ and $\sum_w \tilde{\mu}(\mathrm{m})(w) = 1$.

To be concrete, consider the unnatural informative cheap-talk equilibrium of the pure coordination game in Figure 2. Each move is associated to an arbitrary equilibrium message, while condition (4) determines beliefs by equilibrium strategies, regardless of how that fact might be communicated from player to player in the actual game. This seems to be a strange way to model beliefs when the only additional information the receiver gets in each information set is the verbal information on meeting place provided by the sender. In our terms, the messages in the unnatural informative equilibria of cheap-talk games are encrypted messages. This would require some meta-message that explains what each message in that equilibrium means. This leads to an infinite regress problem. And what agent sends these meta-messages? This does not seem a reasonable interpretation for one-shot interactions. This anomaly is what motivates our model of natural language. However rational these players may be, they cannot decipher encrypted messages.

Similar comments apply to the unnatural informative equilibrium of the costly talk game in Figure 3. Costly talk does not eliminate unnatural informative equilibria. Consider the following game devised by Aumann (1990), where prudent Alice prefers to play safe and choose d even if she and Bob verbally agreed to play c. In their lexicographic communication game where the two players make their announcements simultaneously, Demichelis and Weibull (2008: 1298) present an equilibrium where both players announce "d" and play c when the other player announces "d". Unlike evolutionary games, we see no way that this convention can be established in our one-shot games. Rather, in the optimistic equilibria where all credible messages are believed, the sender prefers to announce "c". If instead no messages are believed, our fall-back position are the diffuse priors of the mixed-strategy Nash equilibrium where c is played with probability 7/8 and d with probability 1/8, though the default expectations could alternatively be the pure strategy Nash equilibrium (d, d).[17] At any rate, the mechanism for this outcome would be quite different: receivers do not reinterpret the messages in case of disbelief, they disregard them and fall back on their priors.

[Insert Table 3 Here]

We now introduce our notion of equilibrium using meaningful talk. We require it to satisfy Assumptions 1 and 2. If the conditions of Lemma 1 apply, beliefs are not updated. If, instead, these conditions do not apply, we impose the restriction that in equilibrium the receiver may either believe all or none of the credible messages. Otherwise, the epistemic steps of decoding and inference would become entangled with a strategic step by which the receiver could choose to believe what suited its interests best. Equilibrium strategies have to be consistent with beliefs.

DEFINITION 5: In a meaningful-talk game with imperfect information, a *natural language* equilibrium is given by conditions (1) through (5) in a perfect Bayesian Nash equilibrium, as well as the conditions on beliefs that follow:

(6) If "m" is either incomprehensible, or irrelevant, or vacuous, or $B^R("m") = 0$, then $\tilde{\mu}(\mathrm{m})(w) = \frac{p(w)}{\sum_w p(w).}$; if there exists a $w \in \mathbf{W}$ for which $\widetilde{\omega}^S(w)("m") > 0$, then $\widetilde{\omega}^S(w)("m") = \omega$ for all $w \in \mathbf{W}$.

(7) If "m" is is comprehensible, relevant, non-vacuous, and $B^R("m") = 1$ for some "m" $\in$"$\mathbf{M}$", then all such credible messages are believed. For those "m" ="$\mathbf{S}$" such that $B^R("m") = 1$, either $\widetilde{\omega}^S(w)("m") = 1$ for $w \in \mathbf{S}$, $\widetilde{\omega}^S(w)("m") = 0$ for $w \notin \mathbf{S}$, and

[17] If the default pure strategy Nash equilibrium were (c,c), there would be no point in talking.

$\tilde{\mu}(\mathrm{m})(w) = \frac{\tilde{\sigma}^S(w)}{\sum_w \tilde{\sigma}^S(w)}$ for $w \in \mathbf{S}$, $\tilde{\mu}(\mathrm{m})(w) = 0$ for $w \notin \mathbf{S}$; or $\tilde{\omega}^S(w)("m") = 0$ for all $w \in \mathbf{W}$, and $\tilde{\mu}(\mathrm{m})(w) > 0$ for $w \in \mathbf{S}$, $\tilde{\omega}^S(w)("m") = 0$ for $w \notin \mathbf{S}$.

The natural language equilibrium requires that there be conformity between what the receiver literally believes and the underlying equilibrium strategies of the game. In other words, if a given message is believed by the receiver, the strategies must correspond to the equilibrium that potentially matches this credible message, "as if" the required equilibrium constellation is sparked off by verbal communication. A pedestrian way to achieve this, without requiring any imagination on the part of the receiver, would be for the sender to add a reminder about the intended equilibrium that accompanies this message. This relates to the discussion in Myerson (1989), where the sender may promise to do something, or suggest the receiver to do something.[18]

LEMMA 2: *Natural language equilibria always exist in imperfect information games.*

PROOF: *If the receiver disregards all messages, the sender has no incentive to choose a message that is conditional on its move. If the sender sends a message that is not conditional on its move, the receiver has no incentive to heed any message. Hence, an uninformative equilibrium always exists.*

As to the interpretation of the uninformative equilibria, the sender need not actually play strategies that are not conditional on its type, since the receiver has no way of actually verifying that. What is important is that this represents the uncertainty of the receiver about what the sender is actually doing, as in the epistemic interpretation of Aumann and Adam Brandenburger (1995). This makes perfect sense when the message is either incomprehensible, or irrelevant, or vacuous. It might be less intuitive when the message is both relevant (i.e., it refers to an action that actually is possible) and credible. However, meaningful talk by itself is not able to remove the possibility that in equilibrium a credible message might not be taken at face value, but rather interpreted as meaning the priors, as seen in the pessimistic equilibria of the pure coordination game. In this aspect, our formalization resembles standard cheap-talk games where there are always babbling equilibria.

[18] While Myerson (1989) uses natural language as the medium of communication, his setup and equilibrium concepts are quite different. The communication process is more structured since Myerson has in mind a negotiation where there is a mediator between both parties. The presence of a mediator also allows implementing correlated equilibria in situations where unilateral communication between a sender and a receiver lead to babbling equilibria.

If an informative natural language equilibrium, there is a corresponding informative cheap-talk equilibrium because a natural language equilibrium is a perfect Bayesian Nash equilibrium that must satisfy two additional conditions.

THEOREM 1: *If an informative natural language equilibrium exists, the sender has to be better off than in an uninformative equilibrium.*

PROOF: *Suppose not, so the sender is strictly worse off if it reveals its strategy. However, the sender may say whatever it feels like, so it can always choose an uninformative message. By Lemma 1, this message will not lead to an updating of priors. Hence, if the sender decides to be informative, it has to be because it improves its payoffs.*

This is our main result on equilibrium selection. In a setup with costly talk, Demichelis and Weibull (2008:1303-4) point out that unilateral communication tends to lead play toward the Nash equilibrium preferred by the sender. In our setup, this can happen in optimistic equilibria. For instance, in the battle of the sexes the player with proposal powers can propose the pure-strategy equilibrium it prefers when all credible messages are believed. Besides the optimistic equilibrium, there are pessimistic equilibria where the fall-back position are the mixed strategies in the Nash equilibrium of the game without communication where each player picks its preferred strategy 2/3 of the time (either go to a football match or a shopping mall).

[Insert Table 3 Here]

Schelling (1960: 59) gives an early example of how unilateral communication can benefit the sender: one player announces his position and states that his transmitter works, but not his receiver, saying that he will wait where he is until the other arrives. Introducing unilateral communication in imperfect information games leads to a strategic setup similar to the agenda-setter model of Thomas Romer and Howard Rosenthal (1978), where the agenda setter can propose its most preferred alternative, subject to the restriction that the proposal must not be worse than the status-quo for the veto player. However, these proposals are speech acts, not mere talk.

D. Equilibria with Incomplete Information

In a meaningful-talk game with incomplete information, $\mathbf{W} = \mathbf{T}$. The sequence is as follows. First, the priors $p(a^S) \in \mathbf{P}$ about the possible types $t \in \mathbf{T}$ are exogenously given. Second, the sender S sends a message $"m" \in " \mathbf{M}"$. Third, the receiver R updates its priors through the decoding and inferential steps. Fourth, the receiver picks $a^R \in \mathbf{A}^{\mathrm{R}}$. Finally, $v^l\colon \mathbf{W}\mathrm{x}\mathbf{A}^l \rightarrow \boldsymbol{\mathcal{R}}$ is the utility function of player $l = S, R$. Strategies and beliefs are given by $(\omega^S, \sigma^S, \mu)$, where:

- A strategy for the sender is a vector of probability distributions $\omega^S = (\omega^S(w_1), \ldots, \omega^S(w_W))$, as above.
- A strategy for the receiver is a vector of probability distributions $\sigma^R = (\sigma^R("m_1"), \ldots, \sigma^R("m_M"))$, as above.
- A belief for the receiver is a vector of probability distributions $\mu = (\mu("m_1"), \ldots, \mu("m_M"))$, as above.

DEFINITION 6: In a cheap-talk game with incomplete information, a perfect Bayesian Nash equilibrium satisfies conditions (1) through (4):

(1) For each $w \in \mathbf{W}$,

$$\widetilde{\omega}^S(w) = \arg\max_{\omega^S(w)} \sum_{"m"} \omega^S(w)("m") \sum_{a^R} v^S(w, a^R)\tilde{\sigma}^R("m")(a^R) .$$

(2) For each $"m" \in "\mathbf{M}"$,

$$\tilde{\sigma}^R("m") = \arg\max_{\sigma^R("m")} \sum_{a^R} \sigma^R("m")(a^R) \sum_{w} v^R(w, a^R)\tilde{\mu}(\mathrm{m})(w).$$

(3) If for a message $"m" \in "\mathbf{M}"$, there exists a $w \in \mathbf{W}$ such that $\widetilde{\omega}^S(w)("m") > 0$, then $\tilde{\mu}(\mathrm{m})(w) = \frac{\widetilde{\omega}^S(w)("m")p(w)}{\sum_w \widetilde{\omega}^S(w)("m")p(w)}$.

(4) If for a message $"m" \in "\mathbf{M}"$, $\widetilde{\omega}^S(w)("m") = 0$ for all $w \in \mathbf{W}$, then $\tilde{\mu}(\mathrm{m})(w) \in [0,1]$ and $\sum_w \tilde{\mu}(\mathrm{m})(w) = 1$.

DEFINITION 7: In a meaningful-talk game with incomplete information, a *natural language equilibrium* is given by conditions (1) through (4) in a perfect Bayesian Nash equilibrium, as well as the conditions on beliefs that follow:

(6) If "m" is either incomprehensible, or irrelevant, or vacuous, or $B^R("m") = 0$, then $\tilde{\mu}(\mathrm{m})(w) = \frac{p(w)}{\sum_w p(w).}$; if there exists a $w \in \mathbf{W}$ for which $\widetilde{\omega}^S(w)("m") > 0$, then $\widetilde{\omega}^S(w)("m") = \omega$ for all $w \in \mathbf{W}$.

(7) If "m" is is comprehensible, relevant, non-vacuous, and $B^R("m") = 1$ for some "m" $\in$"$\mathbf{M}$", then all such credible messages are believed. For those "m" $=$"$\mathbf{S}$" such that $B^R("m") = 1$, either $\widetilde{\omega}^S(w)("m") = 1$ for $w \in$ **S,** $\widetilde{\omega}^S(w)("m") = 0$ for $w \notin$ **S,** and $\tilde{\mu}(\mathrm{m})(w) = \frac{p(w)}{\sum_w p(w)}$ for $w \in$ **S,** $\tilde{\mu}(\mathrm{m})(w) = 0$ for $w \notin$ **S**; or $\widetilde{\omega}^S(w)("m") = 0$ for all $w \in$ **W,** and $\tilde{\mu}(\mathrm{m})(w) = \frac{p(w)}{\sum_{w \in \mathbf{S}} p(w)}$ for $w \in$ **S,** $\widetilde{\omega}^S(w)("m") = 0$ for $w \notin$ **S.**

We now state results that parallel those for imperfect information games.

LEMMA 3: *Natural language equilibria always exist in incomplete information games.*

PROOF**:** *If the receiver disregards all messages, the sender has no incentive to choose a message that is conditional on its type. If the sender sends a message that is not conditional on its type, the receiver has no incentive to heed the messages. Hence, an uninformative equilibrium always exists.*

If an incomplete information game has an informative natural language equilibrium, a corresponding informative cheap-talk equilibrium exists. We now establish a theorem that parallels Theorem 1. To cover the cases where some sender types might be just indifferent, we would have to add the assumption that these sender types choose not to reveal themselves in case of indifference.

THEOREM 2: *If an informative natural language equilibrium exists, and no senders are indifferent between this and the default equilibrium of the game without communication, some sender type has to be better off than in an uninformative equilibrium.*

PROOF: *Suppose not, so that all types of senders are worse off in the natural language equilibrium if their type is (partially) revealed, in comparison to an uninformative equilibrium. But this implies that no type has an incentive to reveal any information. According to Lemma 1, if no sender reveals any new information, beliefs are given by the priors of the game without communication. Hence, no sender type has an incentive to be informative.*

This theorem implies that informative equilibria must make sense for at least one type of sender.[19] The informative equilibria of some cheap-talk games do not satisfy this criterion, such as Example 2 in Farrell (1993). Even if some sender types are better off, the informative equilibria of some cheap-talk games rely on message that, in our framework, are not credible, for instance the original Crawford and Sobel (1982) model when the expert has a positive bias. With meaningful talk the updating of priors has to be introduced through the communication process that actually takes place, not through out-of-equilibrium beliefs postulated in the perfect Bayesian Nash equilibria of the game. Hence, these informative equilibria require bilateral communication to first incorporate warnings from the receiver (Streb 2013).

VI. Relation to the Philosophy of Language

For Wittgenstein (1953: 21), “The meaning of a word is its use in the language.” In giving the meaning of a word, Wittgenstein (1953: 31) considers that any explanatory generalization should be replaced by a description of its use: “don't think, but look!” (Biletzki and Matar 2009). Hence, Wittgenstein (1953) proposes to study language games. We have shown, at a highly abstract level, that there is no single use; rather, the use (i.e., the equilibrium meaning) varies with the strategic incentives.[20] Words at times are literally true, but at others they must be interpreted in terms of the priors of the game.

In relation to the use of words, Rescorla (2010, Section 7) discusses how in Lewis (1975) the expectation of conformity to a linguistic convention, which gives everyone a good reason to conform, is based on epistemic reasons (beliefs of others). Lewis (1975) says that a language is used by a population if and only if senders are truthful and receivers are trusting most of the time (if not all the time). The requirement in Lewis (1975) seems unduly stringent. It may clarify matters to distinguish (i) understanding a message, which depends on the linguistic conventions shared by the speakers, and (ii) being truthful and believing a message, which depends on the specific equilibrium of each game. While the

[19] To cover the cases where some sender types might be just indifferent, we would have to add the assumption that these sender types choose not to reveal themselves in case of indifference.

[20] Parikh (2010) discusses the equilibrium meaning of language, but he does not embed this within a strategic setup. His concern is about the cost for the sender of being more precise. In this regard, the cost-benefit approach in Sobel (2011: 30-33) seems a fruitful avenue to study the problem of describing and interpreting information.

literal meaning of a word depends on the linguistic conventions, and these also apply in equilibrium when there are no incentives for misrepresentation, these conventions are still present in the background even when that is not the case. Indeed, Rescorla (2011) points out that some conventions are more honored in the breach than in the observance. In the market for lemons, the very fact that in an optimistic equilibrium sellers refrain from saying "This car is a lemon", lest their words be taken at face value, attests to the underlying linguistic conventions in society.

This takes us to Grice's (1975) four maxims on the cooperative principle (Ariel Rubinstein 2000 discusses them in chapter 3). Maxims one (conciseness), two (truthfulness), three (relevance) and four (perspicuity) are not general maxims that hold in all games. Rather, they can be seen as the optimistic equilibrium of a coordination game. The pure coordination game is of course the best-case scenario for successful communication — even so, we have seen communication can fail. A polar case is matching pennies, a zero-sum game: if both players call "heads" or "tails" at the same time, row wins, else column wins (these verbal actions are speech acts, because they commit the players in the bets). Here, verbally communicating intentions beforehand is useless, so Grice's cooperative principle breaks down. Grice (1975: 45) is aware of this, because he explicitly considers talk exchanges in which there is a common purpose, or at least a mutually accepted direction.

An example of the power of imprecision, which goes against Grice's maxim four of perspicuity, appears in the following game where there is a pure-strategy Nash equilibrium, (L, L), and two mixed-strategy Nash equilibria where both players pick either (0, 1/2, 1/2) or (9/11, 1/11, 1/11). In case the messages are not believed, our default is the equilibrium without communication with the most diffuse priors, where the beliefs are that the three strategies are played with probabilities (9/11, 1/11, 1/11). With precise messages $\{"L"\}$, $\{"M"\}$, $\{"R"\}$, only $"L"$ is credible. If we instead consider the partition $\{"L"\}$, $\{"M"$ or $"R"\}$, then both messages are credible. Hence, with imprecision it is possible to reach the Pareto-superior mixed strategy equilibrium where M or R are played with probability 1/2. This, of course, follows the thrust of Crawford and Sobel's (1982) pioneering contribution on the most informative partition achievable for different degrees of bias of the sender. The sender will select the optimal degree of precision.

[Insert Table 4 Here]

Sperber and Wilson (1995: 268) characterize Grice's cooperative principle as a principle of maximal relevance, which they rightly consider will not be satisfied in many situations because the interests of the sender will limit the amount of information it will be willing to reveal. They instead propose a principle of optimal relevance (Sperber and Wilson 1995: 270). This is consistent with our game-theoretic approach to natural language. By Theorems 1 and 2, the sender will only provide relevant information if it is in its interest to do so.

VII. Final Remarks

Our approach strives to close the gap between language in economic theory and daily life. Our aim is, to use Sobel's (2011: 13) words, "to impose restrictions on the use of messages within a game that capture the way that messages are used outside of strategic interactions." We restrict the endogenous meaning in games taking into account the exogenous meaning in society, building on Farrell's (1993: 515) insight that the meaning of natural language, though not always reliable, is certainly comprehensible. We add the inverse proposition, that if a common language is not used in its usual sense, the receiver will not be able to access the sender's personal information.

We couple the decoding step with an inferential step by which the receiver may either believe the literal meaning of the message or disregard it when updating priors. This restriction on beliefs leads to eliminate informative equilibria where expressions have an equilibrium interpretation completely unrelated to their literal meaning. Though our agents might be thought of as having limited rationality, or limited imagination, because they return to the priors in case of disbelief, we think of them instead as fully rational agents who cannot decipher encrypted messages: there is no way the sender and receiver can coordinate on their own on one of these equilibria, at least not through plain language. These unnatural language equilibria are an artifact of our present tools for the game-theoretic representation of communication, not a feature of natural language.

Explicit communication through natural language complements tacit coordination (Schelling 1960) as a way to select equilibria under asymmetric information.[21] Linguistic symbols may provide information despite the fact that they are not moves, if there are credible messages and an informative natural language equilibrium makes the sender better off. The symbolic information provided by the sender requires a leap of faith for the receiver, which leads us to talk of optimistic and pessimistic equilibria. Even in the pure coordination game where players share common interests, so there is an optimistic equilibrium if the receiver believes the sender and the sender is truthful, there are also pessimistic equilibria if the receiver disregards the sender's message and the sender reciprocates by being uninformative. More generally, the equilibrium meaning of words depends on each specific game.

Our approach to verbal communication as a means of equilibrium selection, which is founded on the strategic analysis of cheap-talk models (Crawford and Sobel 1982), is complementary to costly talk models such as Kartik, Ottaviani, and Squintani (2007) and Callander and Wilkie (2007). Misrepresentation costs are an important insight: in the pure coordination game, the minimalist formulation of lexicographic honesty costs in Demichelis and Weibull (2008) suffices to rule out babbling equilibria. However, costly talk by itself may lead to paradoxical results, such as unnatural informative equilibria.

Meaningful talk can be interpreted as a combination of what Barton Lipman (2000) calls the "logical approach", i.e., an approach based on the meaning of a sentence in isolation, and the "equilibrium approach", which takes into account the context and other extra-logical factors as modeled in game theory. Lipman (2000: 118) considers that a model that can combine both approaches, which appear side by side in Rubinstein (2000), would be more plausible, and perhaps more useful. For other disciplines, the fact that language as used in practice depends on the strategic context implies that the interpretation of the uses of language must be done in terms of the equilibrium meaning. For economics, the fact that natural language is a shared social convention which the receiver uses to decode the messages of senders implies that the equilibrium meaning must somehow be derived from the literal meaning.

[21] More broadly, as summarized by Rescorla (2010), equilibrium selection without verbal communication uses either psychological considerations (Schelling 1960), rational reflection (John Harsanyi and Reinhard Selten 1988), or prior experience (Drew Fudenberg and David Levine 1998).

We are just beginning to scratch the surface of verbal communication. Sperber and Wilson (1995: 9-11), for instance, are concerned not only about the semantic representation of a sentence, but also about pragmatic issues like the speaker's attitude to the thought expressed — things like tone of voice to express irony, so the exact opposite of what is being literally being said reflects the speaker's true intention or "propositional attitude". Their approach exceeds the purely symbolic dimension explored here, insofar as it also involves natural signs like body language. Our approach is also more attuned to uses in formal venues. For instance, the message "Come at eight" means one thing in legal and business settings, another in informal settings like a dinner invitation, where it may mean "Come no earlier than 8:30" in San Diego, or "Come at nine" in Buenos Aires.

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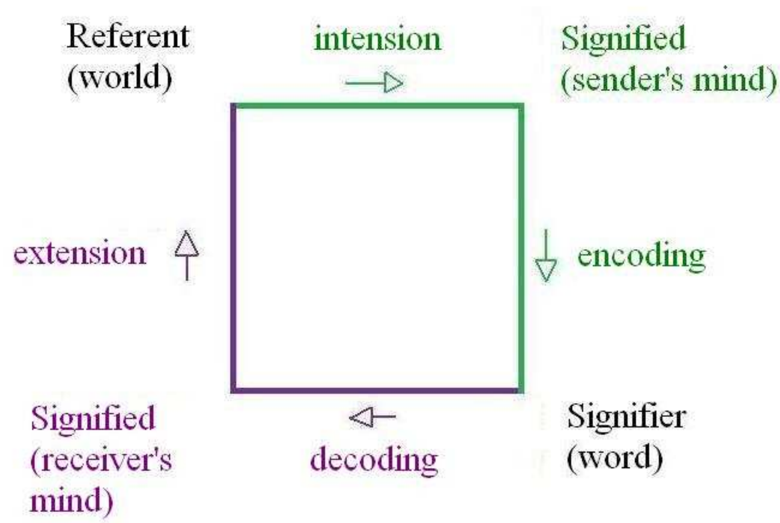

FIGURE 1. ENCODING AND DECODING SEQUENCE IN UNILATERAL COMMUNICATION THE TITLE OF THE FIGURE

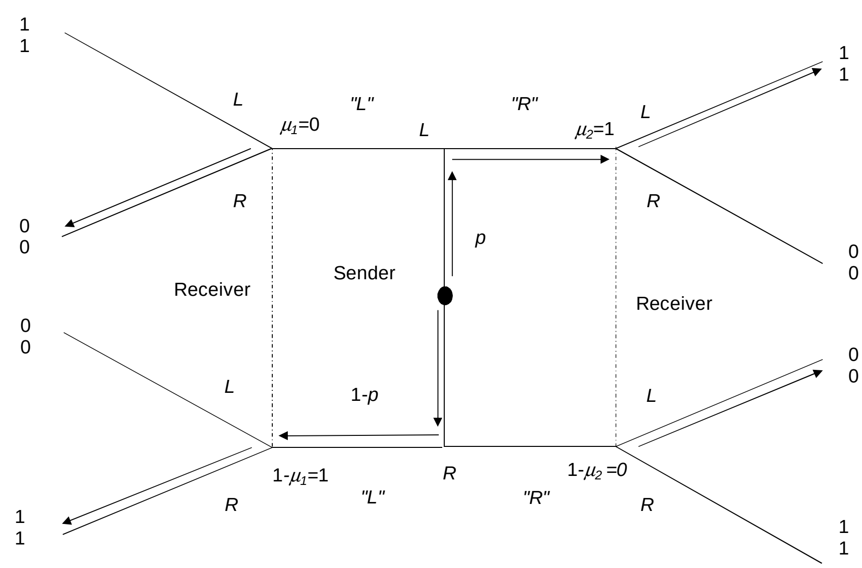

FIGURE 2. CHEAP TALK: UNNATURAL INFORMATIVE EQUILIBRIUM IN PURE COORDINATION GAME

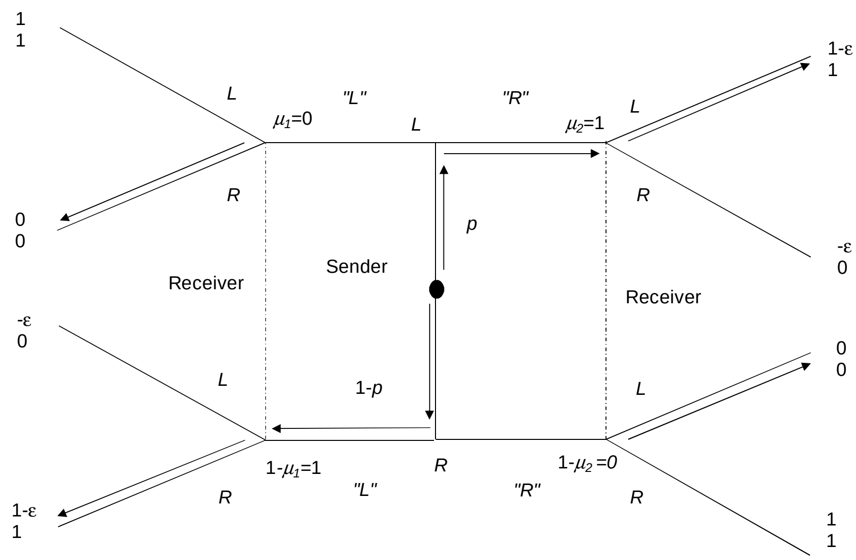

FIGURE 3. COSTLY TALK: UNNATURAL INFORMATIVE EQUILIBRIUM IN PURE COORDINATION GAME

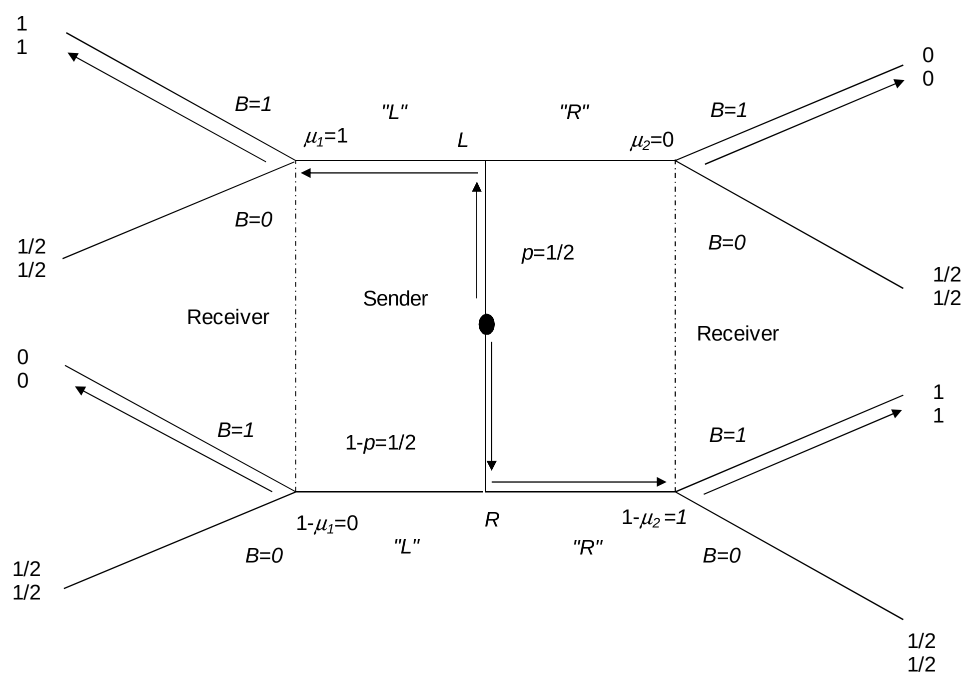

FIGURE 4. MEANINGFUL TALK: INFORMATIVE NATURAL LANGUAGE EQUILIBRIUM IN PURE COORDINATION GAME

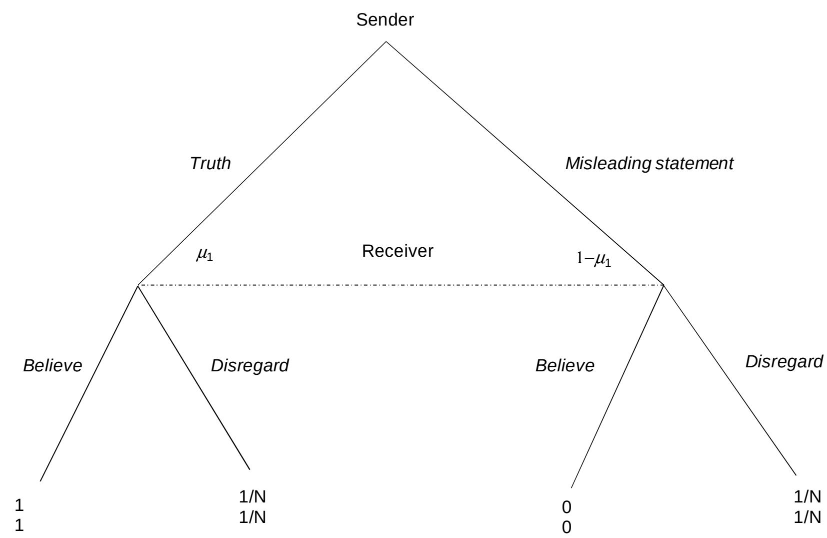

FIGURE 5. MEANINGFUL TALK: COORDINATING UNDER IMPERFECT INFORMATION

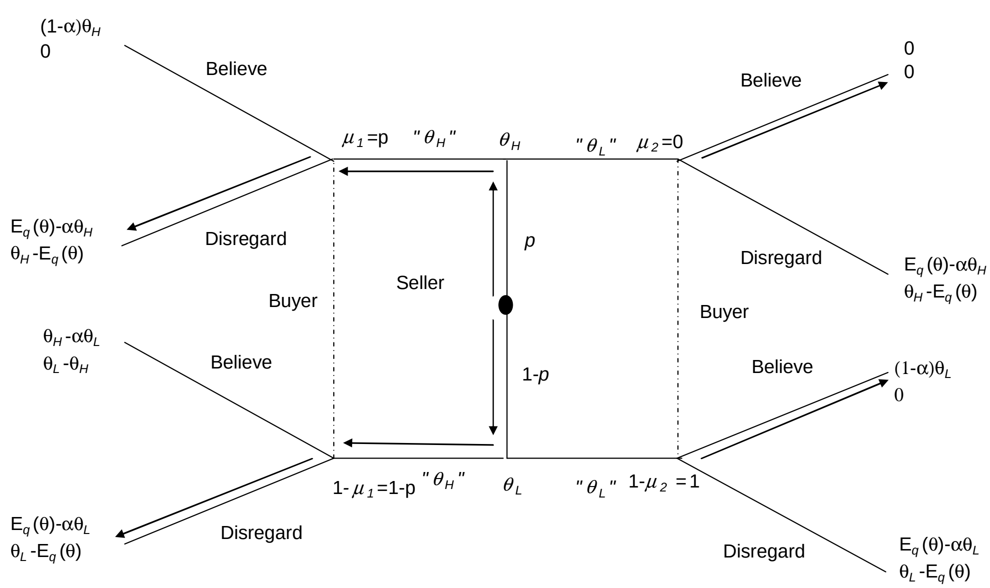

FIGURE 6. THE MARKET FOR LEMONS: PINNING DOWN EQUILIBRIUM MESSAGES

TABLE 1— PURE COORDINATION GAME BETWEEN BUYER AND SELLER

	Left (*L*)	*Right* (*R*)
Left (*L*)	1,1	0,0
Right (*R*)	0,0	1,1

TABLE 2— BOB AND PRUDENT ALICE

	c	*d*
c	9,9	0,8
d	8,0	7,7

TABLE 3— BATTLE OF THE SEXES

	Shopping (*S*)	*Football* (*F*)
Shopping (*S*)	2,1	0,0
Football (*F*)	0,0	1,2

TABLE 4— GAME WHERE AMBIGUITY IS INFORMATIVE

	L	*M*	*R*
L	1,1	0,0	0,0
M	0,0	3,3	0,6
R	0,0	6,0	3,3