Timing of Messages and the Aumann Conjecture: A multiple-Selves Approach*

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Abstract

The Aumann (1990) conjecture states that cheap-talk messages do not necessarily help to coordinate on efficient Nash equilibria. In an experimental test of Aumann's conjecture, Charness (2000) found that cheap-talk messages facilitate coordination when they precede the action, but not when they follow the action. Standard game-theoretical modeling abstracts from this timing effect, and therefore cannot account for it. To allow for a formal analysis of the timing effect, I study the sequential equilibria of the signaling game in which the sender is modeled as comprising two selves: an acting self and a signaling self. I interpret Aumann's argument in this context to imply that all of the equilibria in this game are 'babbling' equilibria, in which the message conveys no information and does not affect the behavior of the receiver. Using this framework, I show that a fully communicative equilibrium exists — only if the message precedes the action but not when the message follows the action. In the latter case, no information is transmitted in any equilibrium. This result provides a game-theoretical explanation for the puzzling experimental results obtained by Charness (2000). I discuss other explanations for this timing-of-message effect and their relationship to the current analysis.

Keywords *pre-play communication, Nash equilibrium, coordination games, multiple selves*
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1 Introduction

"Cheap talk" communication is a prevalent part of economic interactions across many domains. Although cheap-talk pre-play communication does not carry the potential strategic power of costly signaling, it is nonetheless likely to have an effect in some types of games, especially when the sender and the receiver have some common interests (Crawford and Sobel, 1982; Farrell and Rabin, 1996). One important class of such games consists of coordination games such as the Stag-Hunt game depicted as Game 1 below. The game has two equilibria in pure strategies, namely (*A*,*A*) and (*B*,*B*). As (*B*,*B*) pareto-dominates (*A*,*A*), the two players clearly have a shared interest to coordinate on the cooperative outcome (90,90). However, playing the cooperative strategy B involves greater strategic uncertainty than the 'safe' option *A*. The payoff-inferior equilibrium (*A*,*A*) is, in the language of Harsanyi and Selten (1988), *risk dominant*.[1]

	A	*B*
A	70,70	80,10
B	10,80	90,90

Game 1: Stag-Hunt

Intuitively, it seems that if the players can discuss the game before playing, they would easily be able to coordinate on the pareto-dominant equilibrium. In other words, the Nash equilibrium is a "self-enforcing agreement". By the nature of Nash equilibria, a message from the sender indicating that she plays *B* is indeed self-committing, i.e., the sender has no incentive not to comply with the message if she expects it to be believed.[2] However, Aumann (1990) has argued that such a message is not self-signaling, in the sense that it does not inform the receiver that the sender indeed plays *B*. Essentially, the argument is the following one: Rather than conveying the literal information contained in the message, the message merely informs the receiver that the sender wishes him to believe that she plays *B*.[3] Since this is true regardless of the sender's actual strategy, the message carries no relevant new information for the receiver. In other words, Aumann (1990) claims that the beliefs of the receiver should not be affected by the message sent by the sender.

Notwithstanding the normative appeal of Aumann's (1990) argument, there is some experimental evidence showing that pre-play messages can be effective in this setting

[1]Harsanyi (1995) considers risk dominance to be the crucial choice criterion among different equilibria.

[2]In this paper I consider the sender to be female and the receiver to be male.

[3]Farrell (1993) goes even further, and suggests that the message might inform the receiver that the sender wishes him to believe that she wishes him to believe that she plays *B*. This line of reasoning can be extended recursively ad infinitum.

under some conditions (Clark et al., 2001; Charness, 2000).[4] One important variable to come out of the literature is the timing of the signal, which was first raised in the literature by Farrell (1988), based on his analysis of to games with pre-play communication. The analysis, utilizing a new solution concept, predicts that cheap-talk pre-play messages lead to coordination on the pareto-efficient equilibrium. Consequently, Farrell (1988) conjectured that Aumann's (1990) argument only holds when the message follows the action. Charness (2000) followed up on Farrell's (1988) comment in an experiment with one-way messages from one player to another. In the *AS* treatment, the sender first decides on an action and then sends a message indicating her game action, whereas in the *SA* treatment, the temporal order is reversed. Although the two temporal orders are equivalent from an informational perspective, they were found to result in significantly different behavior in the experiment.[5] When the game decision made by the sender follows the message, the proportions of *B* decisions and (*B*,*B*) outcomes greatly and significantly increase. Conversely, when the message was preceded by the game decision, *B* choices were not significantly more frequent than in a no-communication baseline treatment, but were significantly *less* frequent than in the *SA* treatment.[6] Thus, the experimental data supports Farrell's (1988) conjecture.

In this paper, I propose a framework in which the timing of messages can be modeled, and apply it to the experimental game of Charness (2000). The results of the analysis reveal a hidden subtlety in the theoretical argument. Most importantly, the analysis provides an explanation for the puzzling experimental results. In the new framework, the game is represented as a signaling game, in which messages and beliefs can be analyzed. To model the timing in the game, I model the sender as comprising two selves: an acting self and a signaling self. This modeling choice gives rise to a three-player extensive-form game, which is then solved using standard game-theoretical tools. In this framework, I interpret Aumann's (1990) statement to mean that all sequential equilibria in the game are "babbling" equilibria, in which "the Sender's message is uninformative and is ignored by the receiver" (Crawford, 1998, p. 287). I find that, when the action precedes the message, sequential equilibria exist, in which the message conveys some information. However, when the message is informative to the degree that the receiver no longer ignores it, it cannot be sequentially rational. Thus, the claim holds in

[4] Clark et al. (2001) found that two-way pre-play communication lead to a significant increase in coordination on the cooperative equilibrium and that subjects were much more likely to choose the cooperative action if the cooperative messages were sent. Nonetheless, they concluded that Nash equilibria are not self enforcing in this game, since, even with communication, subjects chose the cooperative action only 42% of the time and only 57.5% of the choices conform to a rule conditioning on cooperative messages.

[5] Luce (1990) argues that abstracting from the temporal aspect of decisions is "A clear failing of the modeling" (p. 228).

[6] The increase in coordination on the payoff-dominant equilibrium in the *AS* treatment was marginally significant under a single-period analysis. Furthermore, less conservative tests, which ignore within-subject and within-matching group dependencies, detect a significant increase in all measures, suggesting that messages that follow the action do have a moderate effect on cooperation.

a weaker variant, namely in all sequential equilibria the message is *either* uninformative *or* ignored by the receiver (or both). Conversely, when the message precedes the action, many communicative sequential equilibria exist, defined as equilibria in which the message is *both* informative and acted-upon. In particular, there exists a pure equilibrium in which the message is fully informative and is perfectly acted upon. This is true not only in the Stag-Hunt game, but generally for coordination games.[7]

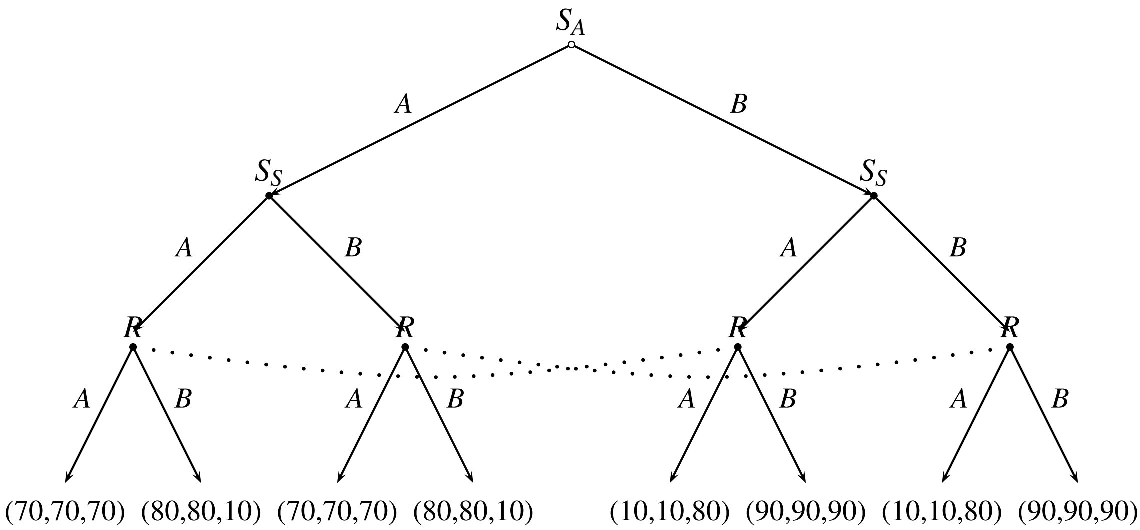
The intuition behind the result can be understood in terms of a sequential process involving mistakes. The sender makes two decisions, an action decision and a signaling decision. When considering an equilibrium in which the signal is aligned with the action (and is believed by the receiver), the multiple-selves model makes the sequential nature of the decision process explicit, and requires the equilibrium to specify how the sender would react upon discovering she has made a mistake in her first decision (for example, by absentmindedly pressing the wrong key). If the sender has sent the wrong message, it is rational for her to alter her action accordingly, so that the message is still reliable. Conversely, if the sender has made the wrong action, it is not rational for her to change her intended message to correspond to the actual action, in line with Aumann's (1990) argument. According to this interpretation, the multiple-selves model should not be taken literally, but rather as a technical device to capture intra-personal sequential processes.

The rest of the paper is organized as follows: Section 2 presents the multiple-selves approach to the game and the theoretical results, and generalizes the results beyond the Stag-Hunt game. Section 3 reviews alternative ways to explain the timing effect and their relation to the current analysis. Section 4 concludes.

2 A multiple-selves approach to signaling actions

The multiple-selves approach has been widely used in economics, philosophy and psychology, mostly to analyze situations in which the different selves have conflicting interests (Moldoveanu and Stevenson, 2001), most prominently in issues of self control (Strotz, 1955; Schelling, 1984), and particularly with regard to time preferences (Thaler and Shefrin, 1981; Fudenberg and Levine, 2006). The view of an agent as multiple selves with identical preferences making decisions over time was previously used to analyze problems associated with imperfect recall (Piccione and Rubinstein, 1997; Aumann et al., 1997; Gilboa, 1997; Halpern, 1997). To the best of my knowledge, this paper is the first application to modeling the timing of decisions made by a single player with consistent information and preferences.

[7] For some games, a communicative equilibrium exists under both protocols, as Aumann (1990) illustrates using the Battle-of-the-Sexes game. On the other hand, if the players have strictly-opposed preferences, cheap talk can never have an effect (Crawford and Sobel, 1982).



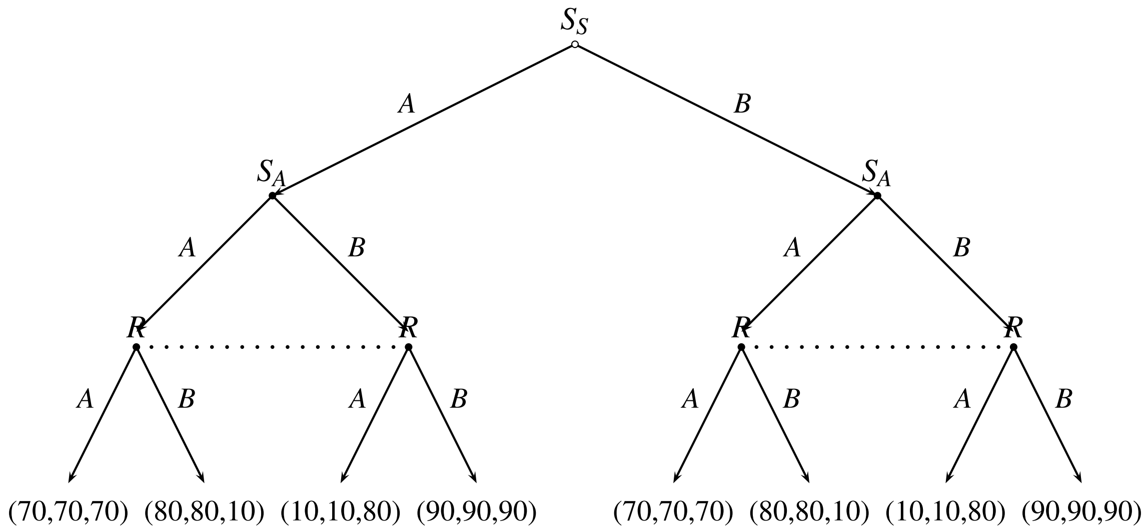
Game 2: Stag-Hunt with signaling, action first

To turn the normal form Game 1 into a signaling game with multiple selves, construct an extensive form game with imperfect information, which has three players: the sender's acting self (denoted by S_A), the sender's signaling self (denoted by S_S), and the receiver (denoted by R). The receiver is always the last mover, and only observes the choice of the sender's signaling self, whereas the order of the first two movers is determined by the protocol. The resulting game trees for *action-then-signal* and *signal-then-action* are shown as Games 2 and 3, respectively.

A sequential equilibrium in the game is a tuple $\{\sigma_1, \sigma_2, \rho, \beta\}$, where $\sigma_1 \in [0,1]$ is the mixed strategy of the first mover, indicating a probability assigned to choosing B; $\sigma_2 : \{A,B\} \rightarrow [0,1]$ is the strategy of the second mover, mapping the observed first mover's choice to a probability assigned to choosing B; $\rho : \{A,B\} \rightarrow [0,1]$ is the strategy of the third mover's decision, mapping the observed signal to a probability assigned to choosing the action B. Finally, $\beta : \{A,B\} \rightarrow [0,1]$ is the third mover's belief, mapping the observed signal to the probability assigned to the action of S_A being B. Note that σ_1 is an action and σ_2 is a message in Game 2 and vice versa in Game 3.

Let's return to the original argument in favor of Nash equilibria as self-enforcing agreements. In our signaling games, it is taken to mean that the sender sends a message B, which reliably conveys the information that she plays B, i.e., if the action were A, the message would also be A. Consequentially, the receiver believes this message and acts accordingly.[8] Formally, the following conditions should be fulfilled in order to maintain

[8]The analysis is related to the model proposed by Cooper et al. (1992), who also look for reliable-communication equilibria. However, their results rely on the analysis of the normal-form game, which abstracts from temporal effects, and depend on further assumptions regarding the existence of altruistic players in the population.



Game 3: Stag-Hunt with signaling, message first

such a reliable message to cooperate in a sequential equilibrium:

1. The first mover chooses B; $\sigma_1 = 1$.
2. The second mover mimics the choice of the first mover; $\sigma_2(A) = 0$ and $\sigma_2(B) = 1$.
3. The third mover follows the signal; $\rho(A) = 0$ and $\rho(B) = 1$.

Proposition 1. *A sequential equilibrium fulfilling conditions 1–3 exists in the message-first Game 3, but not in the action-first Game 2.*

Proof. First, check that conditions 1–3 can simultaneously hold in Game 3. Given that, by conditions 2 and 3, both the acting sender and the receiver follow the signal, the first mover obtains a payoff of 90 by sending B versus 70 by sending A, hence condition 1 holds. Condition 3 states that the receiver follows the signal. Since the acting sender's best response to the receiver is to choose the same action, she maximizes her payoff by following the signal as well, i.e., condition 2 holds. Lastly, given condition 2, the receiver should follow a signal B with B; $\rho(B) = 1$. When the off-equilibrium signal A is observed, the receiver's consistent belief is that the acting sender played A, to which he best-responds by playing A; $\rho(A) = 0$. Hence, condition 3 holds.

Next, consider the action-first Game 2. Here, conditions 2 and 3 cannot hold simultaneously. To see this, assume that condition 3 holds, i.e., the receiver follows the signal. Now, if the signaling sender observes an action A, she expects a payoff of 70 from sending an A signal versus a payoff of 80 from sending a B signal. Therefore, payoff maximization dictates that $\sigma_2(A) = 1$, thus contradicting condition 2, in line with Aumann's (1990) argument. □

Proposition 1 establishes that Game 3 has a communicative sequential equilibrium. Thus, allowing for a pre-play message from one player extends the set of available equilibria beyond babbling equilibria. In contrast, such a fully-communicative equilibrium does not exist in Game 2. Can a more general negative statement be made about Game 2? Are there only babbling equilibria in this game, or can some information transmission be supported in equilibrium? It is, in fact, possible for the receiver to condition his beliefs on the message, for example in the equilibrium in which $\sigma_1 = 1; \sigma_2(\cdot) = 1; \rho(A) = 0$ and $\rho(B) = 1; \beta(A) = 0.5$ and $\beta(B) = 1$. However, there is no information transmission involved, since the signal is not correlated with the sender's action, and is therefore not reliable. The opposite, i.e., a reliable signal which is ignored, is also possible in equilibrium. Consider, for example, the equilibrium in which $\sigma_1 = 0; \sigma_2(A) = 0.01; \sigma_2(B) = 1; \rho(\cdot) = 0$ and $\beta(\cdot) = 0$. The message is much more likely to be B when the sender's action is B, but, since both messages are received in equilibrium with a positive probability, the consistent belief of the receiver is $\rho = 0$ regardless of the message. Proposition 2 generalizes these observations:

Proposition 2. *Game 2 has no communicative sequential equilibrium, in the sense that the message conveys information ($\sigma_2(A) \neq \sigma_2(B)$) and is acted upon ($\rho(A) \neq \rho(B)$).*

Proof. Assume that $\rho(A) \neq \rho(B)$ in equilibrium. Without loss of generality, let $\rho(A) < \rho(B)$. The optimal message is now $\sigma_2(A) = \sigma_2(B) = 1$. □

Proposition 1 can be easily extended to generic two-player games.[9] Namely, pre-play communication can be informative and conducive to coordination in the case of multiple equilibria. More specifically, if a pareto-dominant equilibrium exists in the original game, there exists a communicative equilibrium in the corresponding signaling game leading to coordination on the efficient equilibrium outcome.

Proposition 3. *Let G be a normal-form game with two players, a sender and a receiver, who have strict preferences over all possible strategy profiles; and let $\Gamma(G)$ be the signaling game obtained when the sender can send a message to the receiver, after which G will be played. If G has two distinct equilibria, there exists a communicative sequential equilibrium in $\Gamma(G)$, in which the players coordinate on the actions corresponding to the equilibrium in G that delivers the higher payoff to the sender.*

Proof. Choose a message m. In the communicative sequential equilibrium of $\Gamma(G)$, the sender sends m, following which the players coordinate on the desired equilibrium of G. If any other message is sent, the players coordinate on the alternative equilibrium of G.

[9] In this setup, there is a straightforward generalization of the way in which communication is incorporated into the game, as the receiver has a unique best response to any signalled action (if the message is believed). When the number of players increases, a more complex protocol of communication must be applied, indicating the identity and timing of active communicators (Blume and Ortmann, 2007). I leave this extension for future work.

Given these strategies, all actions are optimal given correct beliefs as they constitute an equilibrium in G. Furthermore, the sender lowers her payoff by deviating from sending the message m. □

Corollary 1. *If G has a pareto-dominant equilibrium in, there exists a communicative sequential equilibrium in $\Gamma(G)$, in which this equilibrium is obtained.*

Note that the proof can be trivially extended to any finite set of equilibria in G by assigning a message to each equilibrium in E, and assigning the equilibrium in G in which the sender receives her lowest equilibrium payoff to be played following any other message.

3 The significance of timing

The multiple-selves analysis reveals how the order of the decisions made by the sender can affect the set of equilibria in the game. In this section I briefly describe three other theoretical approaches explaining the timing effects found by Charness (2000), and discuss their relation to the current analysis

3.1 Salience

In discussing the timing effect, Charness (2000) wrote: "Perhaps the reversal of the order of signal and action brings the cognitive task and self-interest issue into sharper focus, reducing the credibility of a signal" (p. 190). Aumann (1990) argues that a sender would like to send a B signal, regardless of what she *had already* played or *intends* to play. However, it is only when the sender finds herself in the position of choosing a signal after having played A that this argument becomes most evident. Thus, in the *AS* treatment, subjects are more likely to realize that a B signal should always be chosen, both as senders and when they next come up as receivers (since the roles were randomly reassigned before each period). Conversely, in the *SA* treatment, subjects are not forced to face this realization, and can therefore keep the naïve notion that messages are truthful.[10]

The multiple-selves interpretation of the game suggests that there is more to it than simply the salience of the realization. Specifically, the concreteness of the act and the mutability of the intention not only affect the salience of the unreliable strategy, but in fact affect the best-response strategies, and hence the equilibrium structure. This result can be taken as the underlying reason for the claim that "...the transparency of the cognitive task appears to critically affect the credibility of the signal" (Charness, 2000, p. 193).

[10]Indeed, this notion is so compelling that Aumann was required to write a short paper to confront it and it is explicitly assumed by Farrell (1988), see section 3.2.

3.2 Sensible outcomes

The initial suggestion that the timing of the message might matter came from Farrell (1988), who analyzed pre-play cheap-talk communication by taking into account the natural-language content of messages. Underlying the analysis is the assumption that "the players share a common language and that they will believe a speaker if there is no reason for him to deceive them" (p. 209. See also Farrell, 1993). A message is taken to be a *suggestion* for every player to play a subset of the (mixed) strategies available to her. Farrell (1988) defined a new solution concept he termed *sensible outcomes*, which is based on the notion of *consistent* suggestions. The new solution concept is defined in such a way that it implies the play of (B,B) in the message-first Stag-Hunt game.

A suggestion is consistent if every move suggested to each player is a best response to some strategy profile of the other players included in the suggestion. Hence, any suggestion to play a pure Nash equilibrium is, by definition, consistent, and as such it can support a sensible outcome. Furthermore, in defining sensible outcomes, Farrell (1988) assumed that the sender "will choose the suggestion... that he believes will be best for him" (p. 211). It follows that (B,B) is the unique sensible outcome in Game 3 (cf. Farrell, 1988, Proposition 1).

Since the solution concept of sensible outcomes is defined for pre-play communication, it cannot be extended to the case where the message follows the action. Accordingly, Farrell (1988) concluded that, if the latter case is considered, "Aumann's criticism is compelling; if the former, than matters are rather unclear" (p. 213).

The current analysis differs from that of Farrell (1988) in several respects. First, the effect of timing on the normative prescriptions in the game is derived using standard game-theoretical tools, rather than being based on assumptions that are reasonable, but may seem ad-hoc. Second, it is easily generalizable to any protocol of communication, whereas the notion of sensible outcomes is specifically defined for one-sided pre-play communication, and as such does not apply to the timing effect in any formal or explicit way. On the other hand, modeling the sender as comprised of distinct agents, while allowing for new equilibria in the message-first game, makes it impossible to eliminate the risk-dominant equilibrium, as it removes the justification for allowing the sender to 'choose' the equilibrium, as is assumed by Farrell (1988).

3.3 Cost of lies and promises

Another possible interpretation of the timing effect is to assume that players bear some intrinsic cost of misrepresenting their action. The timing is crucial from this point of view, as it alters the nature of the misrepresentation. If a false message follows the action, it is a lie.[11] If it precedes the action, then the action is promise-breaking.

[11] As the exact text in Charness (2000) was 'I indicate that my play is *B*', this deceptive message may not be perceived as an explicit lie by some.

The experimental evidence supports both the hypothesis that lying carries a cost (Gneezy, 2005; Hurkens and Kartik, 2009) and that breaking a promise carries a cost (Ellingsen and Johannesson, 2004; Vanberg, 2008), possibly mediated by beliefs about expectations induced by the promise (Battigalli and Dufwenberg, 2007; Charness and Dufwenberg, 2006, 2011). An additional assumption is required in order to explain the timing effect observed by Charness (2000) through intrinsic preferences, namely that the cost of breaking promises outweighs the cost of lying. Thus, the timing of the message determines whether it is a promise – which is likely to be kept, or a report – which is likely to be manipulated.

The results of the analysis presented here show that a promise, unlike truth-telling, can be reliable in equilibrium. This can be taken to be the driving force behind the hypothesized behavioral difference between the cost of lying and the cost of promise breaking. However, this notion is difficult to generalize to other games. To see this, consider Game 4, in which A is a dominant strategy for the row player:

	A	B
A	70,70	100,10
B	10,80	90,90

Game 4: Mixed Stag-Hunt and Prisoner's Dilemma

The unique Nash equilibrium of Game 4 is (A,A). Nonetheless, if the row player can make a promise to play B, and breaking the promise carries an intrinsic cost, the outcome would be (B,B).[12] However, modeling the sender as multiple agents, does not give rise to a communicative equilibrium as in the Stag-Hunt game. In this sense, cheap-talk pre-play messages can be used to select between equilibria in coordination games, but not to support strategies that are not rationalizable.[13]

4 Conclusion

In this paper I utilize a multiple-selves approach to capture intra-personal sequence of decisions, and use this approach to test Farrell's (1988) comment on Aumann's (1990)

[12] This is indeed the outcome of the unique subgame-perfect equilibrium if the *action* of the row player is observed by the column player.

[13] Similarly, Rapoport (1997) argues that the timing of the decisions of the players (without communication) selects the equilibrium that is the subgame-perfect equilibrium of the game if early moves are observed when multiple Nash equilibria exist in the normal-form game, but does not extend this argument to allow for inclusion of a subgame-perfect equilibrium in the sequential game that is *not* an equilibrium of the normal-form game.

conjecture that pre-play agreements do not generally facilitate coordination on a pareto-optimal Nash equilibrium. Farrell (1988) suggested that this claim only holds when the messages signal a past action, a suggestion which was corroborated by the experimental results obtained by Charness (2000). Using the new framework, I show that it is indeed not irrational for the sender to follow up on a pre-play message and for the receiver to believe this message. Furthermore, this result can be generalized to any coordination game.[14]

When the message is sent following the action, the situation is different. Here Aumann's (1990) argument ensures that only babbling equilibria exist, hence it is true that "…it is as if [an agreement] had not been made" (p. 205). This difference between the different protocols, which is captured by the multiple-selves model, provides an explanation for the hitherto puzzling results of Charness (2000), and illuminates the intuitive explanations for the timing effect. The analysis brings into focus the reason why communication is more effective in facilitating cooperation if it precedes the action — it could make the sender want to deviate from her planned action, when it is the time to act. The difference between the two temporal orders as it emerges from the analysis can be illustrated by considering the possibility of a player making a mistake. In the *SA* condition, a sender who has sent the wrong signal by mistake would alter her action accordingly, thus creating a contingency between the signal and the action.

This notion is related to the alternative explanations described in Section 3, but is not equivalent to them, and does not depend on additional assumptions. This is not to say that I believe that the other explanations are not valid. Indeed, several effects may be at play in this game. The multiple-selves approach alone is able to provide an explanation of the timing effect, but not the partial efficacy of communication in the *AS* treatment. Similarly, this approach does not provide a clear-cut explanation for the findings of Clark et al. (2001), who found an increased effect of pre-play communication when a sender who plays *A* does not strictly prefer the receiver to choose *B*.[15] It does, however, predict that the timing effect would disappear in this altered game. Possibly some people are not sensitive to the temporal order of the decisions, hence the increased cooperation predicted for the action-first game spills over to the signal-first game studies

[14]Indeed, the set of equilibrium outcomes is the same with and without pre-play communication, as there are still babbling equilibria in which the actions (*A*,*A*) are played. However, given the ubiquity of babbling equilibria, the analysis of strategic communication typically focuses on the most communicative equilibria (Crawford, 1998). Furthermore, the existence of a communicative equilibrium may serve to alleviate the problem of coordination in the following manner: when Alice and Bob play the original game, Alice asks herself whether Bob is a prudent type, who plays in line with the risk-dominant equilibrium. In the game with pre-play communication, Alice should also consider whether Bob is a communicative type, who plays in line with the communicative equilibrium. Only if both answers are 'yes', will she play *A*. As such, the existence of a communicative equilibrium suggests that it will be somewhat favored by the players (Crawford and Sobel, 1982).

[15]The actual game used was slightly different. An analogous game can be created from the games depicted above by substituting a payoff of 75 for payoffs of 70 and 80 throughout.

by Clark et al. (2001). Further experimental work is required to test the specific theories and further elucidate the potential effects of communication in different settings.[16]

Understanding the effect of the timing of signals is important for the application of the theory of cheap-talk messages. An understanding of the principles behind the effect is important in order to predict how experimental findings can be generalized to richer environments and different payoff structures. Previous literature has provided some insights as to the significance of the timing of the messages, but has failed in providing a clear and general theory able to generate unambiguous predictions regarding the timing effect in different games. In this paper I aim to provide a formal, parameter-free model, which is able to organize existing empirical knowledge as well as generate new predictions for new situations. The discussion and the theoretical results provided in the paper point toward future experimental research necessary to provide a better understanding of current empirical findings.

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