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Meaningful Talk

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In cheap- and costly-talk games, an informed player (the sender) sends a verbal message about its type to an uninformed player (the receiver). The use of Nash equilibrium, and its refinements, implies that the assignment of messages to types is what determines the message's interpretation. We propose instead an equilibrium concept where the verbal message itself is the crucial piece of new information in the communication process between sender and receiver, and truth and trust functions are incorporated in the inferential process that takes place in parallel. The sender's message leads the receiver to update priors only if it is comprehensible (i.e., uttered in a language shared by both players), relevant (i.e., more specific than the common priors), and trusted. Trust requires a leap of faith because a verbal message never proves what it states; hence, mistrust equilibria are possible even if an informative equilibrium exists where the sender's message is true. Trust equilibria may be uninformative, in which case linguistic conventions show through what is not stated, e.g., "This car is a lemon." This framework strives to integrate, on the one hand, the game-theoretic view that the equilibrium meaning depends on the sender's strategic incentives, with, on the other, the linguistic view that messages are verbal symbols that convey common understandings through their literal meaning.

JEL classification: D83, C72

Key words: conventional signs, verbal symbols, common understandings, relevance, veracity, trust

> Director [in Japanese to interpreter]: The translation is very important, okay?
>
> Interpreter [in Japanese to the director]: Yes, of course.

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Director [in Japanese to Bob]: You're sitting in your study. There is a bottle of Suntory whiskey on the table. With wholehearted feeling, slowly look at the camera and, as if you were meeting old friends, as Bogie in Casablanca saying "Here's looking at you, kid", say "Suntory time!"

Interpreter [to Bob]: He wants you to turn and look in camera. Okay?

Bob [to interpreter]: That's all he said?

Interpreter [to Bob]: Yes, turn to camera.

From Motoko Rich, "What Else Was Lost in Translation", *New York Times*, September 21, 2003, and Wordreference Forum (http://forum.wordreference.com/showthread.php?t=65052).

1. Introduction

Nash equilibrium and its refinements do not capture the specificity of language games, i.e., games where verbal messages are used to transmit information. We propose an alternative solution concept, sparked by Farrell's (1993: 515) deep insight that though a message in a common language might not be credible, it is certainly comprehensible. Farrell is stating a sufficient condition for verbal communication. We add the inverse proposition: if a common language is not used, the receiver will not be able to understand the sender's meaning. This is a necessary condition for communication. In this connection, Bill Murray's character in *Lost in Translation* illustrates the problems of comprehension in an unfamiliar language (in his case, because the interpreter is an idiot). Without a common language, the speaker cannot verbally communicate meaning, either true or false, because there is no way for the hearer to understand the messages.

To formalize these ideas, we build on Crawford and Sobel (1982), who develop a game-theoretic representation of verbal communication under incomplete information between an informed sender and an uninformed receiver as *cheap talk* where messages are payoff-irrelevant.[1] Their goal is to analyze the maximal amount of information the informed party may offer the uninformed party when there are incentives to misrepresent information. However, cheap-talk models concentrate on beliefs induced in equilibrium, not on the equilibrium messages themselves (Wang 2009). Since equilibrium messages are arbitrary, when there is an informative equilibrium, there are infinitely many.

[1] Cheap-talk models set language apart from other signals: unlike cheap talk, with standard signals choices are differentially costly (Gibbons 1992: 210).

Kartik (2009) points out that with *costly talk* a message has a literal or exogenous meaning because the sender faces misrepresentation costs. This is a step in the right direction, but it does not incorporate the fact that messages also have a literal meaning for the receiver. Hence, the multiplicity of informative equilibria where words are not used in their ordinary sense is not eliminated by costly talk.

Farrell (1993) applies the insight that language has a comprehensible meaning to restrict the interpretation of out-of-equilibrium messages, which leads to *neologism-proof equilibria*. Instead, our approach is closer to Myerson (1989), who applies that insight to restrict the interpretation of equilibrium messages. While talk is the vehicle for information transmission, the setup in Myerson (1989) is more structured than ours because he does not study unilateral communication but rather efficient negotiations with the participation of a mediator. His solution concept, which builds on correlated equilibria (Aumann 1974), is an equilibrium refinement that selects a unique equilibrium. Instead, multiple equilibria are possible in our setup, so credible messages need not be trusted.

Some notion of *meaningful talk* underlies much of the literature. For instance, in Milgrom (1981) the sender can make a verifiable report. Unlike our setup where trust implies a leap of faith for the receiver, a verifiable report is a comprehensible message whose truth value can be verified by the receiver because the sender can reveal its type. Given the priors, types with above average quality will reveal their type, so in the remnant pool the same will happen over and over again until there is full unraveling. This is the unraveling logic of the Akerlof (1970) market for lemons in reverse, when separating signals are available.

The paper is structured as follows. Section 2 uses *rendez-vous*, a coordination game that has played an important role in philosophy of language, to illustrate how there are informative equilibria in cheap- and costly-talk models that ordinary people have no way of understanding. The root of the multiplicity of informative equilibria is the application of *perfect Bayesian equilibrium* (PBE) as solution concept. This leads to an epistemic problem because the literal meaning of messages — the only information actually added through verbal communication — is not taken into account in updating priors. Building on the Farrell (1993) distinction between the comprehensibility and credibility of messages, we go beyond the Nash requirement that actions be mutual best-responses to equilibrium beliefs, requiring additionally that beliefs be determined by the common understandings conveyed by the literal meaning of equilibrium messages, and by whether the receiver trusts them or not. Section 3 defines comprehensible and relevant messages, and introduces truth and trust functions. Section 4 then defines *meaningful-talk equilibrium* (MTE), credible messages, and trust and mistrust equilibria. A proposition establishes the correspondence between PBE and MTE. Section 5 concludes.

2. Making sense of informative equilibria in *rendez-vous*

To illustrate how the use of the PBE solution concept in cheap- and costly-talk games leads to informative equilibria that ordinary receivers would be unable to understand, we introduce verbal communication in *rendez-vous*. This simple coordination game has played an important role in the analysis in philosophy of language since Lewis (1969).

The timing is as follows. The receiver has a prior $p(t)$ that the sender has a type t given by its location. Nature then determines the sender's actual type t. We distinguish between the planes of reality and language through the use/mention distinction between type t and message "t", introducing quotation marks for messages. When verbal communication is possible, this is a unilateral communication game under incomplete information (Crawford and Sobel 1982): the sender S sends a message "t" about its type t to the receiver; the receiver observes the message "t" and selects a move a. If the sender's type and the receiver's move are the same ($a = t$), both players get a payoff $v^i = 1$, $i = S, R$; otherwise ($a \neq t$), they each get $v^i = 0$.

In the illustration we consider two types of sender. In the game without communication, the solution concept is Bayesian Nash equilibrium. The priors $p(t)$ involve exogenous beliefs about the sender's type which determine the optimal response of the receiver. We specifically assume that the receiver has a prior $p(l) = 1/2$ that the sender's type is l, and a prior $p(r) = 1/2$ that is r. In the absence of any new information, an equilibrium is for the receiver to pick a mixed strategy $\sigma = (\frac{1}{2}, \frac{1}{2})$ where both locations are equally likely. The expected payoff is $v^S = v^R = 1/2$.[2]

[2] If $p(l) > 1/2$, the buyer would play l; if $p(l) < 1/2$, r. The crucial issue is that, except when $p(l) = 1$ or $p(l) = 0$, communication can help to improve expected payoffs.

If, instead, communication is possible and talk is payoff-irrelevant for both players, we are in a cheap-talk game (Crawford and Sobel 1982). For full disclosure to be possible, at least two messages are required: let the messages be "l" ("My type is left") and "r" ("My type is right"). 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*.[3] There is an informative equilibrium where words are used in their conventional sense: the sender uses "l" to refer to l and "r" to r, and the expected payoffs for both players are $v^S = v^R = 1$. This can be called the *natural* informative equilibrium. Figure 1 represents instead an *unnatural* informative equilibrium where words are used in a way opposite to their literal meaning: the receiver plays l after message "r" and r after message "l".

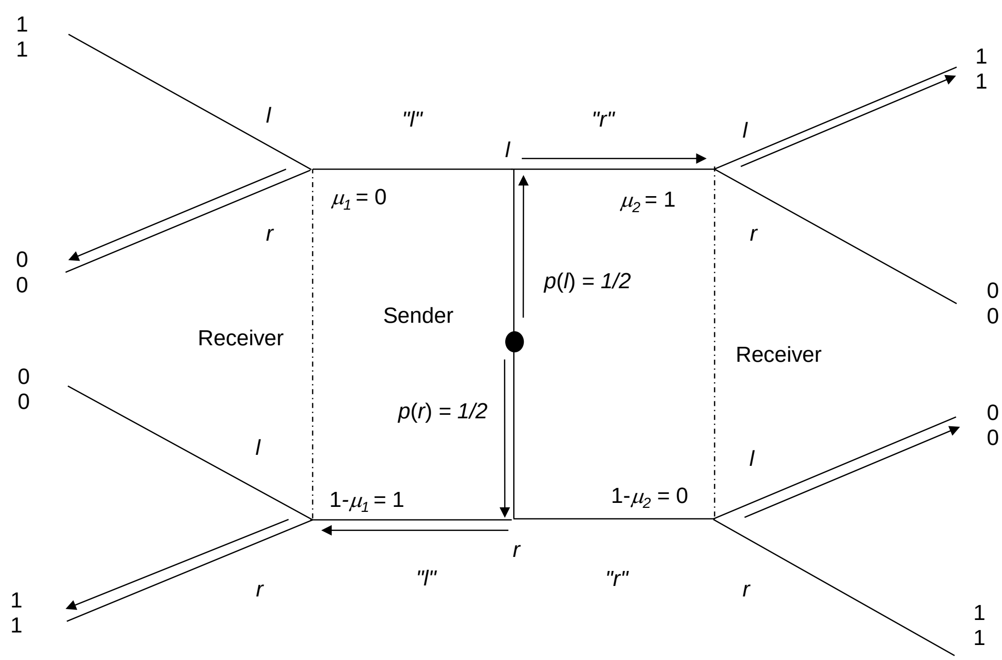

FIGURE 1. CHEAP TALK: UNNATURAL INFORMATIVE EQUILIBRIUM IN *RENDEZ-VOUS*

[3] There are always uninformative equilibria in which the sender's message is not conditional on type, so the receiver ignores it and sticks to the priors.

This feature of cheap-talk games is well-known in the literature. Perhaps less familiar, the same problem crops up in costly-talk games where there is a cost of misrepresentation if message "m" differs from true type m, a nice idea formalized by Kartik, Ottaviani, and Squintani (2007), as well as by Callander and Wilkie (2007) in the specific context of political campaigns. We take these misrepresentation costs to be given by an infinitesimal cost $\varepsilon > 0$.[4] Figure 2 shows that costly talk does not destroy the unnatural informative equilibrium of Figure 1: if the sender deviates from the equilibrium message, its payoff would fall from $1 - \varepsilon$ to 0. Hence, costs of misrepresentation alone are not enough to do away with the excess of informative equilibria.[5]

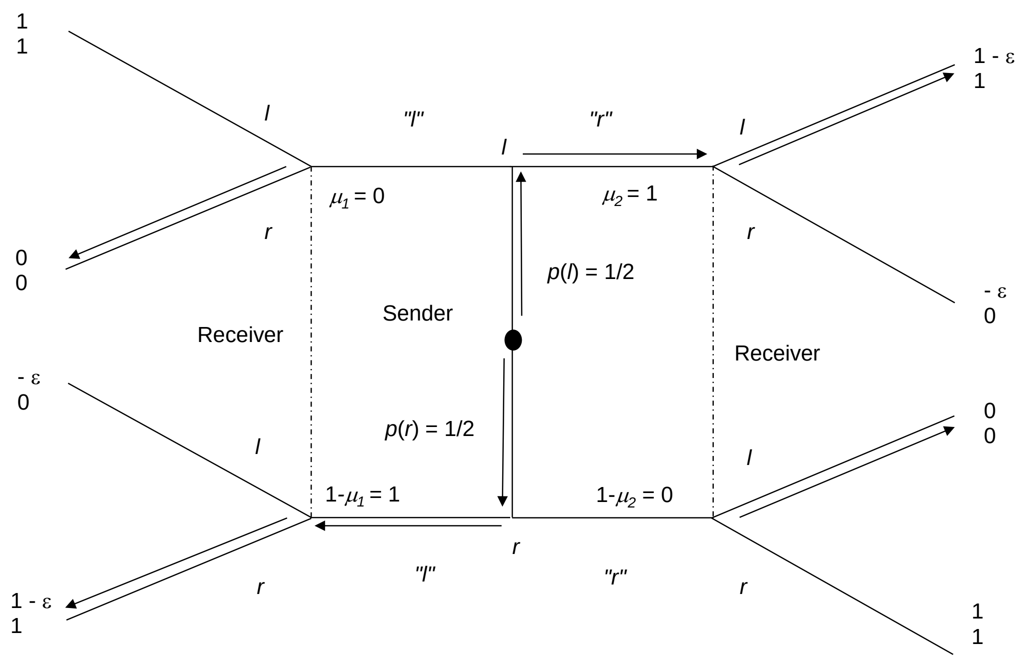

FIGURE 2. COSTLY TALK: UNNATURAL INFORMATIVE EQUILIBRIUM IN *RENDEZ-VOUS*

[4] Demichelis and Weibull (2008) have a minimalist formulation where misrepresentation costs enter lexicographically to break ties in material gains. Misrepresentation costs may arise because lying is shameful, or simply because making something up about the actual type requires an effort.

[5] Costs of misrepresentation do eliminate babbling equilibria in *rendez-vous*: if receivers ignore all messages "t", a seller would rather reveal its true type t because it is the lowest cost message; given that, buyers have an incentive to heed the messages.

More generally, the key stumbling block with existing models of verbal communication turns out to be that the possible equilibrium messages are unbounded. Once we allow any kind of verbal message, infinite informative equilibria where words are not used in their ordinary sense crop up. As Farrell (1993: 515) points out, since meaning cannot be learned from introspection in cheap-talk models, any permutation of messages across meanings gives another informative equilibrium. The same may happen in costly-talk models.

The sheer multiplicity of informative equilibria leaves us where Schelling (1960) left us: focal points. Schelling's selection arguments applied to explicit communication suggest that the only focal point is the natural informative equilibrium where words are used in their literal sense. We now explore an alternative explanation that eliminates unnatural informative equilibria like those in Figures 1 and 2.

3. A strategic model of verbal communication

The messages we consider are not isolated words but rather full sentences that express propositions. Messages cannot be automatically taken at face value because the strategic incentives in each game must be accounted for.

3.1. Messages as verbal symbols

A basic distinction in semiotics, which appears in John Poinsot's 1632 *Treatise on Signs*, is between *conventional signs* or *symbols*, like the phrase "Fire!" or an image of a flame, and *natural signs*, like smoke (Crespo 2012). Signs typically point to something else.[6] Signs are composed of three elements (Chandler 1994).[7] In the specific case of *verbal symbols*, these components are:

(i) The *signifier* (*sign vehicle*): a sequence of letters or sounds "m", e.g., "This car is in great shape."[8]

(ii) The *signified* (*sense, intension*): the concept $\hat{m}$ we think about when we read or hear the signifier.

[6] Self-reference plays no role in the games we analyze. Besides, it can lead to contradictions like the semantic paradox "This sentence is not true."

[7] In Ferdinand de Saussure signs are composed of signifier and signified, while Charles S. Peirce is closer to the modern representation since he also includes a referent (Chandler 1994).

[8] Though the signifier is only part of the whole, it is customary to also call it sign.

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

Following the standard practice in economics, instead of signifier "m" we employ the term *message* "m". The signified $\hat{m}$ is the literal meaning, or more generally the common understandings it conveys, something which depends on the specific linguistic and social conventions. Below we introduce the equilibrium meaning, which is contingent on the use of messages in each specific language game. In regard to the referent m, besides the truth-value of the proposition, we consider the actual type to which the proposition allegedly points.

Since messages can be seen as linguistic conventions, they have two sides: on the one hand an arbitrary (or artificial) character, on the other an ordinary (or natural) character (Rescorla 2015).[9] The arbitrary character of linguistic conventions explains the potential indetermination of equilibrium messages: the conventional expression for indicating left is “gauche” in French, “sinistra” in Italian, “izquierda” in Spanish, etc. The arbitrary character of language is analyzed by Lewis (1969) in his classic work on conventions. This resurfaces in cheap- and costly-talk models as a potentially infinite number of equilibrium messages.

However, what we are trying to answer is not how linguistic conventions develop, but rather how a society uses a shared, pre-existing, natural language to communicate. Hence, we have to look at the other side of conventions, their ordinary character. Kartik (2009) recognizes that costly talk introduces some standard or norm for saying things, so a message like "l", “my type is left”, has a literal or exogenous meaning (otherwise, senders would not be able to experience a cost of misrepresentation). Our model extends the idea of norms to receivers because messages embody a literal meaning that constitutes a source of information. In Myerson (1989: 265), messages already have a literal meaning for all players because they share a common language like English. Indeed, the most basic feature of language is that we are brought up with a shared social convention that applies both to senders and receivers: for young children, language is simply their mother tongue.

[9] The idea of language as a social convention, i.e., as something both natural and artificial, harks back to Plato, Aristotle, and Hume, while Lewis (1975) constitutes the standard modern reference (Rescorla 2015).

3.2. Language games

Inspired by the distinction in Farrell (1993) between comprehensibility and credibility of messages, we look at verbal communication as a two-sided process, an encoding-decoding process in which the verbal message is transmitted, and an inferential process where the message is interpreted.

Encoding-decoding process: comprehensible and relevant messages

In the encoding-decoding process, the first issue is comprehensibility. In the spirit of Farrell (1993), we assume that if a common language is used, the receiver will be able to understand the different words the sender utters. We add the inverse proposition: if a common language is not used, the receiver will not be able to understand the sender.

In this process, the signified $\widehat{m}$ is the *literal* meaning. The literal meaning is crucial in asymmetric information games: since the referent is unobservable from the receiver's vantage point, the receiver must use the literal meaning to ascertain the type. More formally, in the encoding stage, the sender S uses the message "m" to express the literal meaning $\widehat{m}$. In the decoding stage, the receiver R uses the message "m" to recover the literal meaning $\widehat{m}$. Since thoughts are interior processes, only the message is manifest:

(1) $$"m" = e(\widehat{m}),$$

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

We focus on symbolic information, abstracting from body language like tone of voice. We assume that "m", the message uttered by the sender, coincides with the message heard by the receiver (i.e., there is no noise in the communication). We also rule out errors of perception. The question we analyze is whether the sender has incentives to willfully distort information so the message "m" it utters differs from its actual type w.

A *language* "$\mathbb{M}$" shared by the players allows talking about different partitions of the world at large $\mathbb{W}$, with statements "Q" that point to a subset $\mathrm{Q} \subset \mathbb{W}$. The finest partition identifies individual elements through singleton sets. Coarser partitions imply more imprecise statements. We characterize a common language as a bijection over the powerset of $\widehat{\mathbb{W}}$, $e\colon \mathrm{P}(\widehat{\mathbb{W}}) \to "\mathbb{M}"$. One direction, $"\mathrm{Q}" = e(\widehat{\mathrm{Q}})$, denotes the encoding step by which the sender describes in words a perceived state of the world (a subset of types in our case). The other direction, $\widehat{\mathrm{Q}} = e^{-1}("\mathrm{Q}")$, denotes the decoding step by which words are interpreted by the receiver in terms of an actual state of the world.

The standard assumption in linguistics is that the receiver can understand the literal meaning of a message $"m"$ uttered by the sender if, and only if, $"m"$ belongs to a common language $"\mathbb{M}"$. Jakobson and Halle (1956: 72), for instance, state that "the efficiency of a speech event demands the use of a common code by its participants." Sperber and Wilson (1995: 43) point out that communication is an asymmetric process where "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." Since actual messages $"m"$ can be any verbal symbol at all, *comprehensible* messages are given by $"m" \in "\mathbb{M}"$, *incomprehensible* messages by $"m" \notin "\mathbb{M}"$.

Let the set of types in a game be a finite subset $\mathrm{W} \subset \mathbb{W}$, which can be described with a subset of messages $"\mathrm{M}" \sqsubset "\mathbb{M}"$. Comprehensible messages are either *relevant*, if they refer to a strict, non-empty, subset Q of W, or *irrelevant*, if they refer to a set Q such that either $\mathrm{Q} \cap \mathrm{W} = \emptyset$ or $\mathrm{Q} \cap \mathrm{W} = \mathrm{W}$. Irrelevant messages do not add information to the priors, so beliefs cannot be updated from the literal information they provide.[10]

The literal meaning as the semantic representation of a sentence may be more attuned to formal venues. For instance, the message "Come at eight," means one thing in legal, business, and academic settings, another in informal settings like a dinner invitation. As a dinner invitation, it may mean "Come no earlier than eight thirty" in San Diego or "Come at nine" in Buenos Aires; in Brasilia, a political scientist tells his American and Canadian friends to come at nine, and his Brazilian friends at seven thirty, when he wants them to show up more or less at the same time. Hence, *literal meaning* can be replaced more generally by *common understandings* to allow for interpretations that are group-specific.

Inferential process: truthful and trusted messages

[10] Keynes (1921: 59) defines irrelevance in terms of new evidence that does not lead to changing a conclusion. Sperber and Wilson (1995) define an input as relevant when, together with available contextual assumptions, it yields positive cognitive effects.

What inferences the receiver may draw from comprehensible and relevant messages will depend on the equilibrium of the game. We introduce the truth and trust functions here and discuss the equilibrium concept and credibility in the next section.

Truthfulness and trust cannot be defined without the social conventions shared by the players in their common language. To determine whether the statement implied by the message is true or not, the referent must also be taken into account.[11] With a two-valued logic, the sender may be either truthful or not. A sender's *veracity-function* (or, equivalently, *truth-function*) specifies whether a message is veracious (truthful). It is a function V^S: "M"xW → {0,1}, where for type $w \in$ W, $V^S("m", w) = 1$ if and only if $w \in$ Q when $"m" =$ "Q", otherwise $V^S("m", w) = 0$. Imprecise messages are less informative than precise messages, but they can be truthful. A receiver's *trust-function* is a function T^R: "M" → {0,1}, where $T^R("m") = 1$ if message $"m"$ is trusted, i.e., interpreted according to its literal meaning, and $T^R("m") = 0$ if not.

There are many ways of being untruthful. Any degree of truthfulness is potentially possible if we define mixed strategies over truthful and perfectly misleading messages. The same holds for trust. We address these issues when we characterize equilibrium.

4. Solution concepts

A definition of PBE that underlies cheap-talk games is first presented. An alternative solution concept in then introduced, meaningful-talk equilibrium (MTE), and its correspondence with PBE is established.

4.1. The standard solution concept for language games

In a cheap-talk games with incomplete information, the sequence is as follows. The sender type $w_i \in$ W and the priors $p(w) = (p(w_1), \dots, p(w_I)) \in$ P about the possible types $w = (w_1, \dots, w_I)$ are exogenously given. The sender S observes its type w_i and sends a message $"m_j" \in$ "M". The receiver R observes "m_j", but not w_i, forming beliefs $\mu("m_j")$ and picking an action $a_k \in$ A in response. Payoffs are given by $v^S(w_i, a_k)$ and $v^R(w_i, a_k)$.

Strategies and beliefs $(\sigma^S(w), \sigma^R("m"), \mu("m"))$ are as follows:

[11] This is the standard point of view of Peirce, Frege, and other logicians.

- $\sigma^S(w) = (\sigma^S(w_1), \dots, \sigma^S(w_I))$, a strategy for the sender, is an I-tuple of probability distributions $\sigma^S(w_i) = (\sigma^S(w_i)(\text{"m}_1\text{"}), \dots, \sigma^S(w_i)(\text{"m}_J\text{"}))$ for $i = 1, \dots, I$, where $\sigma^S(w_i)(\text{"}m_j\text{"}) \in [0,1]$ and $\sum_{\text{"}m_j\text{"}\in\text{"M"}} \sigma^S(w_i)(\text{"}m_j\text{"}) = 1$;
- $\sigma^R(\text{"}m\text{"}) = (\sigma^R(\text{"m}_1\text{"}), \dots, \sigma^R(\text{"m}_J\text{"}))$, a strategy for the receiver, is a J-tuple of probability distributions $\sigma^R(\text{"}m_j\text{"}) = (\sigma^R(\text{"}m_j\text{"})(a_1), \dots, \sigma^R(\text{"}m_j\text{"})(a_K))$ for $j = 1, \dots, J$, where $\sigma^R(\text{"}m_j\text{"})(a_k) \in [0,1]$ and $\sum_{a_k\in \text{A}^R} \sigma^R(\text{"}m_j\text{"})(a_k) = 1$;
- $\mu = (\mu(\text{"m}_1\text{"}), \dots, \mu(\text{"m}_J\text{"}))$, a belief for the receiver, is a J-tuple of probability distributions $\mu(\text{"m}_j\text{"}) = \left(\mu(\text{"m}_j\text{"})(w_1), \dots, \mu(\text{"m}_j\text{"})(w_I)\right)$ for $j = 1, \dots, J$, where $\mu(\text{"m}_j\text{"})(w_i) \in [0,1]$ and $\sum_{w_i\in \text{W}} \mu(\text{"m}_j\text{"})(w_i) = 1$.

The sets W and A^R are finite. Though the set of messages "M" need not be finite, we assume "M" = "P(W)" because the powerset of W is sufficiently rich to convey all the relevant messages that are possible in the game. It includes the true but irrelevant message "I won't tell my type" which points to the whole set W. Incomprehensible messages $\text{"}Q\text{"} \notin \text{"}\mathbb{M}\text{"}$ and irrelevant messages $\text{"}Q\text{"} \in \text{"}\mathbb{M}\text{"}$ such that $\text{Q}\cap\text{W}=\emptyset$ are informationally equivalent to $\text{"}Q\text{"}=\text{"W"}$ so we abstract from them.

First, a standard equilibrium is defined in terms of the optimal message strategies for the different sender types, the optimal responses of the receivers to these messages, and the specification of beliefs on and off the equilibrium path. Specifically,

DEFINITION 1: *Perfect Bayesian equilibrium* (PBE). In an incomplete information sender-receiver game, a PBE is given by strategies and beliefs $(\tilde{\sigma}^S(w), \tilde{\sigma}^R(\text{"}m\text{"}), \tilde{\mu}(\text{"}m\text{"}))$ that satisfy conditions (1) through (4):

(1) For each $w_i \in \text{W}$,

$$\tilde{\sigma}^S(w_i) = \arg\max_{\sigma^S(w_i)} \sum_{\text{"}m_j\text{"}} \sigma^S(w_i)(\text{"}m_j\text{"}) \sum_{a^R} \tilde{\sigma}^R(\text{"}m_j\text{"})(a_k)\, v^S(w_i, a_k).$$

(2) For each $\text{"}m_j\text{"} \in \text{"M"}$,

$$\tilde{\sigma}^R(\text{"}m_j\text{"}) = \arg\max_{\sigma^R(\text{"}m_j\text{"})} \sum_{a_k} \sigma^R(\text{"}m_j\text{"})(a_k) \sum_{w_i} \tilde{\mu}(\text{"}m_j\text{"})(w_i)\, v^R(w_i, a_k).$$

(3) If for a message $\text{"}m_j\text{"} \in \text{"M"}$, there exists $w_i \in \text{W}$ such that $\tilde{\sigma}^S(w_i)(\text{"}m_j\text{"}) > 0$, then $\tilde{\mu}(\text{"}m_j\text{"})(w_i) = \frac{\tilde{\sigma}^S(w_i)(\text{"}m_j\text{"})p(w_i)}{\sum_{w_i} \tilde{\sigma}^S(w_i)(\text{"}m_j\text{"})p(w_i)}$.

(4) If for a message $"m_j" \in$ "M", $\tilde{\omega}^S(w_i)("m_j") = 0$ for all $w_i \in$ W, then $\tilde{\mu}("m_j")(w_i) \in$ [0,1] and $\sum_{w_i} \tilde{\mu}("m_j")(w_i) = 1$.

This definition helps to clarify our critique of the multiplicity of informative equilibria in cheap- and costly-talk games. Consider the unnatural informative equilibrium of *rendez-vous* in Figure 1. Condition (3) determines beliefs by equilibrium strategies, regardless of how that fact might be communicated from sender to receiver by the actual message $"m_j"$. This is an odd way to model beliefs when the only additional information the receiver gets in each information set is the verbal information $"m_j"$ on the location provided by the sender. This problem is not specific to cheap-talk models, as the unnatural informative equilibrium of the costly talk game in Figure 2 shows. Rather, what is problematic is the application of the PBE concept to signaling in language games without considering how receivers can infer the equilibrium meaning if the sender's message does not stick to the ordinary conventions in the common language. We now introduce an alternative notion of equilibrium.

4.2. An alternative equilibrium concept for language games

We combine the Crawford and Sobel (1982) framework of strategic information transmission with the feature that players rely on a preexisting language that they share. Equilibrium beliefs are not determined by the actual strategies of the sender. Instead, beliefs are determined by the literal meaning of message that is uttered and whether it is trusted or not. However, the actual strategies chosen by the sender are crucial to determine whether this is an equilibrium or not, i.e., if trusting a message is indeed warranted for the receiver.

DEFINITION 2: *Meaningful-talk equilibrium* (MTE). In an incomplete information sender-receiver game, a MTE is given by strategies, beliefs, truth- and trust-functions $(\tilde{\sigma}^S(w), \tilde{\sigma}^R("m"), \tilde{\mu}("m"), V^S("m", w), T^R("m"))$ that satisfy conditions (1) through (4):

(1) For each $w_i \in$ W,

$$\tilde{\sigma}^S(w_i) = \arg\max_{\sigma^S(w_i)} \sum_{"m_j"} \sigma^S(w_i)("m_j") \sum_{a^R} \tilde{\sigma}^R("m_j")(a_k)\, v^S(w_i, a_k).$$

(2) For each $"m_j" \in$ "M",

$$\tilde{\sigma}^R(\text{"}m_j\text{"}) = \arg\max_{\sigma^R(\text{"}m_j\text{"})} \sum\nolimits_{a_k} \sigma^R(\text{"}m_j\text{"})(a_k) \sum\nolimits_{w_i} \tilde{\mu}(\text{"}m_j\text{"})(w_i)\, v^R(w_i, a_k).$$

(3) If, for message $\text{"}m_j\text{"}=\text{"Q"}\in\text{"M"}$, there exists $w_i \in$ W such that $\tilde{\omega}^S(w_i)(\text{"}m_j\text{"}) > 0$:

(i) $\tilde{\mu}(\text{"}m_j\text{"})(w_i) = \frac{\tilde{\sigma}^S(w_i)(\text{"}m_j\text{"})p(w_i)}{\sum_{w_i}\tilde{\sigma}^S(w_i)(\text{"}m_j\text{"})p(w_i)}$ if $\text{"}Q\text{"}\neq\text{"W"}$, $T^R(\text{"Q"}) = 1$, and $V^S(\text{"Q"}, w_i) = 1$ (i.e., $\tilde{\sigma}^S(w_i)(\text{"Q"}) > 0$ for $w_i \in$ Q, $\tilde{\sigma}^S(w_i)(\text{"Q"}) = 0$ for $w_i \notin$ Q).

(ii) Otherwise $\tilde{\mu}(\text{"}m_j\text{"})(w_i) = \frac{p(w_i)}{\sum_{w_i} p(w_i)}$, and a switch from $T^R(\text{"Q"}) = 0$ to $T^R(\text{"Q"}) = 1$ must not improve the receiver's payoffs.

(4) If for a message $\text{"}m_j\text{"} = \text{"Q"}\in\text{"M"}$, $\tilde{\omega}^S(w)(\text{"}m_j\text{"}) = 0$ for all $w_i \in$ W:

(i) $\tilde{\mu}(\text{"}m_j\text{"})(w_i) = \frac{I(w_i)p(w_i)}{\sum_{w_i} I(w_i)p(w_i)}$, where $I(w_i) = 1$ for $w_i \in$ Q, $I(w_i) = 0$ for $w_i \notin$ Q, if $\text{"}Q\text{"}\neq\text{"W"}$ and $T^R(\text{"Q"}) = 1$.

(ii) Otherwise $\tilde{\mu}(\text{"}m_j\text{"})(w_i) \in [0,1]$ and $\sum_{w_i} \tilde{\mu}(\text{"}m_j\text{"})(w_i) = 1$.

If $\tilde{\sigma}^S(w_i)(\text{"Q"}) = 1$ for all $w_i \in$ Q in condition (3)(i), the sender is playing pure strategies; additionaly, if each type sends a different message, the equilibrium messages partition the set of types into mutually exclusive and collectively exhaustive singleton subsets. If instead $0 < \tilde{\sigma}^S(w_i)(\text{"Q"}) < 1$ for some $w_i \in$ Q, the sender plays mixed strategies so the sets are exhaustive but they are not mutually exclusive.

Conditions (1) and (2) are the same as in a PBE: that strategies be optimal given beliefs. The novelty has to do with how beliefs are formed. Condition (4)(ii) states that out-of-equilibrium beliefs are not restricted, just as in a PBE, unless (4)(i) out-of-equilibrium messages are trusted (and relevant). On the other hand, condition (3) requires that (i) equilibrium beliefs be determined by Bayes rule if messages are trusted and true, otherwise (ii) the receiver falls back on the priors of the game without communication, and payoffs cannot increase if the receiver switches from not trusting the equilibrium messages to trusting them. This implies that on the equilibrium path the receiver either trusts a message's literal meaning from the encoding-decoding process and uses it to update the priors, or disregards it and the interpretation of the message is context-dependent, hinging on the priors of the game. This isolates the literal meaning (or, more generally, the common understandings it conveys) as the vehicle for information transmission. Since incomprehensible and irrelevant messages can be treated as informationally equivalent to"Q"="W", they add nothing to the priors.

4.3. Credibility

Trust depends on a message being credible (or trustworthy).

DEFINITION 3: *Credibility*. A message "m"∈"M" is *credible* if there is an equilibrium of the game where a message is either on the equilibrium path and true, or off the equilibrium path when trusted.

In other words, a message is *credible* if there is an equilibrium where the literal meaning is the equilibrium meaning. This differs from the notions of credibility in Myerson (1989) and Farrell (1993) we now review, which are not a characterization of equilibrium messages but rather equilibrium refinements (also see Franke 2009: 41).

Our characterization of credibility closely resembles Myerson (1989) where credible messages are equilibrium messages for which the literal and effective meanings coincide. However, the solution concept in Myerson (1989) builds on correlated equilibria (Aumann 1974) and is an equilibrium refinement that selects a unique equilibrium. Hence, credible messages are always trusted. Instead, in our framework there are multiple equilibria, so credibility and trust are two distinct concepts, and credible messages need not be trusted.

Farrell (1993) does not apply his insights about credibility to pin down the interpretation of equilibrium messages, he applies them to restrict the interpretation of out-of-equilibrium messages. Farrell (1993: 519-520) compares the difference between a prearranged set of meanings for anticipated messages and a preexisting natural language as the difference between encrypted codes and ciphers. With *encrypted codes*, a list of meanings is fixed in advance and cryptic messages are chosen to convey those meanings, such as one light for “by land”, two for “by sea" used during the American Revolution to alert if the Redcoats were coming. In a *cipher*, messages are instead cryptically isomorphic to a natural language, so unanticipated messages such as “The redcoats are coming in balloons” can be added. These unanticipated out-of-equilibrium messages are interpreted as *meaningful neologisms*. For Farrell (1993), neologisms are credible if they are *self-signaling*, i.e., if the types $w_i \in \mathrm{Q}$ that deviate from a given equilibrium are the only ones that actually prefer the receiver to believe instead the message "Q" that their type is in Q. Demichelis and Weibull

(2008: 1305) interpret Farrell (1993) in the sense that credibility is a property of the message and the game in question. That also holds with meaningful talk, but in equilibrium, not out of equilibrium.

In Farrell (1993) credible messages are always trusted by receivers (his *self-signaling neologisms*), whereas in MTE credible messages might not be trusted. A further difference has to do with existence of equilibrium. The Farrell (1993) *neologism-proof equilibrium* may refine away all the cheap-talk equilibria so no equilibrium exists (Sobel 2011: 11-12). On the other hand, it is trivial to establish that MTE exist because babbling equilibria always exist (see next subsection). Finally, a major difference has to do with the assumption in Farrell (1993) that a meaningful neologism is always available for senders to declare their type. That does not happen with MTE. This is a key reason for the non-existence of neologism-proof equilibria. Take Example 3 in Farrell (1993), where the receiver has optimal strategies $a(A)$ and $a(B)$ for sender types A and B, but prefers to choose a safe strategy $a(T)$ if all the information it has are its priors $(p(A), p(B))$. B has an incentive for neither player to be distinguished, mimicking A if the message is uninformative, while A wants to separate from B. Farrell's neologism-proof equilibrium implies that no PBE exists since A always has the possibility of sending the self-signaling message "A". There is a way out of this. Figure 3 rephrases Farrell's Example 3 for a prior $p(A) \in [1/4, 3/4]$. If the equilibrium message in the babbling equilibrium is "A", no self-signaling neologism is available for A to destroy this equilibrium: A is being truthful $(V = 1)$, but B isn't $(V = 0)$ because it has an incentive to mimic A's message when it is uninformative. If the receiver expects both players to pool on "A", it will disregard the message $(T = 0)$ and stick to its priors. Hence, self-signaling neologisms may not always be available, contrary to Farrell's initial assumption.[12] If A were to say something like "I am really, really A" to destroy this uninformative equilibrium, this would not help much, unless, perhaps, this included natural signs like body language which go beyond the purely symbolic dimension explored here.

[12] To sustain the equilibrium, we assume that out-of-equilibrium messages such as "B" are interpreted by the receiver as uninformative messages that do not affect priors (in what we call below a "mistrust equilibrium"). It would also be an equilibrium if the out-of-equilibrium message "B" were interpreted as denoting B (in what we call below a "trust equilibrium").

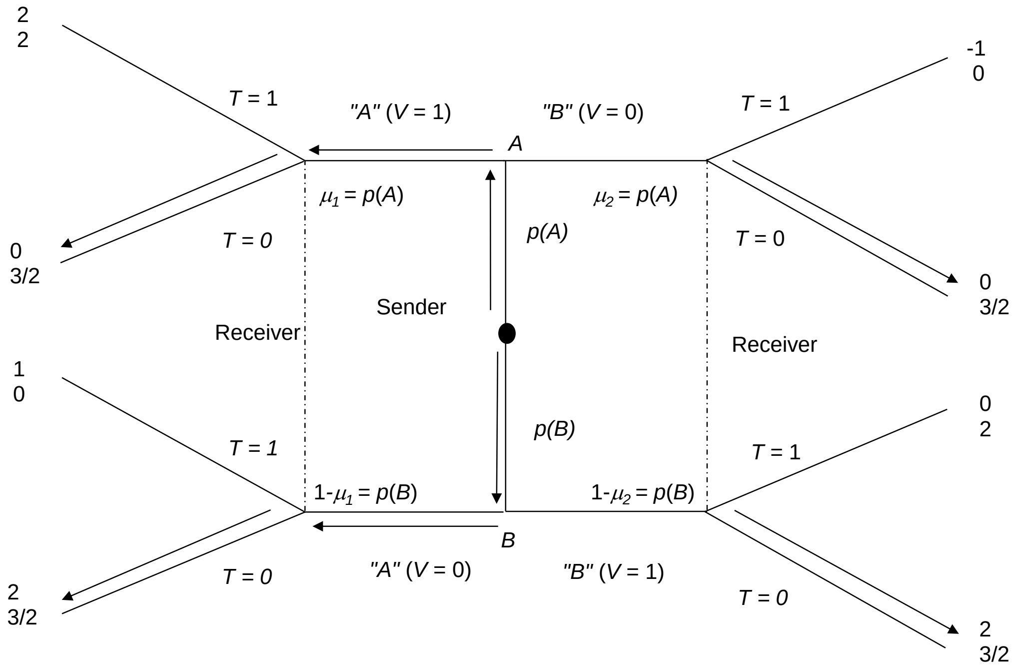

FIGURE 3. MEANINGFUL TALK: NO MEANINGFUL NEOLOGISM AVAILABLE IN EQUILIBRIUM

4.4. Existence and classes of meaningful-talk equilibria

Existence of MTE is trivial to establish because of the following remark.

REMARK 1: Uninformative MTE always exist.

PROOF**:** If the receiver mistrusts all messages ($T^R(\text{"Q"}) = 0$) and falls back on the priors, it is a best response for the sender not to be truthful ($V^S(\text{"}m\text{"}, w) = 0$), picking messages that are not conditional on its type.[13] Given this best response of the sender, the best response of the receiver is indeed to ignore all messages■

To characterize the classes of MTE, we first define trust equilibria. The set of trust (or optimistic) equilibria are restricted to messages that refer to strict subsets of "W" to avoid true but irrelevant statements like “My type is in W”.

[13] The sender need not actually play strategies that are not conditional on its type, because the receiver has no way of verifying that. What matters is the uncertainty of the receiver about what the sender is actually doing, as in the epistemic interpretation of Aumann and Brandenburger (1995).

DEFINITION 4: A *trust* equilibrium is a MTE where $T^R(\text{"}m_j\text{"}) = 1$ for some relevant and credible messages "m_j"∈"M".

It is simple to characterize the sufficient condition for a trust equilibrium to be informative, that messages on the equilibrium path be relevant.

REMARK 2: A MTE is *informative* if it is a trust equilibrium where the sender has an incentive to utter credible messages that are relevant.

PROOF: A message "m_j"="Q" is relevant if "Q" ∈ "M" = "P(W)" and "Q" ∉ {"∅", "W"}. If a relevant message on the equilibrium path is credible and trusted, then the types in Q that truthfully send that message allow updating the priors using the literal meaning of "Q". The equilibrium will thus be more informative than merely using the priors■

The set of trust equilibria is broader than the set of informative equilibria because the messages that are trusted by the receiver might be off the equilibrium path, only predicting what will not be said. As an example of a trust equilibrium that is uninformative, take the Akerlof (1970) market for lemons. Let there be two types of quality, $\theta_i \in \{\theta_L, \theta_H\}$, $\theta_L < \theta_H$, with an opportunity cost of $\alpha\theta_i$, with $\alpha < 1$. The product is high quality with probability $0 < q < 1$ and low quality with probability $1 - q$. Risk-neutral buyers are willing to pay the average quality offered on the market, $\mathrm{E}[\theta] = (1 - q)\theta_L + q\theta_H$. High-quality sellers accept this price only if:

(3) $$\mathrm{E}[\theta] \geq \alpha\theta_H.$$

If condition (3) is satisfied, the minimal messages required are "θ_L", “This car is a lemon”, and "θ_H", “This car is in great shape”.[14] Consider the price offers $p_i \in \{\theta_L, \mathrm{E}[\theta], \theta_H\}$. An uninformative equilibrium exists in which all seller types state "θ_H".[15] Sellers could also pool on "θ_L", but that does not correspond to our experience with this market. Why? Figure 4 depicts a trust equilibrium where buyers take "θ_L" at face value ($T = 0$), so all types of sellers have an incentive to say "θ_H". The only prediction of the model is about what might not be said in equilibrium.

[14] If condition (3) is not satisfied, only lemons are left on the market, so there is no point in talking.
[15] The reaction to any other announcement has to be a low price.

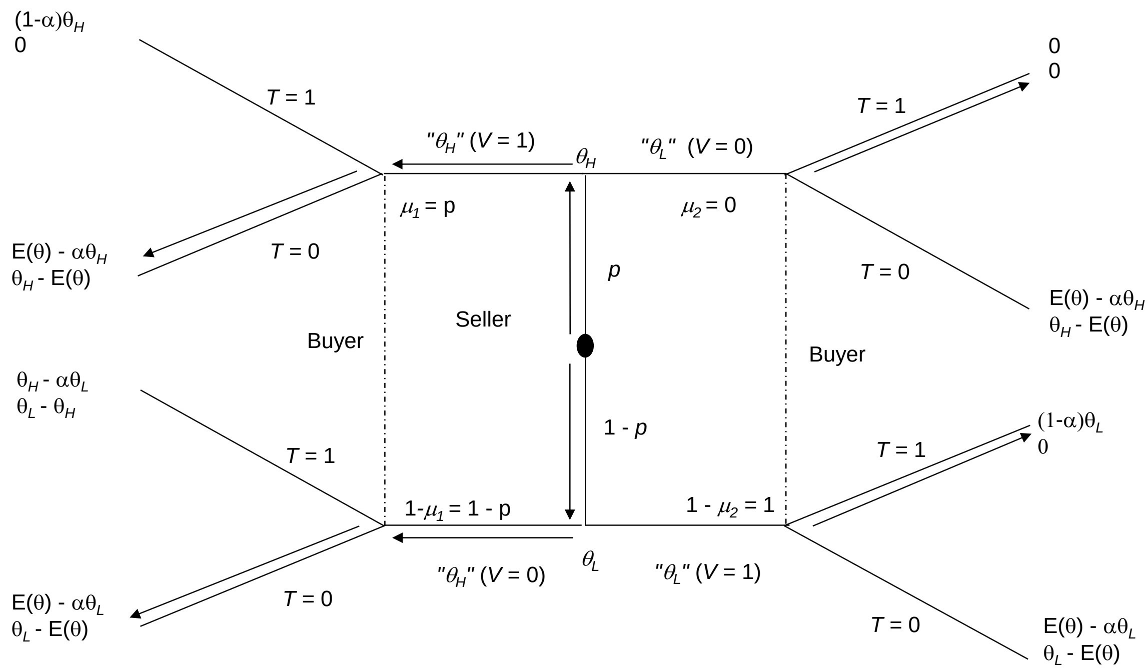

FIGURE 4. MEANINGFUL TALK: AVOIDING THE MESSAGE "THIS IS A LEMON"

In *mistrust* equilibria, on the other hand, the literal meaning does not determine the equilibrium meaning because messages are interpreted in terms of the priors of each game, so the interpretation is context-dependent. The set of mistrust (or pessimistic) equilibria is a subset of uninformative equilibria where all messages are disregarded, i.e., interpreted in terms of the common priors.

DEFINITION 5: A *mistrust* equilibrium is a MTE where $T^R(\text{"}m_j\text{"}) = 0$ for all relevant and credible messages "m_j"∈"M".

A babbling equilibrium makes perfect sense when the messages are incomprehensible or irrelevant, but it might be less intuitive when the messages are comprehensible, relevant, and credible. Verbal messages, however, never provide direct evidence of the meaning they convey, so trust requires the receiver to accept something as true without being able to actually see it.

4.5. Correspondence between PBE and MTE

To show how MTE differs from PBE, we first reformulate the game of *rendez-vous* in terms of the two-sided process of verbal communication. We then establish a general correspondence between both sets of equilibria.

Unlike Figures 1 and 2, with the configuration of equilibrium messages depicted in Figure 5 only an uninformative MTE exists: the receiver's payoffs would drop to 0 if it switched from mistrust ($T = 0$) to trust ($T = 1$). On the other hand, the natural informative PBE in the cheap and costly-talk games of Figures 1 and 2 where "l" refers to l and "r" refers to r do correspond to an informative MTE in Figure 5. This is the only informative MTE — though there may be different way of expressing this if synonyms with the same meaning exist.

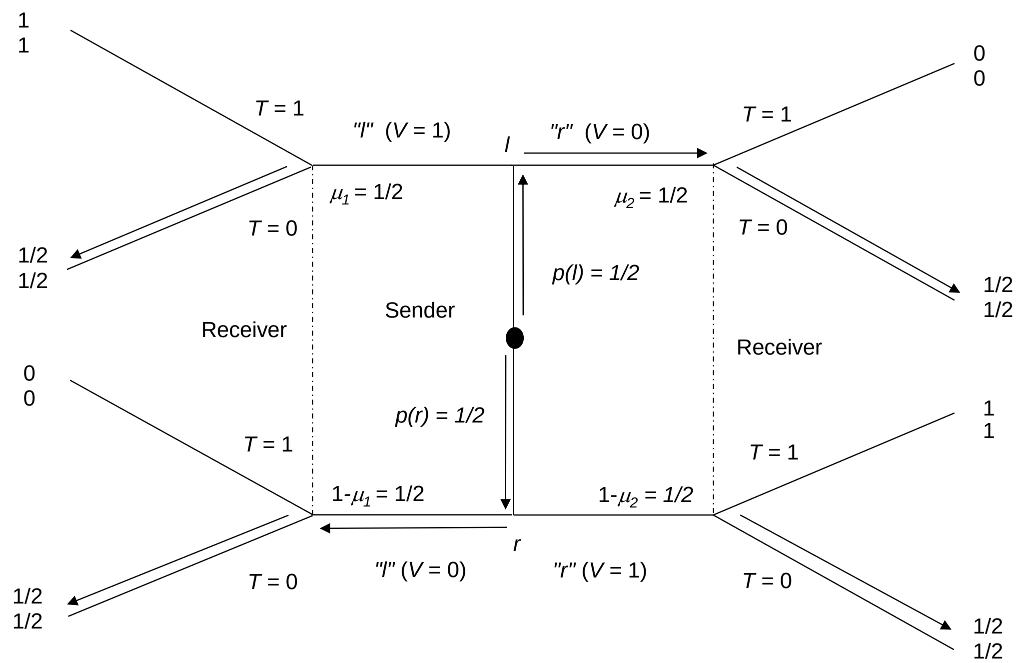

FIGURE 5. MEANINGFUL TALK: NO UNNATURAL INFORMATIVE EQUILIBRIUM IN *RENDEZ-VOUS*

Condition (3) of MTE is quite strict because it rules out reinterpretations like "l" ("My type is left") referring to r, and "r" ("My type is right") to l. Instead of having the receiver fall back on the priors, the receiver could indeed assign messages on the equilibrium path an interpretation that differs from what is literally stated. The snag we encounter is that if language is not used in its ordinary sense, there is no way for coordinating alternative interpretations of the receiver with different misrepresentations that the sender may fabricate, at least none that go beyond the common priors. Concretely, consider a seller and a buyer of a used car who want to get together in New York City. Ignoring the issue of quality, four pieces of information must be conveyed from the seller to the buyer: that what is for sale is a car, the seller's phone number, the meeting time, and the meeting place. The conceptual problem of communication is the same for each piece of information. What would happen if the seven digits of the seller's phone number were randomly scrambled in an ad? Or suppose that the seller's message "I will be at the information booth in Grand Central Station at twelve noon" is not trusted by the buyer. Instead of second-guessing whether this message might instead mean something else like "I will be in the lobby of the Chrysler Building at 9 a.m.", condition (3) of MTE implies that in case of mistrust the buyer returns to its diffuse priors that any place and time is equally likely.

The terminological distinctions in Farrell (1993) allow us to rephrase our critique of the unnatural informative equilibria of cheap- and costly-talk games illustrated in Figures 1 and 2 as follows: the audience would have to be capable of deciphering messages to understand unnatural informative equilibria. This is not a reasonable interpretation for one-shot interactions between ordinary people. Our hearers do not have limited rationality or imagination because they revert to the priors in case of mistrust: fully rational agents cannot coordinate on their own to figure out what ciphers mean, at least not through plain language, because this leads to an infinite regress problem. This anomaly motivates our model of meaningful talk: speakers rely on the ordinary meaning of words to convey information to the hearer, because otherwise the receiver will not be able to interpret the sender's message correctly.

Figure 5 also shows that MTE is not a refinement of PBE because the set of uninformative equilibria is larger. Once equilibrium messages are not trusted, condition (3)(ii) does not require equilibrium messages not to be conditional on type, i.e., that $\widetilde{\omega}^S(w_i)("m") = \omega$ for all $w_i \in$ W. The requirement is that the receiver cannot increase payoffs by switching from mistrust (where a best response to the priors is played) to trust (where a best response to the literal meanings announced by the sender is played).

We now establish the correspondence between these two different solution concepts.

DEFINITION 6. A MTE and a PBE *correspond* to each other if and only if the players use the same equilibrium messages and responses for given priors about sender types.

MTE is more stringent that PBE in terms of the conditions for an informative equilibrium and less stringent in terms of the conditions for an uninformative equilibrium. We first show that MTE singles out the informative PBE equilibria of cheap- and costly-talk games where words are used in their ordinary sense. Then we show that all uninformative PBE are uninformative MTE. The last proposition shows that the inclusion in Propositions 1 and 2 is strict.

PROPOSITION 1. If an informative MTE exists, a corresponding informative PBE exists.

PROOF. By condition (3)(i) of a MTE, beliefs in response to equilibrium messages are computed by Bayes' rule if the receiver trusts the sender's messages and the sender is truthful. If the messages are truthful and relevant, beliefs in a MTE are computed according to the actual probabilities that each type has of a sending a given message. Thus, MTE corresponds to a natural informative PBE where the equilibrium messages carry their ordinary meaning because conditions (1) and (2) of a PBE are satisfied, i.e., each type of sender maximizes its payoffs by truthfully uttering relevant messages and the receiver maximizes its payoffs by trusting them and acting in response to those beliefs. Finally, in a MTE beliefs in response to out-of-equilibrium messages are either as in condition (4) of a PBE, if no out-of-equilibrium messages are trusted, or they single out beliefs in a particular PBE, if some out-of-equilibrium messages are trusted■

PROPOSITION 2: If an uninformative PBE exists, a corresponding uninformative MTE exists.

PROOF. If a PBE is uninformative, messages are not conditional on type. In a MTE, condition (3)(ii) requires that, if the receiver does not trust the messages, it must be true that it cannot increase its payoffs by trusting them and taking them at face value. If the receiver were to take the messages at face value, its expected payoffs from trusting the message imply it would optimize in response to the mistaken type. The expected payoffs cannot be larger than those from disregarding the messages and correctly optimizing in response to the actual distribution of types represented by the priors■

PROPOSITION 3. Informative MTE correspond to a strict subset of informative PBE, and uninformative PBE correspond to a strict subset of uninformative PBE.

PROOF. The set of equilibrium messages in an informative PBE is not bounded. If the equilibrium messages do not belong to a common language, in a MTE the receiver will not be able to understand what the sender is saying. Consequently, the receiver cannot update its priors, whether it trusts the messages or not. Hence, any informative PBE that does not use messages from a common language corresponds to an uninformative MTE■

5. Final remarks

Schelling (1960: 119) points outs that game theory is sometimes pitched at too abstract a level of analysis. We strive to close the gap between language in economic theory and in daily life. We draw on two traditions, what Lipman (2000) calls the *logical 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. According to the logical approach, sentences carry a literal meaning. According to the equilibrium approach developed by Crawford and Sobel (1982), unilateral communication games between a sender and a receiver under asymmetric information must be analyzed strategically. We thus “impose restrictions on the use of messages within a game that capture the way that messages are used outside of strategic interactions” (Sobel 2011: 13). Unlike other signals, verbal symbols have a literal meaning that conveys common understandings. This is crucial in explaining why sentences can be informative despite the fact that they do not provide direct evidence on types.

To Farrell’s (1993: 515) insight that a common language is a sufficient condition for a receiver to understand the sender, we add that it is a necessary condition. Comprehensible and relevant messages from the encoding-decoding process are not always reliable, so in the inferential process the receiver judges whether the message is trustworthy.[16] This leads to a solution concept for language games that goes beyond Nash equilibrium. Our notion of credible messages resembles that in Myerson (1989) insofar as the literal and effective

[16] In linguistics, the traditional encoding-decoding (or semiotic) model of communication has been questioned. Just like in our approach, Sperber and Wilson (1995) also point out that the strategic incentives of the sender may affect what information is actually revealed.

meanings coincide in informative equilibria. The difference is that here multiple equilibria are possible: since messages point to types, without providing proof of what they state, trust requires a leap of faith for the receiver; hence, mistrust equilibria exist even when credible messages are available.

Trust equilibria are broader than informative equilibria because linguistic conventions can show through what is never stated. In the market for lemons, for instance, the fact that sellers may refrain from saying "This car is a lemon," lest their words be taken at face value, attests to the underlying linguistic conventions in society. The distinction between linguistic conventions and their use thus helps to understand why conventions are in some instances more honored in the breach than in the observance (Rescorla 2015).

We have concentrated on the symbolic information provided by the literal meaning of messages, ignoring things such as body language. Meaningful talk is thus a formal pragmatics, i.e., a study of utterance comprehension within an idealized strategic context (Franke 2009, Streb 2017). We haven't looked at how language might also allow coordinating expectations, as in Schelling (1960). We are just scratching the surface of verbal communication.

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