Demanding or Deferring?
The Economic Value of Communication with Attitude

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Abstract This paper investigates why natural language communication is systematically found to promote coordination better than intention signaling. We hypothesize that, when communicating with natural language, people both use and respond to intentions and attitudes, where attitude indicates the strength of desire to have their intentions followed. We test our hypothesis using controlled laboratory experiments. We find (i) free-form messages do include both intentions and attitudes; (ii) people respond both to intentions and attitudes when making decisions; and (iii) the use of attitude significantly improves coordination.

Keywords communication; coordination; experiment; attitude; gender

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1. INTRODUCTION

Language is a powerful and complex human tool facilitating social and economic decisions. Over the last decades there has been significant theoretical and empirical progress towards understanding how communication improves coordination. While much of this early progress has occurred within the context of intention signaling models, natural language communication has a more richly detailed structure that can convey multiple meanings concisely. That this structure has evidently survived an evolutionary process has led some economists to argue for its importance not only to understanding grammar (e.g. Selten and Warglien 2007) but also for understanding human social and economic decisions (e.g. Rubinstein 2000). Farrell (1993) argues that richness of language should play a more prominent role in game theory. Recent empirical evidence suggests Farrell was correct. In relation to constrained signaling, efficient economic outcomes emerge more readily when players can communicate using rich natural language (see Charness and Dufwenberg 2006, 2010; Cooper and Kühn, 2014 and 2015; Cason and Mui 2015). Our aim here is to present and test a formal framework that predicts people both use and respond to multi-meaning natural language in a way that improves coordination. In doing so, we bridge theory (Farrell 1993, Rabin 1994) and experiments (Charness and Dufwenberg 2006, 2010; Cooper and Kühn, 2014 and 2015; Cason and Mui 2015) in a way that sheds light on why and how rich language promotes efficient outcomes in coordination environments.

To illustrate the importance of rich natural language, consider routine discussions over where to dine or which film to view. If everyone conveys indifference, by stating that "it's up to you", or "I do not care", the conversation is likely to be long and inefficient. At the same time, the same is true if all report a preferred option without a clear attitude. For example, one person says, "I feel like French," and another responds, "I'm thinking Indian," a different long conversation ensues. People typically solve these problems by making statements that combine intention signaling with attitudes,[1] that is, they indicate strength of desire to have their suggestions followed. For example, one person's, "I really want French tonight" meeting another's "I'm thinking Indian, but it's up to you" will lead to immediate agreement. Intuitively, it makes good sense to communicate in a way that allows common ground to be rapidly found.

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[1] In the psychology literature, attitude is understood as one component of a broader model of behavior, which includes social norms and behavioral intentions. The way define attitude in this paper is closely related to the behavioral intentions part of the concept. (see Osgood et al. 1957, Fishbein 1967c, Fishbein 1975).

One can incorporate attitudes into an intention-signaling model with rich language that includes two-dimensional meanings. One dimension is intention, which signals the intended move in the game. The other dimension is attitude, which indicates the strength of desire to have the intentions followed. An attitude could be demanding, meaning that the message sender demands that the receiver to follow the stated intentions. Alternatively, the message could be deferring, meaning that the senders offer to follow the receiver's stated intentions.

To further illustrate this idea, consider a two-stage game in which players send each other simultaneous cheap-talk messages in the first stage and make simultaneous actions in the second stage. Suppose the language space players use to communicate is two-dimensional, common and complete. That is, players understand each other's messages, each of which includes a signaled *intention* (so-called *E-meaning;* Rabin 1991, 1994*)* as well as an *attitude* (which we denote as *A-meaning*).

First, we apply the notion of *Credibility* from Farrell (1993)[2] to a communication environment with multi-dimensional meanings to define an *agreement-equilibrium*, which requires that players act in accordance with the *intentions* of their messages when the action is a best response to the *intentions* of her partner's message.

Furthermore, we introduce the notion of *Attitude Ranking*, which posits that players indicating weaker desire to have their *intentions* followed (that is, those who are more willing to defer) cede decision authority to the player indicating stronger desire (that is, those who are more demanding). With this assumption, we demonstrate the existence of another group of equilibria, denoted *negotiated-equilibria*, which require that players act in accordance with the relatively more demanding player's *intentions* when paired players' messages differ in both intentions and *attitudes.* We show that *negotiated-equilibria,* in which one player concedes to the other players' requested equilibrium can happen in one-shot simultaneous communication.

In simplified multi-dimensional language with only two *intentions* and two *attitudes*, communication failure can occur whenever players indicate differing *intentions* along with the same *attitude*. It is easy to see, however, that if the *attitude* is continuous (instead of binary) then communication failure occurs with probability zero. The intuition is that in this case *attitudes* differ with probability one, meaning they can surely be used to arbitrate disagreement over

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[2] Farrell (1993) introduced *Credibility*, the intuition of which is that communication works well when there is no incentive to lie. Demichelis and Weibull (2008) include lexicographic preference for honesty, second to material preferences, to capture a similar idea.

intentions. To the extent that time is costly, because communicating with *attitude* allows more rapid agreement it is also in this sense efficient.

To investigate empirically how people use language to help coordination, we conduct pure coordination games with pre-played free-form communication in the laboratory. The messages we collected show that people naturally and without prompting communicate with both *intentions* and *attitudes*. Furthermore, we find people respond well to their counterparts' *intentions* and *attitudes* when making their decisions. Overall, the use of attitudes significantly improves coordination.

As comparison, we conduct the same coordination game without communication, with one-dimensional restricted communication, and two-dimensional restricted communication. We find that free-form communication promotes coordination as well as two-dimensional restricted communication, and much better than no communication or one-dimensional restricted communication. In both free form and two-dimensional communication treatments, people rapidly coordinate on *agreement-equilibria* and *negotiated-equilibria*. When communication failure occurs, the coordination rate with free-form communication is much higher than with two-dimensional restricted language. This result suggests that even though natural language communication in our environment can be well-modeled by a restricted language with two-dimensional meanings, attitudes might be more finely-partitioned than the two categories in our model.

Economic theory has long conjectured that natural language communication facilitates efficient economic outcomes because it includes a rich, multi-meaning structure that people use and to which people respond (e.g. Marschack, 1965). To our knowledge, our paper is the first to apply the idea of multi-dimensional meaning to the context of coordination. Further, this paper is the first direct test of whether people naturally use multi-dimensional language when communicating, and whether people respond to multi-dimensional natural language in a way that promotes coordination.

The remainder of this paper is organized as follows. Section 2 reviews the literature on pre-play communication. Section 3 models communication with two-dimensional meanings. Section 4 describes the design of our experimental test. Section 5 summarizes and discusses our main findings. Section 6 offers concluding remarks and further discussion.

2. RELATED LITERATURE

This section is a survey of related theory and experimental evidence on behavior in games with pre-played communication. We focus on intention signaling, multi-dimensional signaling and natural language communication.

2.1. *Intention Signaling*

Both theoretical and experimental evidences suggest that the effectiveness of intention signaling in promoting coordination not only depends on the payoff structure of the underlying game, but also the structure of communication mechanisms (e.g. Cooper et al. 1989, 1992; Holt and Davis 1990; Van Huyck et al. 1993; Charness 2000; Clark et al. 2001; Charnes and Grosskopf, 2004; Duffy and Feltovich 2002, 2006, Blume and Ortman 2007). For instance, Cooper et al. (1989) found one-way communication (i.e. only one player can send a message) resolves coordination problems in the Battle of Sexes game, while two-way simultaneous communication (both players can send messages) is of less value in solving 2-person coordination problems. Cooper et al. (1992) confirmed that two-way communication does not always decrease the frequency of coordination failure in different types of coordination games. Clark et al. (2001) tested Aumann's conjecture with two-way signals and showed, consistent with theory, informative communication does not necessarily lead to Pareto-efficient equilibrium outcomes.

Blume and Ortmann (2007) studied Minimum and Median games[3] where multiple Pareto-ranked equilibria exist. In their design, all (nine) players send numerical messages simultaneously to indicate which of the (seven) options they intend to choose. Cheap talk facilitates coordination in games with a unique efficient equilibrium. Choi and Lee (2014) studied the role of network structure of pre-play communication in determination of outcomes in coordination games. In addition to providing evidence that increasing the length of communication both improves the chance of successful coordination and reduces the asymmetry in the distribution of outcomes, they also discovered substantial variations in both efficiency and equity of coordination across networks.

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[3] Van Huyck, Battalio and Beil (1990) designed the so-called Minimum and Median games, where coordination among multiple players is required for efficient equilibrium. They showed that adding a pre-play auction enables players to coordinate on Pareto-efficient equilibrium.

Farrell (1987, 1988) took the important step of studying intention signaling in simple sequential games with complete information, where an underlying game is preceded by one or more rounds of structured pre-play communication in which players make nonbinding announcements about their intended moves. Farrell (1987) studies Battle of the Sexes and Farrell (1988) considers a finite n-person game. Farrell suggested cheap-talk need not be ignored, and moreover it could make equilibrium focal.

Rabin (1991, 1994) extended the analyses of Farrell (1987, 1988). In Rabin's model, players make repeated, simultaneous statements about their intended moves before they play a coordination game. He made it possible to combine the assumptions that players maximize expected payoffs given beliefs with a variety of behaviorally motivated restrictions on beliefs. He generalized Farrell's (1987) result to an unlimited number of rounds of communication.

Several studies have looked at the strategic aspects of intention signaling. Crawford (2003) allows for the possibility of bounded strategic rationality and rational players' responses to the misrepresentation of intentions. Demichelis and Weibull (2008) generalized cheap-talk models by introducing a small cost of lying, and find this so-called lexicographic communication game is evolutionarily stable if and only if it results in a unique Pareto-efficient outcome. Ellingsen and Östling (2010) used a level-k model of strategic thinking to describe players' beliefs in games with one-way and two-way communication of intentions. They found that communication facilitates coordination in common interest games with positive spillovers and strategic complementarities.

2.2. *Multidimensional Signaling*

In the last decade increasing effort has been made by theorists to investigate multidimensional signaling. In these papers multi-dimensional messages were sent from the informed player(s) to the uninformed player(s). It is worth noting that the sender-receiver environments previously studied are distinct from the coordination environment reported in this paper.

Battaglini (2002) proved that, contrary to the unidimensional case, with multidimensional cheap talk full revelation of information in all states of nature is generically possible, even when the conflict of interest is arbitrarily large. Also, Levy and Razin (2007) analyzed the Crawford and Sobel (1982) cheap talk game with multidimensional states and found communication on one dimension can reveal information about the others. Finally, Chakraborty and Harbaugh (2010) showed that with multi-dimensional talk, experts with state-independent preferences can always make credible statements.

That multi-dimensional cheap talk can improve information transmission has been confirmed in the laboratory. Lai, Lim and Wang (2015) designed experimental games that capture the logic of Battaglini (2002). They allow two senders to transmit information to a receiver over a 2-by-2 space. Their findings confirm that more information is extracted in a multidimensional setting. The extent to which information is transmitted depends on whether dimensional interests are aligned between a sender and the receiver, as well as the size of the message space. Vespa and Wilson (2015) implemented a multi-sender cheap talk model and showed that competing senders provide enough information for nearly full revelation. Battaglini and Makarov (2014) studied how behavior changes with the addition of an audience as well as from varying the degree of conflict between a sender's and a receiver's preferences. They found evidence that the addition of an audience alters the communication between sender and the receiver in a way consistent with the theoretical predictions: participants become more truthful as senders and more trusting as receivers.

2.3. *Natural Language Communication*

Formal game theoretic modeling of natural language communication is rather limited. An influential theoretical advance closely related was provided by Farrell (1993), where he carefully discusses the meaning of a message. He argues that a message may have meaning in one of three ways. First, a meaning may be established by use: Wittgenstein (1957) urged "Don't ask the meaning; ask the use." The meaning of messages that are used in equilibrium, for example, is established by Bayes' rule, which tells us their meaning-in-use. Second, messages may have meanings that can be determined, or at least somewhat restricted, by introspection. This yields restrictions on out-of-equilibrium beliefs in generic signaling games; but not cheap-talk games. Finally - and this is the key element absent in previous analyses - a message may have a focal meaning, especially if it is phrased in a preexisting language. Farrell (1993) uses rich language assumption to propose equilibrium refinements. It will become clear below that our model builds closely on this previous research by Farrell and Rabin.

In the laboratory, free form cheap-talk has been shown to improve efficiency significantly in games including prisoners' dilemmas (Dawes, MacTavish, and Shaklee 1977), public goods (Isaac and Walker 1988), as well as games of signaling (Cooper and Kagel 2005) and coordination (Brandts and Cooper 2007). Many studies implement pre-play cheap-talk as free-form written messages, including both paper-pencil experiment and chat-box (e.g. Cooper and Kagel 2005; Xiao and Houser 2005, 2009, 2011; Charness and Dufwenberg 2006; Brandts and Cooper 2007; Schotter and Sopher 2007; Kimbrough et al. 2008; Ellingsen and Johannesson 2007; Sutter and Strassmair 2009; Heinnig Schmidt et al. 2008; Lundquist et al. 2009, Cason et al. 2012). Some studies also use face-to-face communication (Isaac, Ramey and Williams 1984; Daughety and Forsythe 1987a, 1987b; Binger et al. 1990; Valley et al. 1998).

More recently, a few experimental papers have suggested that free-form communication works better than restricted-form in facilitating efficient outcomes. Charness and Dufwenberg (2006) studied the impact of free-form communication on trust and trustworthiness. Charnness and Dufwenberg (2010) conducted the games with identical designs, except players were only given two restricted messages to choose from, one stated "I promise to choose Roll" ("bare promises"), while the other was blank. The impact on trust and trustworthiness was weaker with restricted as compared to free-form communication. In Cason and Mui (2015)'s experiment, a leader can decide whether to extract surplus from a victim and shares it with beneficiary. They found that the successful joint resistance rate increases from 15% to 58% when moving from more restricted communication to rich communication. Cooper and Kühn (2014) explored how communication fosters cooperation.[4] They find free-form chat improves cooperation much more than limited communication. Also, Cooper and Kühn (2015) investigates whether making it easier for subjects to reach an agreement by allowing more rounds of restricted communication can increase cooperation. Their results indicate that restricted communication is not a good substitute for the use of chat even after allowing subjects to have more rounds of interaction.

In broad brush-stroke, one message of the empirical literature is that the efficiency of economic outcomes is surprisingly high in the presence of pre-play communication, and more so when communication includes natural language. The question left unanswered is: why? The evidence we are going to show in this paper, which points to the importance of richly-structured multi-meaning free-form messages, is another step towards answering this question.

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[4] Also called collusion in Cooper and Kühn (2014) context.

3. MODEL

3.1. *Setup*

Two individuals are playing a two-stage game G* (C, $\mathcal{G}$) where they can communicate in the first stage C and play a coordination game in the second stage $\mathcal{G}$. We call G* (C, $\mathcal{G}$) an extended game of G if and only if players play G in stage $\mathcal{G}$, and correspondingly the game G is called the underlying game of G* (C, $\mathcal{G}$).

We focus on the case where the underlying game G is a symmetric game. Let the finite set A include all pure actions a_i of game G. Let the set S includes all the mixed strategy s_i, where $s_i \in \Delta(A)$ is a randomization over the set A of pure strategies. $U_i(a_i, a_j)$ is player i's payoff as a function of pure strategies and $\pi_i(s_i, s_j)$ is the expected payoff derived from $U_i(\cdot)$, $i, j \in \{1,2\}, j \neq i$. The set $\boldsymbol{E}$ contains the Nash equilibria of game G. Nash equilibria are denoted as $E_1, \dots, E_K$ and the strategies that constitute equilibrium $E_k \in \boldsymbol{E}$ are denoted as ($\mathrm{s_i^{E_k}}$,$\mathrm{s_j^{E_k}}$). Let $\boldsymbol{\mathcal{E}}$ be a subset of $\boldsymbol{E}$ containing Pareto-efficient Nash equilibria, denoted by $\mathcal{E}_1, \dots, \mathcal{E}_K$. The strategies that constitute a Pareto-efficient equilibrium $\mathcal{E}_k \in \boldsymbol{\mathcal{E}}$ are denoted by ($s_i^{\mathcal{E}_k}$,$s_j^{\mathcal{E}_k}$).

In the first stage C, each player simultaneously sends a cheap-talk message $m_i \in M$, where *M* is a publicly known nonempty message set. By the definition of cheap-talk, messages in M are non-binding, non-verifiable and costless. A function $\varphi: M \times M \rightarrow S$ specifies the second stage strategy $s_i = \varphi_i(m_i, m_j)$ given player *i* sends message m_i and receives m_j, $i \in \{1,2\}, j \neq i$.

Combining both stages, the finite set A^* contains the pure strategies of G*(C, $\mathcal{G}$), $a_i^* = \left(m_i, \varphi_i(m_i, m_j)\right)$. A mixed strategy $\sigma_i \in \Delta(A^*)$ defines the probability assigned to pure strategy A^*. $\mathrm{V}_i(a_i^*, a_j^*)$ is player i's payoff as a function of pure strategies and $\Pi_i(\sigma_i, \sigma_j)$ is the expected payoff derived from $V_i(\cdot)$. We have $\Pi_i(\sigma_i, \sigma_j) = \pi_i(\varphi_i(m_i, m_j), \varphi_j(m_j, m_i))$ given talk is costless. Furthermore, because communication is non-binding, any strategy profile (σ_i, σ_j) which constitutes a Nash equilibrium of G in the second stage $\mathcal{G}$ is a Nash equilibrium of G*(C, $\mathcal{G}$), which we denote as $(\sigma_i^{E_k}, \sigma_j^{E_k})$. Similarly, any strategy profile (σ_i, σ_j) which constitutes a Pareto-efficient Nash equilibrium of G in the second stage $\mathcal{G}$ is a Pareto-efficient Nash equilibrium of G*(C, $\mathcal{G}$), which we denote as $(\sigma_i^{\mathcal{E}_k}, \sigma_j^{\mathcal{E}_k})$.

3.2. *Language Space*

We assume players share a common language space M, which consists of (1) a meaningful vocabulary; (2) a shared understanding among players that it is appropriate to interpret

DEFINITION 3: *The common language space M(G*) is complete with respect to its E-meaning if and only if:*

(1) *For all* $m_i \in M$*, there exists an equilibrium* $E_k \in \boldsymbol{E}$ *of G such that* $m_i \in Q(E_k)$;

(2) *For any two equilibria* $E_k \in \boldsymbol{E}, E_l \in \boldsymbol{E}$ *and* $k \neq l$, $Q(E_k) \cap Q(E_l) = \emptyset$.

DEFINITION 4: *The common language space M(G*) is complete with respect to its A-meaning if and only if:*

(1) *For all* $m_i \in M$*, there exists attitude* $\mathcal{A}_w \in \boldsymbol{\mathcal{A}}$ *such that* $m_i \in D(\mathcal{A}_w)$;

(2) *For all attitudes* $\mathcal{A}_w \in \boldsymbol{\mathcal{A}}, \mathcal{A}_y \in \boldsymbol{\mathcal{A}}$ *and* $w \neq y$, $D(\mathcal{A}_w) \cap D(\mathcal{A}_y) = \emptyset$.

Part (1) of Definition 3 says that all messages contain an *E-meaning*, and Part (2) illustrates that no message can simultaneously signal two different equilibria. Analogously, Definition 4 says that all messages convey an *A-meaning*, and that no single message can convey more than one attitude.

In the development below, following Rabin (1994),[9] we assume players' messages consist solely of proposals to play Pareto-efficient Nash equilibria.

3.3. *Equilibria*

3.3.1. *Agreement-equilibrium*

We now move to how players form an "agreement" in a two-dimensional language space. Rabin (1994) says players have reached an *agreement* when they mention the same equilibrium in the pre-play communication stage. We extend the notion of *agreement* into a language space with both *E-meaning* and *A-meaning*, and proceed to define the concept of an *agreement-equilibrium*.

ASSUMPTION 1 (Credibility): *If it is optimal for a player to honor the E-meaning of her own message given the other player honors the E-meaning of her own message, then the E-meanings of messages from both players will be honored.*

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[9] This is referred to as "Pareto talk" by Rabin (1994). Rabin considers this one of the simplest examples of negotiating language, where it consists solely of proposals to play Pareto-efficient Nash equilibria.

Roughly put, *Credibility* assumes players won't deviate from their words if there is no incentive for them to so.[10]

PROPOSITION 1: *Paired players jointly play* $\mathcal{E}_k$ *in the second stage if they made proposal* $\boldsymbol{m} = (m_1, m_2)$*, where* $m_i \in Q(\mathcal{E}_k), i \in \{1,2\}$*,* $\forall\ \mathcal{E}_k \in \boldsymbol{\mathcal{E}}$ *of underlying game G.*

If paired players signal a shared intention to play the same Pareto-efficient Nash equilibrium of underlying game G then, by the assumption of *Credibility*, they have an implicit agreement to play the signaled equilibrium. This type of equilibrium of G* is called an agreement-equilibrium and can be characterized as follows:

DEFINITION 5: *A strategy profile* (σ_1, σ_2)*, where* $\sigma_i \equiv (m_i, s_i), \forall i \in \{1,2\}$*, constitutes agreement-equilibrium of game G*(C,* $\mathcal{G}$*) iff*

(1)Players make proposal set $\boldsymbol{m} = (m_1, m_2)$ *in stage C, where* $m_i \in Q(\mathcal{E}_k)\ \forall i \in \{1,2\}$;

(2)Players play $\mathcal{E}_k = (s_1^{\mathcal{E}_k}, s_2^{\mathcal{E}_k})$ *in stage* $\mathcal{G}$.

3.3.2. *Negotiated-equilibrium*

We continue by considering how a message's *A-meaning* can be used to achieve equilibrium when paired players signal the intention to play different equilibria.

ASSUMPTION 2 (Attitude Ranking): *Suppose players share a complete and transitive ordering of the elements in* $\boldsymbol{\mathcal{A}}$*. Given* $m_i \in Q(\mathcal{E}_k) \cap D(\mathcal{A}_w)$ *and* $m_j \in Q(\mathcal{E}_l) \cap D(\mathcal{A}_y)$*,* $i, j \in \{1,2\}$*,* $j \neq i$*, if* $\mathcal{A}_w$ *indicates stronger desire of having the message followed than* $\mathcal{A}_y$*, then players will play* $\mathcal{E}_k$ *in stage* $\mathcal{G}$*.*

We assume that players share a complete and transitive ordering for *A-meanings*. This requires players have the same interpretation of attitude with the preexisting common language.

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[10] Farrell (1988, 1993) summarizes the intuition of *Credibility* as "communication cannot work well when there are incentives to lie". Demichelis and Weibull (2008) add a lexicographic preference for honesty (small costs of lying) to their model to capture the similar idea.

For example, we assume that everyone in the game agrees that the message "Let's do X no matter what" expresses a stronger desire to have the message followed than a message like "It's up to you, if you have no strong opinion, let's do X".

Assumption 2 says that if there are two different *E-meanings* and two different *A-meanings* in the two messages from paired players, then both players will honor the *E-meaning* of the message which includes the *A-meaning* indicating stronger desire to have one's message followed. We are now in position to explain how simultaneous "negotiated agreement" can occur within a single round of simultaneous multi-way communication. Given *Attitude Ranking*, players are able to use *A-meanings* to resolve the conflicts between *E-meanings*.

DEFINITION 6: *A strategy profile* (σ_1, σ_2)*, where* $\sigma_i \equiv (m_i, s_i), \forall i \in \{1,2\}$*, constitutes negotiated-equilibrium of game G*(C,* $\mathcal{G}$*) iff*

(1) *Player i makes a proposal which satisfies* $m_i \in Q(\mathcal{E}_k) \cap D(\mathcal{A}_w)$ *in stage C, and player j makes a proposal* m_j *such that* $m_j \notin Q(\mathcal{E}_k)$ *but* $m_j \in D(\mathcal{A}_y)$*, where* $\mathcal{A}_w$ *indicates stronger desire to the message followed than* $\mathcal{A}_y$*;*

(2) *Players play* $\mathcal{E}_k = (s_1^{\mathcal{E}_k}, s_2^{\mathcal{E}_k})$ *in the stage G.*

3.3.3. *Communication-failure*

We close the analysis of equilibria by describing the case where different *E-meanings* but the same *A-meaning* are contained in the messages. That is, neither the conditions of *agreement-equilibrium* nor *negotiated-equilibrium* are achieved with pre-play communication.

ASSUMPTION 3 *When* $m_i \in Q(\mathcal{E}_k) \cap D(\mathcal{A}_w)$ *and* $m_j \in Q(\mathcal{E}_l) \cap D(\mathcal{A}_w)$*, the message set* $\boldsymbol{m} = (m_i, m_j)$ *will be ignored,* $i, j \in \{1, 2\}, i \neq j, \forall \mathcal{E}_k \in \boldsymbol{\mathcal{E}}, \mathcal{E}_l \in \boldsymbol{\mathcal{E}}$ *and* $\mathcal{E}_k \neq \mathcal{E}_l$ $\forall \mathcal{A}_w \in \boldsymbol{\mathcal{A}}$*.*

Assumption 3 says that when paired players' messages convey different *E-meanings* but the same *A-meaning*, since it is not possible to coordinate based on the message.

DEFINITION 7: *A strategy profile* (σ_1, σ_2)*, where* $\sigma_i \equiv (m_i, s_i)$*, constitutes communication-failure for game G*(C,* $\mathcal{G}$*) if*

(1) *For* $m = (m_1, m_2)$, $m_i \in Q(\mathcal{E}_k) \cap D(\mathcal{A}_w), m_j \in Q(\mathcal{E}_l) \cap D(\mathcal{A}_w), \forall \mathcal{E}_k \in \boldsymbol{\mathcal{E}}, \mathcal{E}_l \in \boldsymbol{\mathcal{E}}$ *and* $\mathcal{E}_k \neq \mathcal{E}_l \ \forall \mathcal{A}_w \in \boldsymbol{\mathcal{A}}$.

(2) *Players play the game as if there is no communication stage C.*

Communication-failure does not necessarily lead to coordination failure. Definitions 5, 6 and 7 illustrate all possible message-combinations that paired players are able to send in cheap-talk environments where messages have two dimensions of meaning.

3.4. *Communication Strategies*

We now move to the analysis of communication strategies in the first stage. The assumptions we made allow us to restrict attention to only three different communication situations, i.e. signaling same *E-meaning*, signaling different *E-meanings* with different *A-meanings*, and signaling different *E-meanings* with same *A-meaning*. Suppose it is common knowledge that everyone responds to messages based on these assumptions. Given players' beliefs about what messages they might receive, there exist ex-ante best messaging strategies. However, the strategies highly depend on the payoff structure of the underlying coordination game. For ease of exposition, we concentrate on pure coordination games since that the identical payoffs for two players isolate the function of cheap talk as a pure coordination device as compared to its use for any other information revealing purposes (e.g., indicating different marginal utility of money, or different social preferences or risk attitudes). Note it is straightforward to generalize this framework to other environments.

In a pure coordination game where players are indifferent among all Pareto-efficient Nash equilibria, it restricts attention to communication strategies meant to avoid communication failure. We denote the two pure-strategy Pareto-efficient equilibria as $\mathcal{E}_k$ and $\mathcal{E}_l$, and one Pareto-dominated mixed-strategy equilibrium as $\mathcal{E}_m$. To simply the characterization of equilibria characterization, we assume there are exactly two attitudes available, $\mathcal{A}_w$ and $\mathcal{A}_y$.

PROPOSITION 2: *When the underlying game G is a pure coordination game, in which equal payoffs of pure-strategy Nash equilibria, if a player believes that she is least likely to receive* *message* $m_j \in Q(\mathcal{E}_l) \cap D(\mathcal{A}_w)$, $i \in \{1,2\}$, $j \neq i$, $k \neq l$, *then she maximizes her expected payoff by sending message* $m_i \in Q(\mathcal{E}_k) \cap D(\mathcal{A}_w)$.

Proposition 2 says that in order to maximize expected utility in a cheap-talk game G* with a pure coordination game with the equal payoff for two pure-strategy Nash equilibrium, one needs to minimize the chance of encountering $\mathcal{E}_m$ by sending a message with a different *E-meaning* but the same *A-meaning* of the message one is least likely to receive.

The only time players cannot achieve a Pareto-efficient outcome is when they face *communication-failure.* For each combination of *A-meaning* and *E-meaning* player j can send, there is a corresponding combination of *A-meaning* and *E-meaning* that leads to *communication-failure.* Player i desires to minimize the chance of *communication-failure* given her belief over the distribution her counterparts' messages.[11]

4. GAME: MODIFIED HOLM (2000) PINK-BLUE GAME

Our interest is in determining whether people use and respond to natural language messages in a way that is consistent with the model above. To do this, following Holm (2000),[12] we design a "Pink-Blue" Game, where options are labeled as Pink and Blue, and counterparts' genders are revealed to players at beginning. We use an announcement to ensure it is common knowledge that, for the purpose of this game, "Pink is a color often preferred by females, and Blue is a color often preferred by males". To the Holm (2000) environment, we added a pre-play free-form communication stage C, where players are able to send each other simultaneous messages. After the message exchange, players make decisions in the Pink-Blue game, the payoff matrix for which is described by Figure 1. As indicated by Figure 1, players earn x>0 if they choose the same color, and zero otherwise. We adopt the game to create two different situations, both when there exists a focal point (when players of the same gender are matched) and when there does not exist a focal point (when players of different genders are matched) before communication. We want to investigate how communication plays a role in each of those two cases.

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[11] Further, notice that the more categories of *attitude* there are, the less possible paired players encounter failure. If *attitude* is continuous in one language, even a language with only two-dimensional meanings, i.e. *E-meaning* and *A-meaning*, could achieve full coordination situation.

[12] Holm (2000) discusses the idea that introducing Pink and Blue labels into Battle of Sexes Game where gender is revealed information might improve coordination rate.

Figure 1. Modified Holm (2000) Pink-Blue Game

Player 2 Player 1			
		Blue	Pink
	Blue	x, x	0, 0
	Pink	0, 0	x, x

The Pink-Blue game has three Nash equilibria: two pure-strategy equilibria (Pink, Pink), (Blue, Blue) as well as a mixed-strategy equilibrium where each player plays each action with probability 0.5. Neither of the pure-strategy equilibrium Pareto-dominates the other, but both dominate the mixed strategy equilibrium. Given that Pink-Blue is a complete information game, players can use pre-play communication exclusively to make claims about intended moves in order to break the symmetry (as compared to, for example, using this stage to reveal private information).[13]

Next, we map the Pink-Blue game to the framework described above. We begin by specifying the language space with two possible Pareto-efficient Nash equilibria $\boldsymbol{\mathcal{E}}$={(Blue, Blue) (Pink, Pink)} as *E-meanings*, and two possible *A-meanings* $\boldsymbol{\mathcal{A}} =$ {*demanding, deferring*}, where *demanding* indicates stronger desire of have the message followed than *deferring*.

HYPOTHESIS 1*:* *Players communicate with one of four types of messages in game G*(C, $\mathcal{G}$): Demanding Blue (DmB), Demanding Pink (DmP), Deferring Blue (DfB), Deferring Pink (DfP). i.e.* $m_i \in M = \{DmB,\ DmP,\ DfB,\ DfP\}, \forall i \in \{1,2\}$.

DmB refers to the case where the sender intended to play Blue, and requests the other player also play Blue; *DfB* refers to the case where the sender intended play Blue, but is ultimately deferring the choice to the player, and analogously for *DmP* and *DfP*. Hypothesis 1 is built on Definition 1-4. It implies that players in Pink-Blue Game communicate in this well-defined common and complete space with both *E-meaning* and *A-meaning*.

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[13] Farrell (1987, 1988) and Rabin (1991, 1994) provide formal analysis of communication as a means to convey intentions and thereby improve coordination among rational players. Farrell (1987, 1988) studies signaling intentions in simple sequential games of complete information, where an underlying game is preceded by one or more rounds of structured pre-play communication. Rabin (1991, 1994) extends analysis of Farrell (1987, 1988) and studies coordination in a more general class of games with multiple rounds of communication.

4.1. *Equilibria of Pink-Blue*

Based on Assumption 1-3 and Definition 5-7, we obtain following three hypotheses and summarize all connections between messages and actions in Figure 2. When two players signal the same color, they can achieve an *agreement-equilibrium*. When two players signal different colors with different attitudes, they achieve a *negotiated-equilibrium*. Communication failure occurs when the two players signal different colors with same Attitude. In this case, they ignore the messages and play a mixed-strategy Nash equilibrium.

HYPOTHESIS 2: *If paired players send messages signaling intentions to the same color, they will play that color.*

HYPOTHESIS 3: *If paired players send messages signaling intentions to play different colors with one Demanding and one Deferring attitudes, both the demanding player and the deferring players will play the color the demanding player signaled.*

HYPOTHESIS 4: *If paired players send messages signaling intentions to play different colors but with the same attitude, they will play mixed strategies with half chance choosing Blue, and half choosing Pink.*

Figure 2. Responses with Two Conditions in Modified Pink-Blue Game

Player Player				
	(Blue, Blue)	(Blue, Blue)	$((\frac{1}{2}, \frac{1}{2}), (\frac{1}{2}, \frac{1}{2}))$	(Blue, Blue)
	(Blue, Blue)	(Blue, Blue)	(Pink, Pink)	$((\frac{1}{2}, \frac{1}{2}), (\frac{1}{2}, \frac{1}{2}))$
	$((\frac{1}{2}, \frac{1}{2}), (\frac{1}{2}, \frac{1}{2}))$	(Pink, Pink)	(Pink, Pink)	(Pink, Pink)
	(Blue, Blue)	$((\frac{1}{2}, \frac{1}{2}), (\frac{1}{2}, \frac{1}{2}))$	(Pink, Pink)	(Pink, Pink)

4.2. *Communication Strategies*

Figure 2 illustrates the links between all 16 possible paired communication situations and response actions. In Pink-Blue game, a pair of players is guaranteed to coordinate on a Nash equilibrium in the second stage as long as both players respond to each communication situation in first stage according to our model's three assumptions. However, one presumably wants to avoid Pareto-dominated outcomes that result from communication failure. This can be done by optimally use *E-meaning* and *A-meaning* of messages based on beliefs over the distribution of message types.

HYPOTHSIS 5: *With a focal point of (Blue, Blue) in the second stage game, players will send messages with Blue E-meaning, and with a focal point of (Pink, Pink) in the second stage game, players will send messages with Pink E-meaning.*

HYPOTHESIS 6: *Absent a focal point in the second stage game (male-female group), players will send messages including different E-meaning and same A-meaning of messages they believe least likely to receive.*

Hypothesis 6 is derived directly from Proposition 3. Hypothesis 5 is based on the fact that focal point is a solution that people will tend to use in the absence of communication, because it seems natural, special, or relevant to them.[14] When adding a communication stage to games with natural focal points, and thus high rates of coordination in the absence of communication, the improvements communication can make may be limited. Players are nevertheless able to use communication as way to confirm expectations. If both players are females, (Pink, Pink) is focal, while if both are males (Blue, Blue) is focal. With same-gender groups, the focal point is clear given we made announcement about the color-gender relevance, the role of communication in this case is only to confirm. While in a mixed-gender groups, communication can create a focal meaning, once paired players agree on which equilibrium to play, there is no incentive to deviate.

5. EXPERIMENTAL TEST

We conduct Modified Holm (2000) Pink-Blue game under four different communication conditions: no communication (baseline treatment), one-dimensional restricted communication, two-dimensional restricted communication as well as free-form communication.

In baseline, the game proceeds as follows. We begin by randomly assigning people to pairs. We then reveal the gender of each player to the counterpart. Then the paired players

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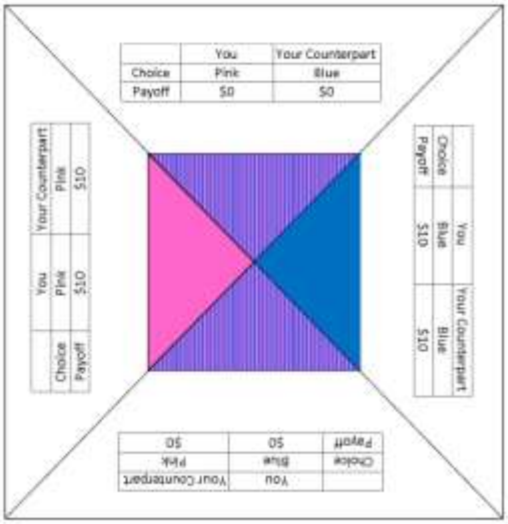
[14] See more at Schelling (1960), p. 57

simultaneously choose a color. If they choose the same color, then both earn the same amount of money in addition to their show-up payment. Otherwise, both earn only the show-up amount.

Figure 3. Instruction Table



To avoid menu effects (for example, the possibility that participants will coordinate on the first listed option), we use a presentation without default “first option”. In particular, we use a square payoff figure (Figure 3) that ensures no option is more salient than any other.

To ensure color-labels were treated the same way across sessions and cultures, in all instructions subjects were informed: "Pink is a color often preferred by females, and Blue is a color often preferred by males".

The three treatments with communication proceed just as in baseline, with the exception that every subject has one chance to send a message to her counterpart simultaneously. They are not able to read the counterparts’ notes until they have finished writing their own messages. Messages are written and delivered after the gender of the counterpart has been revealed and prior to subjects’ Pink/Blue choices. The details of the messages subjects can send in each communication treatment are summarized below.

5.1. *Treatments*

In the one-dimensional restricted communication treatment, subjects are informed they can choose one message from two to communicate with their counterparts: “I am choosing Pink” or “I am choosing Blue”.

In the two-dimensional restricted communication treatment, subjects are informed that each of them can choose one message from four to communicate with their counterparts: “I am choosing Pink no matter what”, “I am choosing Blue no matter what”, “I am choosing the color your message tells me to. If your message says the same, I am choosing Pink.” or “I am choosing the color your message tells me to. If your message says the same, I am choosing Blue.”

In the free-form communication treatment, each subject is given a piece of blank paper. They are told they can write anything except identification information about themselves to their counterpart to communicate.

5.2. *Procedures*

We use a between-subject design. That is, each subject experiences only exactly one treatment. In all treatments, each subject plays three rounds of the same game and faces different counterparts each round. At the beginning of each round, subjects are randomly and anonymously paired. The randomization is not constrained by gender, though most of our subjects experienced games with both genders. At the end of the experiment, one of the three rounds was randomly selected to determine subjects' payoffs.

During the experiment players are seated at separated computer terminals and are given a copy of the experiment’s instructions. These instructions are also read aloud, as we want to ensure subjects understand that the information contained in them is common knowledge.

All four treatments have been conducted at George Mason University, Washington, D.C. The baseline and free-form communication treatments were also conducted in Shanghai Jiao Tong University, Shanghai. Subjects interact only with people from the same university. At Mason, subjects were paid \$5 for showing up and \$10 for coordination success. At SJTU, subjects were paid 10 RMB for showing up and 40 RMB for coordination success (1 US dollar ≈ 6.14 RMB and 1 US dollar ≈ 6.06 RMB when we conducted the experiment in Shanghai, May 2013 and Dec. 2013) The experiment lasted about 40 minutes and the average payoff was designed to be slightly above the local hourly wage for subjects from the two subject pools.

6. RESULTS

Subjects were recruited from the undergraduate population at George Mason University (GMU) and Shanghai Jiao Tong University (SJTU). Each of the 342 participants made 3 decisions for a total of 1,026 observations. Table 1 summarizes our participants' demographics.

Table 1 - Demographics of Participants in Two Pools

	George Mason Univ. Washington D.C., U.S.	Shanghai Jiao Tong Univ. Shanghai, China
Number of Subjects	208	134
Percentage of Males	49.04%	64.18%
Average Age	20.63	21.83
Average GPA	3.24	3.35

The gender ratio of our SJTU pool is unbalanced, which reflects the university's unbalanced gender ratio. This is likely due to the fact that SJTU is famous for its engineering department. About Seventy percent of GMU participants were born in United States, and all of the SJTU participants were born in China. The age and GPA of GMU and SJTU are comparable to each other.

6.1. *Nature of Free-form Communication*

In order to analyze the content of our messages, we used the Houser and Xiao (2011)[15] procedure to classify messages. Thirty-two evaluators from SJTU and 37 from GMU were recruited outside of our experiment subject pool to categorize the free-form messages we collected. Each message was provided to evaluators both in its initial form and its Chinese (or English) translation and classified by these third party evaluators from both universities. Evaluators read messages and placed them into one of the following five categories: "Demanding Pink", "Deferring Pink", "Demanding Blue", "Deferring Blue" and "None of Above". The instructions laid out how evaluators should categorize messages: "[Y]ou should choose 'Demanding Pink' if you believe the message writer intends to play Pink, and requests that her or his counterpart also chooses Pink. You should choose 'Deferring Pink' if you believe

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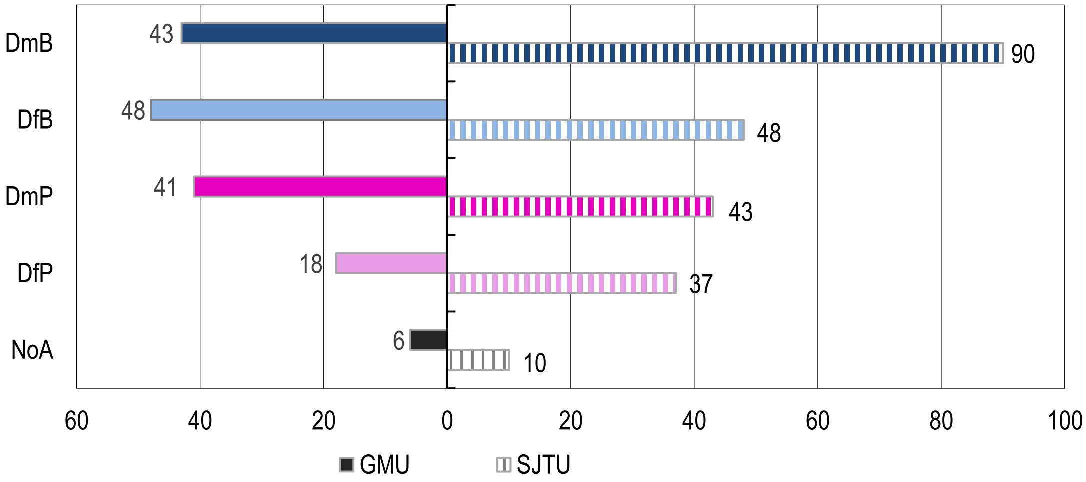
[15] While some previous literature on communication uses research assistants as evaluators, Houser and Xiao (2011) discuss the advantage of using a coordination game classify message content. This classification method is increasingly used to classify messages from free-form communication studies (e.g. Xiao and Houser, 2005; Gächter et al. 2013; Deck et al. 2013; Ong et al. 2012; Chen et al. 2014).

the message writer intends to play Pink, but is ultimately deferring the choice to her or his counterpart." Similar wording was used for "Demanding Blue" and "Deferring Blue." Evaluators are paid based on whether their categorization of three randomly chosen messages are consistent with the most popular categorization for that session.

RESULT 1. *95.83% messages are classified consistently by evaluators from the U.S. and China as communicating with one of the four types: Demanding Blue, Deferring Blue, Demanding Pink or Deferring Pink.*

Figure 4. Number of Messages Classified as Each Communication Style (By Culture)



It is important to emphasize that messages were classified based on message content only. Evaluators were provided no other information. In particular, evaluators did not know which messages were paired and knew neither the gender nor the choices of the message writers. Because evaluations are independent of participants' choices, we are able to use the classified *E-meanings* and *A-meanings* to test whether people wrote and responded to messages as our theory predicts.

To provide a sense of the nature of messages in each category, we have provide below one sample message from each category (see all 384 messages and their classifications at online Appendix).

One message stated "Pick Blue no matter what." 97.30% of American evaluators and 87.50% of Chinese evaluators classified this message as "Demanding Blue."

Another subject wrote the following: “Hi, I will follow what you wrote on this paper. If you signaled Pink, I will choose Pink, if you wrote Blue, I will choose Blue. If you didn't signal any color, please choose Blue.” 94.59% American evaluators and 96.87% Chinese evaluators classify this message as “Deferring Blue”.

“Pink! Girl's Rule! No if ands or but! I will NOT change! 100% Pink!! I will not choose otherwise even if you 100% say different or tell me to change! I will NOT change! Go Pink!” 89.19% of American evaluators and 93.75% of Chinese evaluators classify this message as “Demanding Pink.”

“Going with whatever color you say. (If you don't mention a color I will go with Pink.)” 91.89% of American evaluators and 96.88% of Chinese evaluators classify this message as “Deferring Pink.”

A final example is: “The point of coming to these experiments is to make money. I don't care about the colors and what-not. So let's try and choose the same option.” 97.30% of American evaluators and 96.88% of Chinese evaluators classify this message as “None of Above.”

We used the classification of a message as one of the four categories in our model only if more than 50% of the evaluators from both pools place it in that same category. We classify a message as “None of Above” if more than half of evaluators from both pools believe it belongs to “None of above,” or fewer than 50% of evaluators agree on any of the four named categories.

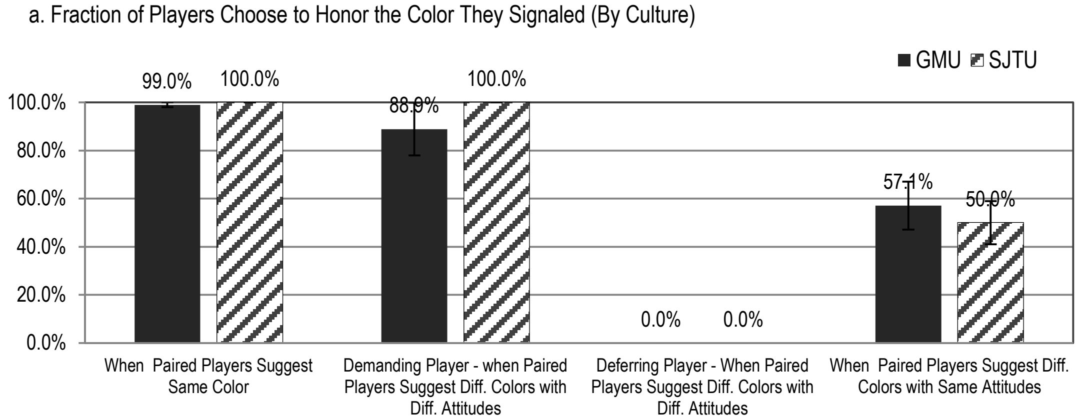
6.2. *Responses to Free-form Messages*

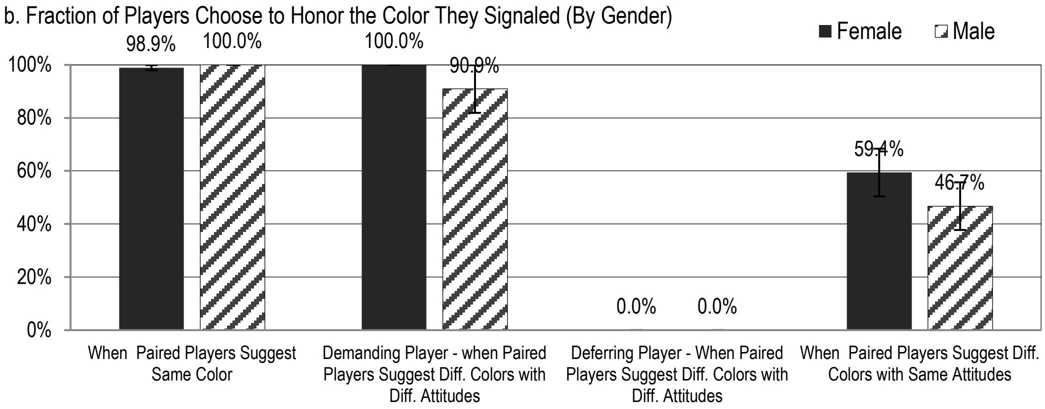
In this subsection, we focus on the analysis of cases where both messages from paired players are classified as one of the four named types (which is 95.83% of the messages we collected). The following three results test the hypotheses about how people respond to messages.

RESULT 2. *When paired players send messages that signal same color, 99.6% of them choose to honor the color they signaled.*

Figure 5 presents the fraction of players that honored the colors of their messages by culture (5a) and gender (5b). Overall, 99.6% of players choose to honor the color of messages when paired players send messages that signal the same color. Consequently, players achieve agreement-equilibrium with 99.2% probability. Furthermore, there is no significant difference between both cultures and genders in the proportion that choose to honor their signaled colors.[16]

Figure 5. Fraction of Players Choose to Honor the Color of Messages


a. Fraction of Players Choose to Honor the Color They Signaled (By Culture)


b. Fraction of Players Choose to Honor the Color They Signaled (By Gender)

RESULT 3. *When paired players send messages that signal different colors, with one player sending a demanding message and the other sending a deferring message, 95.7% of demanding players honor the color they signaled, while no deferring player honors the color they signaled.*

The second and third columns of Figure 5 display the percentages of demanding and deferring players who choose to honor the colors they signaled. 95.7% of pairs coordinate on the *negotiated-equilibrium* when they sent messages that signal different colors with different

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[16] Regarding the independence of the data included in our non-parametric tests, only the first observation from each individual in each comparison category is included. For both cross culture and between gender comparisons, the rate of honoring one's stated color is approaching to100% for each pool respectively. Thus, no P-value is provided here.

attitudes. Result 3 presents strong evidence that people take advantage of and respond to the attitudes of language. As depicted in Figure 5a, the cultural difference of neither how demanding players respond (WMW test: z=-1.173, P=0.241, two-sided test, n_1=8, n_2=11) nor how deferring players respond in this case is not significant (WMW test:[17] z=., P=., two-sided test, n_1=6, n_2=12). As shown in Figure 5b, gender differences are not significant for demanding player responses (WMW test: z=0.949, P=0.343, two-sided test, n_1=9, n_2=10) and deferring player responses (WMW test: z=., P=., two-sided test, n_1=12, n_2=6).

RESULT 4. *When paired players send messages that signal different colors with same attitude, 53.2% of players honor the color they signaled.*

The last column of Figure 5 displays the fraction of people who choose to honor the color they signaled when paired players sent messages that signal different colors with the same attitude. In this case, about 53.2% of players honor the color that they signaled. This number is consistent across cultures (WMW test: z=0.441, P=0.659, two-sided test, n_1=22, n_2=27) and gender (WMW test: z=0.704, P=0.481, two-sided test, n_1=25, n_2=24). With only about half of the subjects choosing to honor the color they signaled, they successfully managed to coordinate 87.1% of the time. This is due to two reasons. First, even if communication fails, players can still use a focal point to solve the problem. (This can be identified by separating same-gender matches from mixed-gender matches. We'll discuss this in the next subsection.) More importantly, another possibility is that the attitudes that subjects indicate in the messages are more finely partitioned than just two categories (i.e. demanding or deferring).

RESULT 5. *When the conditions of an agreement equilibrium or a negotiated equilibrium are satisfied in the first stage, the coordination rate in the second stage is significantly higher than otherwise.*

Since a first stage equilibrium is the result of a player's own communication style as well as their counterpart's, we did not perform non-parametric tests as that requires a randomly assigned

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[17] For both cross-culture and between gender comparisons of deferring players' responses, all players chose to honor demanding players' *E-meaning*s. Thus, no P-value can be provided.

independent variable. To accommodate the binary dependent variable and the issue of non-independence with respect to individuals, we used Probit models that control for random effects at the individual level. The dependent variable in the model is coordination success, which takes value of 1 if two matched players choose the same option and takes a value of zero otherwise. The following independent variables are included in the regressions: a *negotiated equilibrium* condition dummy, which takes value of 1 if the subjects have achieved the conditions for *negotiated equilibrium* in the first stage, and 0 otherwise; a *communication-failure* condition dummy, which takes value of 1 if subjects face the condition of communication failure in the first stage, and 0 otherwise; a culture dummy, which takes a value of one for GMU subjects, and 0 for SJTU subjects; a gender dummy, which takes a value of 1 for male subjects, and 0 for female subjects; a gender counterpart dummy, which is equal to 1 for the subjects who interact with male counterparts in the round, and 0 for the subjects who interact with female counterparts; age; years of residence at the current location; GPA; and relationship status, which takes a value of 1 if the subject is in a committed in a relationship, a value of 2 if subjects has a relationship but not committed to it, and a value of 3 if single.

Model 1 of Table 2 includes all the data we collected. It shows that the coordination rate in the baseline of an *agreement equilibrium* condition is significantly higher than in communication failure cases, while not significantly different than the *negotiated equilibrium* cases.

Model 2 and 3 of Table 2 are pairwise comparisons of when conditions of different equilibria are achieved. Model 2 only includes data of cases where the conditions of either *negotiated equilibrium* or *communication-failure equilibrium* have been achieved. Model 3 only includes data from cases when the conditions of either *agreement equilibrium* or *communication-failure equilibrium* have been achieved.

These regressions show that (i) the coordination rate in cases when *agreement equilibrium* conditions have been achieved is not higher than when *negotiated equilibrium* conditions have been achieved; (ii) the coordination rate in cases when either *agreement equilibrium* conditions or *negotiated conditions* have been achieved is significantly higher than when *communication-failure* conditions have been achieved.

Table 2 - Effect of Communication on Coordination Rate

Dependent Variable: Coordination Success			
Model	1	2	3
Negotiated Equilibrium Conditions	-0.67		
	(0.52)		
Communication-failure Conditions	-1.35***	-0.74*	-1.35***
	(0.43)	(0.43)	(0.47)
Culture	-0.48	-0.25	-0.01
	(0.46)	(0.49)	(0.51)
Gender	0.63	1.12**	0.80
	(0.44)	(0.55)	(0.50)
Gender of Counterpart	0.55	0.96*	0.72
	(0.40)	(0.50)	(0.46)
Age	0.03	0.01	0.06
	(0.09)	(0.10)	(0.11)
Year	-0.01	-0.01	-0.03
	(0.03)	(0.03)	(0.03)
GPA	-0.71	-1.25*	-0.51
	(0.53)	(0.65)	(0.56)
Relationship Status	0.09	0.09	0.08
	(0.22)	(0.26)	(0.25)
Constant	3.94	5.05	2.64
	(2.97)	(3.37)	(3.21)
Number of Observations	343	104	299

*** Significant at the 1% level. ** Significant at the 5% level. * Significant at the 10% level. Standard errors robust to heteroskedasticity are shown in parentheses. All models include random effects, with individual subject effects.

6.3. *Communication Strategies*

The communication styles players use may vary with different gender pairings and across cultures. The next three results summarize some basic findings of communication strategies and its impact on coordination rates.

RESULT 6. *Male-Male matched players send messages with DmB and DfB communication styles more frequently than DmP and DfP. Female-Female matched players send message with DmP and DfP communication style more frequently than DmB and DfB.*

Figure 6. Communication by Matching Type and University

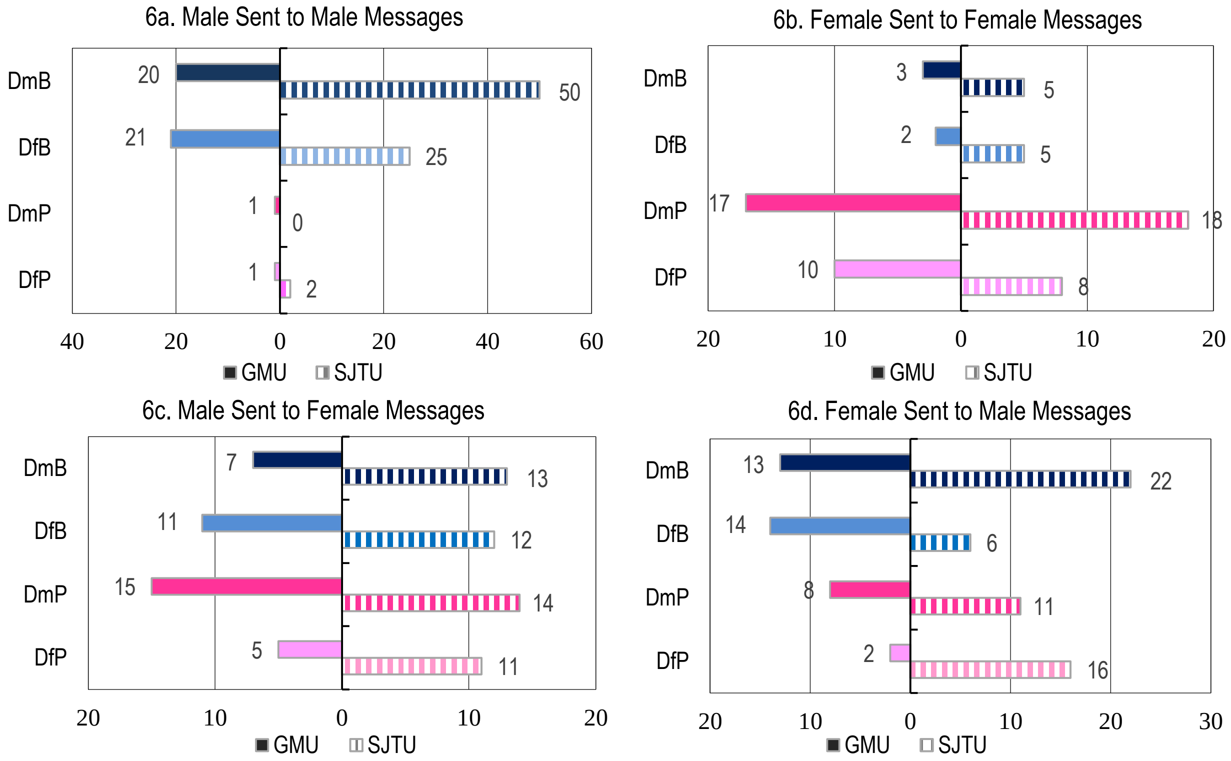


Figure 6 partitions the distribution of communication styles into the four possible pairings (Male-Male, Female-Female, Male-Female, Female-Male) and two cultures (GMU, SJTU). As Figure 6a shows, only 4.7% of cases in GMU and 2.6% of cases in SJTU Male-Male matched players choose communication style with Pink *E-meaning*. Slightly more Blue *E-meaning* messages are sent by females, but still much less than Pink *E-meaning* messages. 15.6 % of cases in GMU and 27.7 % of cases in SJTU Female-Female players choose communication styles with Blue *E-meaning* (see Figure 6b). Comparing part c and part d of Figure 6, one can observe some gender differences in communication styles in the mixed-gender environment, which we will address in next result.

In order to investigate more about the gender differences of communication styles, we adopt a statistical classification procedure proposed by El-gamal and Grether (1995). With this procedure, we are able to group all messages collected from each individual to investigate her communication styles. Based on the observation that some subjects always send the same style of message regardless the gender of the counterpart, while the others vary the *E-meaning* or *A-meaning* according to their counterpart's gender, we assume in our statistical model that players in the game are comprised exclusively of five behavioral types chosen randomly from separate distributions. Each individual is assigned a positive prior probability for four "dogmatic" types and one sophisticated type.

Specifically, we restrict our attention to the following types of players: *dogmatic DmB* players, who always send a *DmB* message; *dogmatic DfB* players, who always send a *DfB* message; *dogmatic DmP* players, who always send a *DmP* message; *dogmatic DfP* players, who always send a *DfP* message; and *sophisticated* players, who send messages with a focal point color as *E-meaning* if a focal point exists (same-gender pairings) but send messages with different *E-meanings* and same *A-meaning* of least popular communication style among the counterparts' population if there is no focal point (mixed-gender pairings).

For each subject *i*, we calculate a sequence of communication style statistics $x_1^i, \dots, x_{T_i}^i$, for each trial based on the classification of her messages and the counterpart's gender. $x_{cs^h,\tau}^i \in \{x_{dDmB,\tau}^i, x_{dDfB,\tau}^i, x_{dDmP,\tau}^i, x_{dDfP,\tau}^i, x_{soph,\tau}^i\}$, where $x_{cs^h,\tau}^i$ equals 1 if the subject i's decision on trial τ agrees with rule *h*, and zero otherwise. We observe T_i decisions for a subject *i*. Now we define the sufficient statistic, $X_{cs^h}^i = \sum_{\tau=1}^{T_i} x_{cs^h,\tau}^i$ (the number of decisions that agree with rule *h*). Following El-Gamal and Grether (1995), we assume different subjects may use different rules and the error rate is same for all subjects and all tasks. We introduce the possibility that subjects make errors with probability ε. This allows each of our decision rules to give a positive probability (likelihood) to all possible patterns of behavior. The likelihood function for subject *i* is:

$$f^{cs,i}\left(x_1^i, \dots, x_{T_i}^i\right) = (1 - \tfrac{\varepsilon}{2})^{X_{cs}^i} \times (\tfrac{\varepsilon}{2})^{(T_i - X_{cs}^i)} \qquad (1)$$

If there are *I* subjects, each indexed by *i*, then a natural way to estimate the communication style is to apply maximum likelihood using:

$$(\widehat{cs}, \hat{\varepsilon}) = argmax_{cs,\varepsilon} \prod_{i=1}^{I} \prod_{h=1}^{H} (f^{cs^h,i}\left(x_1^i, \dots, x_{T_i}^i\right))^{\delta_{ih}} \qquad (2)$$

where $\delta_{ih} \in \{0,1\}$ equals 1 if subject *i* is using rule *h*, and zero otherwise. In summary, we first calculate the maximum likelihood $f^{cs^h,i}$ of each communication rule cs^h for each individual

i; we choose the communication rule to maximize $f^{cs,i}$ for each individual i; we multiply the obtained likelihood over individual $i \in \{1, \dots, I\}$, and maximize the outcome by choosing $(\widehat{cs}, \hat{\varepsilon})$.

Turning on to estimation results, Figure 7 summarizes the outcome of El-gamel and Grether (1995) procedure when applied to our data. Each bin bar represents to percentage of 128 subjects fit into the communication styles.

RESULT 7. *While a large proportion of players use sophisticated communication styles, males are more likely be dogmatic senders who always send Blue messages, and females are more likely to be dogmatic senders who always send demanding messages.*

Figure 7. Communication Styles Classification by El-gamal and Grether (1995) Method (By Gender)

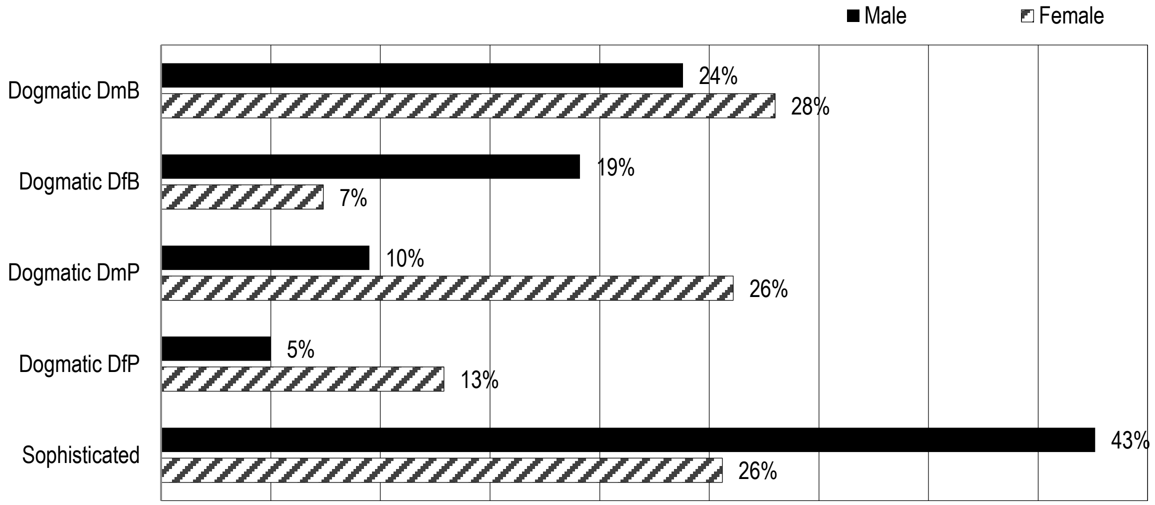


Figure 7 shows that 43% of male players are sophisticated senders and 26% of females are sophisticated senders. Furthermore, while 43% of male players are either *dogmatic DmB* senders or *DfB* senders, only 15% of male players are *dogmatic Pink* message senders. 54% of females are *dogmatic demanding* senders while only 20% of females are dogmatic deferring senders.

6.3. *Baseline, Restricted Communication and Free-form Communication*

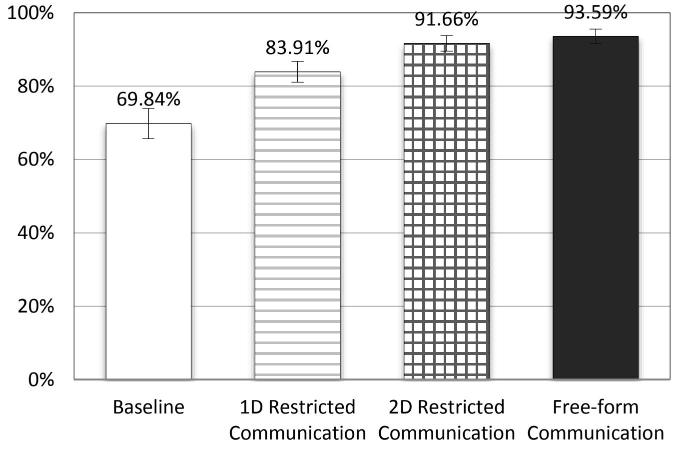
We conducted a baseline treatment with no communication, a treatment with one-dimensional restricted communication and a treatment with two-dimensional restricted communication in George Mason University to compare with free-form communication.

Result 8 compares the impact of all three communication treatments on improving coordination rates and elucidates why one works better than the other.[18]

RESULT 8. *The overall coordination rate in the free-form communication treatment is as high as the two-dimensional restricted communication treatment, but is significantly higher than one-dimensional restricted communication treatment and baseline.*

Figure 8 displays the coordination rate in four treatments. In the treatment with free-form communication, the coordination rate is as high as 93.59%, which is not significantly higher than two-dimensional restricted communication (WMW test: z = -0.659 P=0.510, two-sided test, $n_1 = 168, n_2 = 156$), but is significantly higher than one-dimensional restricted communication (WMW test: z = -2.747 P=0.006, two-sided test, $n_1 = 174, n_2 = 156$) and baseline treatment (WMW test: z = -4.173, P<0.001, two-sided test, $n_1 = 42, n_2 = 52$).

Figure 8. Coordination Rate with Baseline, 1D Restricted, 2D Restricted and Free-form Communication



RESULT 9. *When paired players send messages that signal the same color, the coordination rate is not different between free-form communication and two-dimensional restricted communication. When paired players send messages that signal different colors with different attitudes, the coordination rate is slightly higher in two-dimensional restricted communication.*

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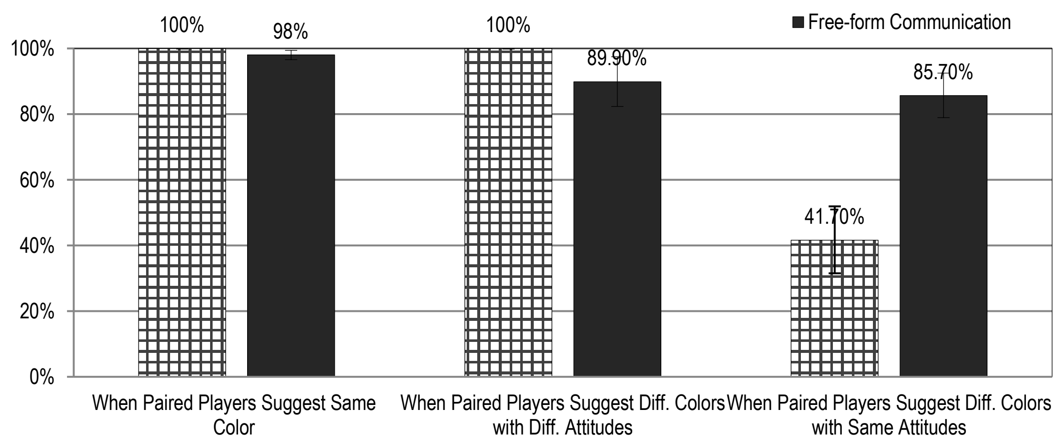
[18] All the results in this subsection only have GMU data included, since that SJTU subjects didn't participate the restricted communication treatments.

Free-form communication improves coordination significantly more than two-dimensional restricted communication when paired players send messages that signal different colors with the same attitude.

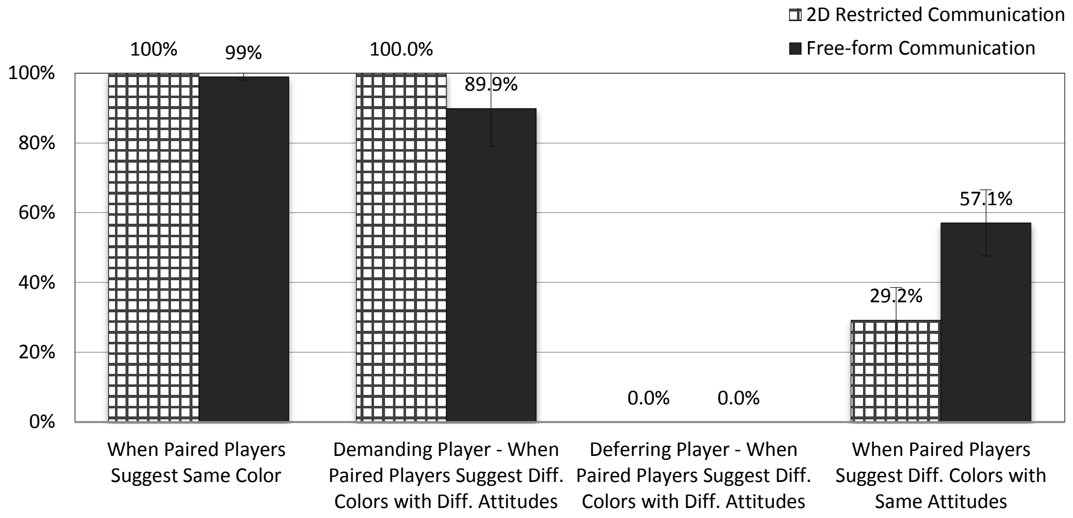
Figure 9 breaks down the coordination rate of two-dimensional restricted communication and free-form communication into the following three different communication cases: paired players signal same color, paired players signal different colors with different attitudes, and paired players signal different colors with same attitudes. In the first case, the coordination rate has no difference in two treatments (WMW test: z = 1.500, P=0.133, two-sided test, $n_1 = 112, n_2 = 100$). When paired players sent messages that signal different colors with different *attitudes*, two-dimensional restricted communication is slightly better than free-form communication. (WMW test: z =1.905, P=0.057, two-sided test, $n_1 = 32, n_2 = 18$). When paired players sent messages that signal different colors with same *attitudes*, free-form communication works much better than two-dimensional restricted communication (WMW test: z = -3.296, P=0.001, two-sided test, $n_1 = 24, n_2 = 28$).

Figure 9. Coordination Rate in Three Communication Cases



RESULT 10. *When paired players send messages that signal different colors with the same attitude, more players honor the color signaled in the messages of the free-form communication treatment than in the two-dimensional restricted communication treatment.*

Figure 10. Fraction of Players Chose to Honor the E-meaning (Color) of Messages



We compare the fraction of players choosing to honor the colors they signaled in two-dimensional restricted communication with free-form communication treatment. As shown in Figure 10, there is no significant difference in the first three columns, which displays the fraction of players choose to honor the color of messages when paired players signal same color, the fraction of the demanding players choose to honor the color of messages when paired players signal different colors with different attitudes, and the fraction of deferring players choose to honor the color of messages when paired players signal different. However, significantly fewer players honor the color of the messages in two-dimensional restricted communication treatment (WMW test: z = -2.005, P=0.045, two-sided test, $n_1 = 24, n_2 = 28$).

7. CONCLUSIONS AND DISCUSSION

This paper provides an explanation for why natural language communication promotes coordination better than classical intention signaling. Independent from intention signaling, we assume each player is able to signal the strength of desire to have her intention followed. We show that, allowing two-dimensional signaling reduces the chance of coordination failure. Conducting a series of experiments, our findings confirm that when communicating in free-form, people write messages that include both signaled intentions and attitudes, and people respond to both when making their decisions. Consequently, free-form communication promotes coordination as well as two-dimensional restricted communication, and significantly better than one-dimensional intention signaling or games without communication. As Robert Gibbons mentioned in his book[19] “The spirit of cheap talk is that anything could be said, but formalizing this would require M (i.e. the set of messages can be sent) to be a very large set” Our results shed light on the fundamental question of how rich a message space should be in order closely to capture key features of cheap-talk.

Use of a predetermined restricted message space might have methodological advantages, for example by allowing for clean tests of theoretical predictions and simplifying data analysis. However, consistent with the existing literature (Charness and Dufwenberg 2009; Cooper and Kühn 2014; Cason and Mui 2015), we find that restricted signaling has less behavioral impact than free-form communication.

We conclude by discussing three future research ideas that extend on our study. The classification procedure we adopt includes a 2×2 message space: two *E-meanings* and two *A-meanings*. However, a likely feature of natural language is that attitudes are more finely-grained. For instance, two demanding messages may differ in that one is more demanding than the other. If so, players may be able to take advantage of a common understanding of more subtle distinctions in attitude to achieve coordination. It would be interesting in our setting to implement classification procedures which include more attitude categories. We speculate that doing so would reduce differences between restricted (predetermined) communication with two-dimensional meanings and free-form communication.

Our model departs from other intention signaling papers (e.g. Farrell 1987, 1988; Rabin 1991, 1994) principally in the nature of the multi-dimensional language space. We intentionally focused on a pure coordination game so that social preferences do not complicate our analysis. In this environment the use and effect of communication is more readily discerned. Of course, many natural environments of interest cannot be modeled as pure coordination games (e.g. when players’ interests are not perfectly aligned), and social preferences do play a ubiquitous role in determining economic choices. An important example is deception when players may benefit from misleading other participants. The role of multi-meaning messages in environments that include the possibility of strategic signaling, and especially when messages can be “deceptive” or “partially deceptive”, is an important open question for future investigation.

In relation to restricted language, natural language communication might better enhance group-identity. This might then promote lie-aversion or guilt-aversion, and might also improve

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[19] See Page 212, *Game Theory for Applied Economists*, 1992 by Princeton University press.

one's understanding of the connections between one's decisions and one's outcomes[20]. In our experiment, group-identity likely plays a rather small role given that one-shot simultaneous communication occurs between anonymously paired subjects, with neither feedback nor face-to-face interaction. Understanding how multi-meaning natural language enhances group-identity would be particularly useful.

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[20] See Frey and Bohnet (1995), Valley et al. (1998), Mohlin and Johannesson (2008), Cooper and Kühn (2015 *Working Paper*).

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APPENDIX – PROOFS

PROOF OF PROPOSITION 1: $\forall\ \mathcal{E}_k \in \boldsymbol{\mathcal{E}}$*, by definition it is necessarily true that* $\pi_i\left(s_i', s_j^{\mathcal{E}_k}\right) \leq \pi_i(s_i^{\mathcal{E}_k}, s_j^{\mathcal{E}_k}),\ \forall s_i' \in S_i$ *and* $s_i' \neq s_i^{\mathcal{E}_k}, \forall i, j \in \{1,2\},\ j \neq i.$ *Given* $m_i \in Q(\mathcal{E}$