Philosophy of Science (2025), **92**, 1235–1244
doi:10.1017/psa.2025.10139

PSA PHILOSOPHY OF SCIENCE ASSOCIATION
PHILOSOPHY OF SCIENCE

CONTRIBUTED PAPER

Marking Indicatives and Imperatives

Ryan Chen

University of California, Irvine
Email: ryanc15@uci.edu

(Received 24 January 2025; revised 19 March 2025; accepted 24 July 2025; first published online 27 August 2025)

Abstract

Previous work on the evolution of the indicative–imperative distinction in signaling games has focused on either the cognitive processes used by signaling agents or information carried by messages. In this paper, I use a simple signaling game model to demonstrate that an overlooked feature of the indicative–imperative distinction can be learned. This overlooked feature is the fact that the indicative–imperative distinction is often marked in natural languages.

1. Introduction

The idea that linguistic meaning is somehow conventional has long been an attractive one. However, demonstrating how a conventionally meaningful system could have evolved or been learned has been much more difficult. David Lewis in *Convention* (1969) developed signaling games in order to explain how the emergence of conventions was possible. Sixty years later, signaling games have been used to model, explain, and better understand the emergence of natural language and its various features (Nowak and Krakauer 1999; Jäger 2007; Skyrms 2010; O'Connor 2014; Steinert-Threlkeld 2020).

This paper is concerned with the indicative–imperative (I–I) distinction found in natural languages. Recent work in the signaling game literature has claimed to explain the possibility of the emergence of various aspects of the I–I distinction (Huttegger 2007; Zollman 2011; Franke 2012). I seek to contribute to this literature by focusing on a feature that has not yet been modeled: the marking of the I–I distinction in natural languages. To illustrate this feature, consider the sentences in (1) and (2).

(1) a. The door is closed.
b. Close the door.
(2) a. The salt is here.
b. Pass the salt (here).

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In these examples, the a-sentences are indicative whereas the b-sentences are imperative. This difference is "marked" in the two sentences (for example, the imperative sentences lack an explicit subject). The marking of the I–I distinction is not just a quirk of English; many (though not all) natural languages have dedicated morphological markers which distinguish imperative clauses from other kinds of clauses (van der Auwera et al. 2013).

A secondary feature of interest in this paper pertains to the idea of common content. For example, 1a and 1b share common content, as do 2a and 2b. In the case of (1), both 1a and 1b are about a door being closed; in the case of (2), 2a and 2b are about salt being at a certain location. The difference is that whilst in the a-sentences the speaker is merely communicating whether or not some state of affairs obtains, in the b-sentences the speaker is directing another to bring about a state of affairs.

To be explicit, this paper is not intended to settle questions concerning the nature of sentential mood (see Portner 2018), nor is it meant to show how full-blown sentential mood, as we see it in natural languages, may have been learned. Rather, this project seeks to show how a very specific aspect (i.e., marking) of the I–I distinction may be evolved or learned. In particular, I offer a signaling game model which may be reasonably interpreted as displaying the following two features:

1. Marked difference: A functional difference between indicatives and imperatives is marked in the language. A functional difference is marked just in case there is an explicit component of the signal which tracks the functional difference.
2. Common content: There exist messages μ and ν such that they agree about the state of affairs they are about, but differ in being indicative or imperative.

In the next section I give a brief overview of signaling games, how they have been used to model the evolution of the I–I distinction, and how previous models fail to capture the marked difference and common content features. In section 3, I provide my own signaling game model which captures these features. I then conclude by considering possible developments of my signaling game model.

2. Signaling games and the indicative–imperative distinction

The simplest signaling game is the $2 \times 2 \times 2$ game with one sender and one receiver. These games involve two states $W = \{w_1, w_2\}$, two messages $M = \{m_1, m_2\}$, and two actions $A = \{\alpha_1, \alpha_2\}$. Payoffs, which are defined on state–action pairs, are fixed at the start of the game by the payoff function $U(w_i, \alpha_j) = 1$ iff $i = j$. These payoffs are the same for both sender and receiver. Before each sender–receiver interaction in the game, a state is chosen at random (with each state having equal probability of being chosen). The sender observes this chosen state and sends a message in accordance with their sender strategy σ: $W \to M$. The receiver then observes the sent message and performs an action in accordance with their receiver strategy ρ: $M \to A$. A sender–receiver strategy profile is a pair $\langle \sigma, \rho \rangle$ consisting of a sender strategy and a receiver strategy.

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In the $2 \times 2 \times 2$ game there are two strategy profiles of particular interest because they are strict Nash equilibria and both the sender and receiver are responding optimally to the state at these equilibria.[1] Lewis (1969) dubbed these strategy profiles "signaling systems," because at these equilibria there is perfect communication between the sender and receiver. One such system occurs when the sender sends m_1 in response to s_1 and m_2 in response to s_2, and the receiver performs a_1 in response to m_1 and a_2 in response to m_2.

But how do senders and receivers end up playing in accordance with a signaling system? Through evolution or learning. This may be modeled in a number of ways. For instance, the continuous two-population replicator dynamics are a system of differential equations which model how a population of senders and a separate population of receivers evolve over time by simulating processes of differential reproduction (for a textbook treatment, see Weibull 1995).

For an example of a learning model, we may consider simple reinforcement learning without punishment as instantiated by an urn learning model (Roth and Erev 1995). In this kind of model, senders possess an urn for each kind of state that they may possibly observe, and receivers possess an urn for each kind of message that they may possibly observe. The sender's urns start with a ball for every possible message that they may possibly send. Likewise, the receiver's urns start with a ball for every possible action that they may perform. The model then unfolds as follows: the sender begins by observing the state of the world, goes over to the corresponding urn for that state, and picks out a ball from that urn. They then send the message which is associated with that ball (and return the drawn ball to the urn it was drawn from). The receiver observes the message, goes over to the corresponding urn, and picks out a ball from that urn. They then perform the action associated with that ball (and return the drawn ball to the urn it was drawn from). If the receiver performs the right action given the state of the world, then both the sender and the receiver add a ball, of the same kind that they had picked out, to the urn that they had drawn from. In the case where the receiver performs the wrong action, nothing happens. This process is repeated, resulting in changes to the proportions of kinds of balls in the urns of both senders and receivers. Changing the proportion of types of balls in a sender urn amounts to changing the conditional probability of a message being sent given that some state of the world obtains. Changing the proportion of types of balls in a receiver urn amounts to changing the conditional probability of acts being performed given some observed message. Repetition of this procedure can lead to senders and receivers learning to coordinate on which message is sent in a given state and what act to perform given the message. In other words, senders and receivers can learn to play in accordance with a signaling system. (For more on learning dynamics in signaling games, see Barrett 2009; Skyrms 2010.)

[1] A strict Nash equilibrium of a signaling game is any pair of sender–receiver strategies $\langle \sigma, \rho \rangle$ such that at any choice point (i.e., when the sender has to decide which message to send or when the receiver has to decide which action to perform), either player would do strictly worse by playing another strategy, given that the other player's strategy is held fixed.

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2.1. Deliberation and the indicative–imperative distinction

The first account of the I–I distinction we consider is Huttegger's (2007) model. Like in the $2 \times 2 \times 2$ game, it involves two states $W = \{w_1, w_2\}$, two messages $M = \{m_1, m_2\}$, and two acts $A = \{\alpha_1, \alpha_2\}$. What is distinctive about Huttegger's model is that both the sender and receiver have to choose whether to deliberate or not before performing their usual actions. To represent this, let $D = \{\text{d}, \text{n}\}$ (where d is for deliberate and n for no deliberation). Sender strategies are now mappings from states to message–D pairs (σ: $W \to D \times M$) and receiver strategies are mappings from messages to action–D pairs (ρ: $M \to D \times A$). Payoffs are defined so that $U(w_1, \text{d}, \alpha_1, \text{n}) = U(w_2, \text{n}, \alpha_2, \text{d}) = 1$ and otherwise $= 0$.

Informally, the idea is that in w_1, α_1 should be performed (e.g., there is an aerial predator, so the receiver should hide in a bush). But w_1 is also a state where the sender should deliberate and the receiver should not deliberate (e.g., because if the receiver deliberates then they will take up too much time and get caught by the predator). In w_2, α_2 should be performed (e.g., the receiver should climb up a tree). But in this case, the sender should not deliberate and the receiver should deliberate (e.g., the sender sees that there is a predator nearby but not close enough that it poses an immediate threat, so the sender merely passes on that information to the receiver who then has time to determine which tree looks sturdy and tall enough to both support the receiver and to hide the receiver from the predator).

There are only two equilibria of the game where sender and receiver perfectly communicate and coordinate on who the deliberator is going to be. One such equilibrium occurs when the sender deliberates and sends m_1 in response to w_1, and does not deliberate and sends m_2 in response to w_2; concurrently, the receiver does not deliberate and performs α_1 in response to m_1, and does deliberate and performs α_2 in response to m_2.

What is crucial for our discussion is how Huttegger (2007) makes the I–I distinction in this model: following Lewis's (1969) account of the I–I distinction, if the sender must deliberate before sending the message and the receiver must not deliberate before acting, then the signal is imperative. If the sender must not deliberate before sending the message and the receiver must deliberate before acting, then the signal is indicative. Hence, in the example equilibrium sketched in the immediately preceding paragraph, m_1 is imperative whereas m_2 is indicative.

The underlying idea behind such a proposal is as follows: in indicative signaling the sender merely passes along what the state of the world is, and the receiver needs to deliberate in order to figure out what to do with that information. In imperative signaling, the sender deliberates in order to send a message telling the receiver which action needs to be taken and the receiver merely does what they are told to do.

A number of objections have been leveled against Huttegger's (2007) model. For instance, Zollman (2011) argues that Huttegger's model fails to capture a plausible asymmetry between indicatives and imperatives. Specifically, it is thought that indicatives should carry perfect (Shannon) information about the state of the world but not about the act to be taken. Likewise, imperatives should carry perfect information about the action to be taken but not the state of the world. On Huttegger's model, messages at the equilibria of interest carry perfect information

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about both the states and acts, and hence fail to capture this aspect of the I–I distinction.

Another objection comes from Franke (2012), who argues that cashing out the I–I distinction in terms of deliberation is methodologically strange from a linguist's perspective.[2] Field linguists do not gather evidence for the I–I distinction by determining whether or not a speaker or a listener has deliberated before speaking. Furthermore, linguists, in general, do not characterize indicatives and imperatives in terms of deliberation (e.g., Portner 2018).

2.2. Informational asymmetry and the indicative–imperative distinction

As mentioned in the previous section, Huttegger's (2007) model has been criticized for not capturing an intuitive informational asymmetry between indicative and imperative signals. Zollman (2011) provides us with a signaling game model which was aimed at capturing this informational asymmetry. In this game, there is one sender and two receivers, receiver$_1$ and receiver$_2$. There are two states $W = \{w_1, w_2\}$, two signals $M = \{m_1, m_2\}$, and two actions $A = \{\alpha_1, \alpha_2\}$. The receivers need to coordinate by taking different actions (e.g., if receiver$_1$ performs α_1 then receiver$_2$ should perform α_2) and the sender needs to signal to the receivers in order to facilitate this coordination. Payoffs are defined such that $U(w_1, \langle \alpha_1, \alpha_2 \rangle) = U(w_2, \langle \alpha_1, \alpha_2 \rangle) = 1$ and otherwise $= 0$ (where $\langle \alpha_i, \alpha_j \rangle$ denotes the situation where receiver$_1$ performs α_i and receiver$_2$ performs α_j). Because senders may send different messages to each receiver, sender strategies take the form of mappings $\sigma: W \rightarrow M \times M$. Receiver strategies take the form of mappings $\rho: M \rightarrow A$.

There are two kinds of equilibria of interest: a-equilibria and d-equilibria ("a" for assertive and "d" for directive). One example of an a-equilibrium occurs when the sender sends the m_1 to both receivers in response to w_1 and m_2 to both receivers in response to w_2; receiver$_1$ responds to m_1 by performing α_1 and responds to m_2 by performing α_2; receiver$_2$ responds to m_1 by performing α_2 and responds to m_2 by performing α_1. One example of a d-equilibrium occurs when the sender sends m_1 to receiver$_1$ and m_2 to receiver$_2$ in response to w_1, and sends m_2 to receiver$_1$ and m_1 to receiver$_2$ in response to w_2; both receivers respond to m_1 by performing α_1 and they respond to m_2 by performing α_2.

What is crucial for our discussion is how Zollman makes the I–I distinction in this model: A message is imperative just in case it carries perfect information about the act to be taken and does not carry perfect information about the state. A message is indicative just in case it carries perfect information about the state and does not carry perfect information about the act to be taken.

In the a-equilibria, messages carry perfect information about the state. However, the information carried by m_1 or m_2 when averaged across both receivers does not carry perfect information about the actions. Hence, at the a-equilibria, all messages are indicative. In the d-equilibria, m_1 and m_2 carry perfect information about the action to be taken. However, the messages taken individually do not carry perfect

[2] It is worth noting here that Huttegger's (2007) model was not solely directed at capturing a linguistic I–I distinction. It also clearly had in mind cases of animal signaling. In such cases, Franke's commentary does not straightforwardly apply.

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information about the state. Therefore, at the d-equilibria, all messages are imperative.

2.3. Discussion

Both Huttegger (2007) and Zollman (2011) use signaling game models to capture some aspect of the I–I distinction. However, both models fail to capture the marked difference feature and the common content feature. Because the messages in both games are interpreted and modeled as single simple units with no component parts, there can be no distinct component of the message whose function is to mark the I–I distinction. Hence, in the models just considered it is not even possible to capture the marked difference feature. Furthermore, both models lack messages at equilibria which share common content. For instance, in Huttegger's model, the messages at the equilibria of interest differ in being indicative and imperative but also differ in terms of what state they are associated with and the action that they prescribe. The situation is somewhat worse for Zollman's model since there are no a-equilibria or d-equilibria in that model where both indicatives and imperatives coexist. The a-equilibria only contain indicatives, and the d-equilibria only contain imperatives.[3]

There are two lessons to draw from this discussion. Firstly, our own model must include messages with multiple components if we are to capture the marked difference feature. Secondly, one cannot begin to capture the common content feature if one lacks a model in which indicatives and imperatives coexist at equilibria. With these lessons in hand, we can now turn our attention towards the Marked Signaling Game.

3. Marked indicative and imperative signaling

The Marked Signaling Game is intended to be a minimal extension of the simple signaling game framework which captures the marked difference and common content features. In the Marked Signaling Game, there is only one sender and one receiver. While acts remain the same, $Act = \{\alpha_1, \alpha_2\}$, states are now triples of state components $W = A \times B \times C$ where $A = \{a_1, a_2\}$, $B = \{b_1, b_2\}$, and $C = \{c_1, c_2\}$. Messages are now pairs of message components $Mes = N \times M$, where $N = \{n_1, n_2\}$ and $M = \{m_1, m_2\}$. At the start of every play of the game, nature randomly picks a state (with every state having equal probability of being picked). However, the sender only observes the $A \times B$ component of the world and not the C component. Hence, upon observation of some $\langle a_i, b_j \rangle$ (for $i, j \in \{1, 2\}$), the sender decides which message to send in accordance with their sender rule σ: $A \times B \to N \times M$. The receiver observes the message and the C component of the world and picks an action to perform in accordance with their receiver rule ρ: $N \times M \times C \to Act$. The payoffs are given in table 1.

[3] Huttegger's (2007) and Zollman's (2011) models are not the only models of the I–I distinction that can be found in the signaling game literature. Discussion of the distinction in signaling games can already be found in Lewis (1969). But see also Franke (2012), Blume and Board (2013), and Martínez and Klein (2016). Like Huttegger's and Zollman's models, none of these works present models which capture the marked difference or common content features that are under discussion in this paper.

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Table 1. Payoff table for the Marked Signaling Game

	α_1	α_2
$a_1b_1c_1$	1	0
$a_1b_1c_2$	1	0
$a_1b_2c_1$	0	1
$a_1b_2c_2$	0	1
$a_2b_1c_1$	1	0
$a_2b_1c_2$	0	1
$a_2b_2c_1$	0	1
$a_2b_2c_2$	1	0

One way to informally interpret this game is to treat elements of A as determining whether or not C matters for the purposes of optimal action. To see this, consider the first four rows of table 1 where a_1 obtains. Note that in these states, knowledge of whether or not the B component is b_1 or b_2 is sufficient to determine what the optimal act is (irrespective of what the C component is). In other words, if a_1 obtains then the C states do not matter for the purposes of determining the optimal act. On the other hand, consider the last four rows of table 1, where a_2 obtains. Here, knowledge of the B states by themselves is not sufficient to determine the optimal act. One needs to consider both the B states and the C states to determine the optimal act.

The equilibria that we are interested in for this game are those in which every message component perfectly tracks one and only one state component. For example, consider the equilibrium presented in figure 1. Here, n_1 perfectly tracks a_1, n_2 perfectly tracks a_2, m_1 perfectly tracks b_1, and m_2 perfectly tracks b_2. These equilibria are what I shall call "non-cross-cutting equilibria." For the Marked Signaling Game, there are eight such equilibria.

Strict Nash equilibria at which there are message components which do not perfectly track any state components, but where both sender and receiver are still acting optimally given the state, are what I shall call "cross-cutting equilibria." One example of such a cross-cutting equilibrium occurs when we take the equilibria depicted in figure 1, but map a_2b_1 to n_2m_2, a_2b_2 to n_2m_1, $n_2m_1c_1$ and $n_2m_2c_2$ to α_2, and $n_2m_1c_2$ and $n_2m_2c_1$ to α_1. At such an equilibrium, the M components do not map onto any particular state component. For instance, m_1's content cannot be identified with any of a_1, a_2, b_1, or b_2 since it is sent when a_1b_1 obtains and when a_2b_2 obtains. There are sixteen such cross-cutting equilibria in the Marked Signaling Game.

Simulations of the Marked Signaling Game using simple reinforcement learning show that senders and receivers can learn to play a non-cross-cutting equilibrium (see the Supplemental Materials for more technical details and for the numerical results). Furthermore, simulations reveal that if agents do end up playing either a non-cross-cutting equilibrium or a cross-cutting equilibrium, about one-third of the time they will end up playing a non-cross-cutting equilibrium. This is because the

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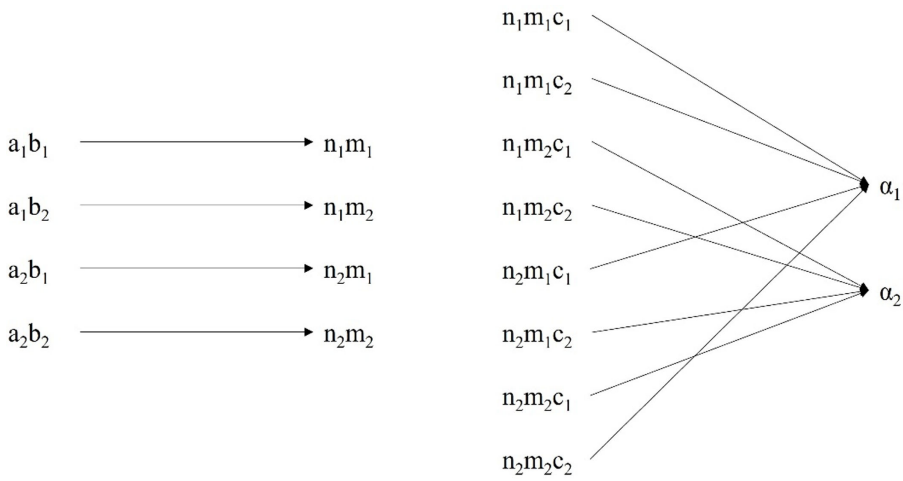


Figure 1. An example of a non-cross-cutting equilibrium.

non-cross-cutting equilibria constitute a third of all the strict Nash equilibria where agents are acting optimally.

Messages in non-cross-cutting equilibria may be interpreted as capturing the marked difference feature and the common content feature. Let us suppose that our sender and receiver end up playing the equilibrium depicted in figure 1. Here, we may interpret the *N* components of the message as marking the I–I distinction. Specifically, n_1 marks that the content carried by the *M* component is sufficient to determine the action that the receiver ought to take. In other words, upon reception of a message with n_1, the receiver immediately knows what to do and may act accordingly. In contrast, n_2 marks that the receiver needs to consider the *C* state component in order to determine the right action. In other words, upon reception of a message with n_2, the receiver has merely gained information about what the *B* state component is. It is in this sense that we may treat n_1 as an imperative marker and n_2 as an indicative marker.

The Marked Signaling Game also captures the common content feature. In the equilibrium depicted in figure 1, we see that n_1 and n_2 mark the *M* message components. But because we are at a non-cross-cutting equilibrium, the *M* message components perfectly track their respective *B* state components. Hence, we may interpret m_1 as meaning b_1 and m_2 as meaning b_2. Then, messages of this game consist of both an I–I marker (i.e., the *N* message components) and a component which simply indicates a state of affairs (i.e., the *M* message components). In other words, there are messages in this game which agree about the states of affairs that they are about, but which disagree in being indicative or imperative.

In summary, the way the I–I distinction is being characterized for this game is as follows: A message is imperative just in case there exists a message component μ which, when combined with other distinct meaningful message components, results in a message that by itself is sufficient to determine which action the receiver should take. A message is indicative just in case there exists a message component ν which,

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when combined with other distinct meaningful message components, results in a message that is not by itself sufficient to determine which action the receiver should take. Built into this characterization are the marked difference and common content features.

One might object that messages in the Marked Signaling Game at non-cross-cutting equilibria do not display the I–I distinction at all. For example, in the equilibrium depicted in figure 1, it may be argued that the N components of the game just track the A states and hence just have their corresponding A states as their meanings. In other words, the objection is that all that is going on here is indicative signaling. The aim of this paper is not to argue that this is not a legitimate interpretation of the game. Rather, it is to argue that there is a plausible and applicable interpretation of this game which does involve drawing an I–I distinction in terms of the marked difference and common content features. It is also worth mentioning that there are ways to extend the game to make this objection less attractive. For instance, we could make the receiver first decide whether or not to consult C before acting as a part of the game. The aim here has been to keep the game as simple as possible so that extension is not pursued.

4. Conclusion

In this paper I have sought to capture an aspect of the I–I distinction which has yet to have been modeled in the signaling game literature: the marking of the indicative–imperative distinction. There is further work to be done concerning whether or not other aspects of the I–I distinction, as modeled by previous researchers, can be mixed with the Marked Signaling Game to model a fuller I–I distinction. For instance, it would be worthwhile to see whether we could develop models where the informational asymmetry is tracked by a message component (thereby getting a different kind of I–I marker). Another underdeveloped area in the literature concerns the concurrent evolution and learning of indicatives, imperatives, and interrogatives. Future work in this direction may shed better light on the minimal necessary conditions that need to obtain for such phenomena to emerge.

Acknowledgements. I would like to thank the following people for their help and suggestions: Jeffrey Barrett, Nathaniel Imel, Cailin O'Connor, Brian Skyrms, Chris Torsell, and Jack VanDrunen.

Funding Information and Declaration. None to declare.

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Cite this article: Chen, Ryan. 2025. "Marking Indicatives and Imperatives." *Philosophy of Science* 92 (5): 1235–1244. https://doi.org/10.1017/psa.2025.10139

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