

Game-Theoretic Modeling of Semantic Interpretation in Cross-Linguistic Translation

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Abstract

Translation is about more than just choosing a word that has a similar dictionary definition; it's about predicting what will make sense to a reader given a target expression. This paper plays out that interaction as a signaling game between an informed translator and a reader in the target language. The translator is observing a meaning he wishes to convey and selects an expression that is short and has multiple interpretations or a more explicit expression that specifies one interpretation. The reader puts together the expression and guesses the translator's decisions. If utilities give them credit for a correct inference, the translator has to expend an extra communication investment on being explicit with the word. Bayesian updating and sequential best responses are used to analyze a two-meaning model. If it is cheaper to clarify than to be successful in interpretation, then there is a separating equilibrium, where the most likely meaning is expressed in the shorter phrase and the less likely meaning is expressed in the longer phrase. Based on this convention, there is an expected semantic recovery probability of 1.00 and expected utility of the translator of 0.94 for the made-up example with prior probabilities of 0.70 and 0.30 and cost of clarification 0.20. If the two meanings are both expressed explicitly, the utility is 0.80; if the two meanings are both expressed on a short statement, the utility is 0.70, which is less. These values are based on the assumptions of payoffs and shared conventions, and not empirical translation scores. The results of the paper are related to the concept of ambiguity preservation, audience expectations, and contextual error analysis. Future studies should quantify beliefs and communication cost among readers as well as assess the learning and retention of proposed conventions across language pairs.

Keywords: Translation pragmatics, signaling games, semantic interpretation, bayesian reasoning, communicative efficiency.

1. A translation choice that depends on the reader

If a person is referred to as such in a story based on family information, provide the details provided. If the person is identified as such by the other individuals in a story, provide the information provided. The same distinction can be maintained in Spanish by saying "tío materno" or "tío paterno", or simply "tío" if there is no need for distinction or if there is a convention. In the expressions there are differences in the amount of information that is explicitly expressed. A reader's understanding of what is said is shaped by both what was said, and what the translator selected for inclusion, with regard to his or her purpose.

This is an artificial example of a distinction of the kind of relationships that are referred to, and not an assertion of

the universal preference for one family relationship by native speakers of Spanish or English. The distinction can be expressed in both languages, and may be omitted from either. The question is, whether there is enough information in the target reader's mind to recover the source meaning after the translation choices have been made.

For a long time, translation scholarship has been focused on the relation between expression, meaning and the receiver. Jakobson speaks about translation across linguistic systems and Nida serves up some thoughts on principles of correspondence in translating while Baker talks about equivalence at a number of linguistic and pragmatic levels (Baker, 2018). These views drive the study to analyse the translation decision in which the target reader is engaged rather than be an external evaluating agent later in the process (Ashour, 2026; Freitag et al., 2021).

Rules of pragmatic interpretation also rely on assumptions regarding communicative selections. This account of conversation relates what is communicated to expectations of what the conversant is going to say. An available explanation can similarly be reasoned by a reader when they believe that the less likely meaning was meant. This kind of reasoning is only helpful if the assumptions of the reader are similar to the translator's policy.

In this paper, we capture that interaction in a toy signaling game. It's designed to discuss when ambiguity, explicitness, and audience assumptions facilitate successful interpretation. The contribution consists of the formulation in terms of translation and the work out of an equilibrium comparison. No translators were recruited and no machine translation benchmark was evaluated; it is a theoretical study.

2. Translation as a signaling game

2.1. Communication conventions and strategic inference

Lewis' study of conventions uses coordination and signaling. In interacting populations, Skyrms investigates the theory of signaling, information, and learning (Rei et al., 2020). These foundations enable an expression to be considered as a choice, the interpretation of which is partially determined by a shared signaling practice.

This view is further developed in Game-theoretic pragmatics for linguistic communication. Strategies for pragmatic reasoning are reviewed by Franke and game-theoretical pragmatics are discussed by Jäger (Franke, 2013; Jäger, 2011). There are related formulations in probabilistic accounts: In Frank and Goodman's model of pragmatic reasoning in language games, the pragmatic interpretation is described as a probabilistic inference (Frank & Goodman, 2012; Goodman & Frank, 2016). These studies are not direct empirical support for the translation game which is proposed here, but studies of communication in general (Mokhtarinjad et al., 2017).

In the current model, the translator and reader share a desire to restore the meaning that the writer wanted. They are not exactly the same, since the translator incurs an explicitness cost as well. This is thus a coordination problem instead of a zero-sum contest, and a communication-cost asymmetric one at that. On the other hand, with different interests there can be more complicated information transmission involved, and deception and persuasion are not in the base model.

2.2. What each participant knows

Nature selects an intended meaning $m \in \{A, B\}$, with

$$P(m = A) = p, \quad P(m = B) = 1 - p, \quad 0 < p < 1$$

The translator's job is to observe the meaning in the source context. The reader is only shown the selected target and the public background info. It is assumed that both meanings, prior probabilities, available expressions and costs are common knowledge.

This assumption leaves out the problem of conveying a known source interpretation. It does not cover situations where the translator does not know the meaning of the source. If so, then uncertainty at the source-analysis stage needs to be modeled prior to the signaling decision. Similarly, the reader might encounter more context than is allowed in base game; that would alter the prior or decrease the need for it.

2.3. Short and explicit translation options

The target-language message set is $U = \{u_0, u_A, u_B\}$. The short expression u_0 is compatible with either meaning. Expression u_A explicitly identifies A , and u_B explicitly identifies B . Truthful semantic compatibility restricts the translator's choices: type A can use u_0 or u_A , while type B can use u_0 or u_B .

Table 1: Message options in the two-meaning translation game.

Target expression	Compatible meaning	Translator cost	Reader information
Short expression u_0	A or B	0	Meaning remains lexically unspecified
Explicit expression u_A	A	kappa	A is identified
Explicit expression u_B	B	kappa	B is identified

Kinship illustration: A may be the maternal uncle and B the paternal uncle. There are three different types of messages: short “tío”, and the more explicit “tío materno” and “tío paterno”. The assumed cost is a theoretical penalty for extra wording/reproduction. It is not a cost or a guess as to the level of difficulty of these specific words in Spanish in table 1.

2.4. Semantic recovery and participant utilities

After observing a message, the reader chooses an interpretation $a \in \{A, B\}$. Correct semantic recovery provides benefit $V > 0$. The utilities are

$$U_T(m, u, a) = V\mathbf{1}\{a = m\} - c(u)$$

$$U_R(m, u, a) = V\mathbf{1}\{a = m\}$$

Where $c(u_0) = 0$ and $c(u_A) = c(u_B) = \kappa$, with $\kappa \geq 0$.

The translator's utility value captures recovery utility net of explicit cost of explicitness. It is beneficial for the reader to be able to recover. The distinction avoids the double counting of communication advantage within society. The two utilities are reported separately in the paper. These are things that can be added in real applications (reading effort, stylistic fidelity, etc., asymmetric semantic-error costs), but which are not included in the numerical example.

3. How interpretation and translation become mutually consistent

3.1. The reader reasons about the translation policy

Let $\sigma(u | m)$ describe the translator's message policy. For a message that occurs with positive probability, the reader's posterior belief is

$$\mu(m | u) = \frac{P(m)\sigma(u | m)}{\sum_{m'} P(m')\sigma(u | m')}$$

The reader chooses the meaning with the greater posterior probability, because both correct meanings receive the same benefit. Explicit expressions have fixed semantic compatibility, so u_A supports A and u_B supports B. The short expression may acquire a narrower pragmatic interpretation depending on which translator type uses it.

This forms the core difference between lexical compatibility and strategic interpretation. The phrase can be lexically compatible with both meanings but consistently indicate one meaning through a certain policy. A fresh reader who is not aware of such a policy will have a different understanding of the same phrase.

3.2. A separating equilibrium with selective explicitness

Assume $p \geq 0.50$ and consider the following strategy profile: type A uses u_0 , type B uses u_B , and the reader interprets u_0 as A and u_B as B. Both messages occur with positive probability. Bayesian updating gives

$$\mu(A | u_0) = 1, \quad \mu(B | u_B) = 1$$

The reader therefore recovers both meanings. Type A receives utility V from the short expression. Switching to u_A gives $V - \kappa$, so the deviation is not profitable. Type B receives $V - \kappa$ from explicit wording. Switching to u_0 would cause interpretation as A and give utility zero. Type B consequently prefers its assigned message when

$$\kappa \leq V$$

Since u_A is an unutilized explicit form, it will be understood as A due to the semantical constraint. Under such a situation, the described strategies and beliefs constitute a perfect Bayesian equilibrium: the reader plays optimally at each corresponding information set while the translator has no better move on his own. Perfect Bayesian equilibrium concept implies sequential rationality and consistent beliefs (Gibbons, 1992). In case of equality, type B is indifferent; if $0 < \kappa < V$, its incentive to clarify is strict.

These signals discriminate between two meanings of the source despite the fact that one of them is explicitly defined. It is a separating convention and not a partially informative equilibrium.

3.3. A second convention and the problem of coordination

A second separating convention assigns u_A to type A and the short expression to type B . The reader then interprets u_0 as B . The same incentive check supports this convention when $\kappa \leq V$.

Both conventions can be equilibria. The prior determines which uses less explicit wording on average. When $p > 0.50$, leaving the more frequent meaning implicit costs $(1 - p)\kappa$, whereas leaving the less frequent meaning implicit costs $p\kappa$. The former has the greater expected translator utility. This efficiency comparison does not eliminate the other equilibrium or establish that real audiences automatically coordinate on the cheaper convention.

At $p = 0.50$, the two selective conventions have equal expected cost. Their success still requires a shared understanding of what the short expression signals. Language conventions, prior exposure, and translator documentation can matter for equilibrium selection (Skyrms, 2010).

3.4. When pooling becomes stable

Consider a pooling profile in which both types use u_0 . For $p > 0.50$, the reader's posterior remains the prior, so it chooses A . Type A obtains V and does not benefit from paying for explicit wording. Type B obtains zero but could use u_B and obtain $V - \kappa$.

Pooling is therefore stable against that deviation when $\kappa \geq V$. At the threshold $\kappa = V$, pooling and the selective separating profiles can all be supported with weak incentives. Below the threshold, pooling fails because the less frequent type can profitably clarify its meaning.

This is based on the simplified cost and compatibility structure. It is not a complete list of all mixed strategies and/or message systems and/or audience models. It determines the most significant pure profiles in terms of translation comparison in the paper.

4. Worked communication profiles

4.1. A hypothetical audience and normalized payoffs

Set $p = 0.70$, $V = 1.00$, and $\kappa = 0.20$. These values are constructed assumptions. The prior means that 70% of source cases in the hypothetical task concern A ; it does not represent a universal frequency of maternal uncles, a language-specific statistic, or a measured belief among readers.

Four policies for translation are compared. The short expression is used for both meanings in the pooling policy. The all-explicit policy specifies both meanings. A is left implicit and B is named by the efficient selective convention. The "reverse selective convention" assigns A and assumes the existence of B .

The probability that the selected meaning by the reader is the same as the intended meaning is called semantic recovery probability. Explicitness cost: the expected cost of the messages. The cost is deducted from the recovery benefit by a translator utility. The recovery benefit under the assumptions is the Reader utility.

4.2. Recovery and effort under four policies

Table 2: Calculated outcomes when $p = 0.70$, $V = 1.00$, and $\kappa = 0.20$.

Communication profile	Recovery probability	Expected wording cost	Translator utility	Reader utility
Pooling with majority decoding	0.70	0.00	0.70	0.70
Explicit wording for both meanings	1.00	0.20	0.80	1.00
A implicit and B explicit	1.00	0.06	0.94	1.00
A explicit and B implicit	1.00	0.14	0.86	1.00

In comparison to the all-explicit policy, the efficient selective convention has a 70% lower expected wording cost and still allows for complete recovery in the model in table 2. Its translator utility will be enhanced by 0.14. In the reverse convention, it is also fully recoverable and is more costly since the more common type requires the use of the expensive message.

These are policy considerations within the spectrum of acceptable reader reactions. The $k = 0.20$ level of pooling

is not an equilibrium, as the *B* translator can profitably clarify. The all-explicit policy is provided as a clear comparison, and is not given an equilibrium status unless reader beliefs are stated after the unused short expression. The two selective conventions agree with the equilibrium conditions previously obtained.

The recovery probability of 1.00 is due to perfect recognition of explicit messages and complete agreement of the short-message convention. This is not 100% accurate translation observed. The figures were not created by a test set or reader judgments nor by a trained system.

4.3. Prior asymmetry and communication cost

For $p \geq 0.50$, the expected translator utility under the efficient convention is

$$\mathbb{E}[U_T] = V - (1 - p)\kappa$$

The pooling recovery probability is p . For either orientation of the prior, the minimum expected explicitness cost among the two selective conventions is

$$C_{\text{selective}} = \min(p, 1 - p)\kappa$$

Table 3: Effect of meaning frequency with $V = 1.00$ and $\kappa = 0.20$.

Probability of A	Pooling recovery probability	Efficient selective recovery	Selective wording cost	Selective translator utility
0.50	0.50	1.00	0.10	0.90
0.70	0.70	1.00	0.06	0.94
0.90	0.90	1.00	0.02	0.98

As one meaning becomes more common, a convention that reserves explicit wording for the rarer meaning requires clarification less frequently in table 3. Pooling also performs better on average, but still misinterprets the rare cases. Aggregate recovery alone can therefore obscure which source meaning is being lost.

4.4. What changes when clarification is expensive

The selective utility for the 0.70 prior is $1 - 0.30\kappa$. At clarification costs of 0.20, 0.80, and 1.00, it equals 0.94, 0.76, and 0.70. At 1.20, the same policy would give 0.64, and would not be sequentially stable: The minority translator sees an advantage in switching.

The gain in expected translator utility over pooling, for $\kappa \leq V$, is

$$\Delta = (1 - p)(V - \kappa)$$

The formula picks out the function of the minority sense. The rate at which that meaning is used dictates the frequency with which clarification is important, and the difference between the semantic benefit and the cost of the words dictates whether or not clarification is worth its individual cost. The deviation condition or the numerical expressions were checked directly and they set the model's arithmetic and not an empirical finding.

5. From equilibrium predictions to translation evaluation

5.1. Reader conventions must be measured

The optimal translation policy may be suitable for a presumed reader, but not for an actual reader. Assuming the short expression as *A* in the reader's mind, and the translator to take the reverse rule, all the implicit *B* cases are misread. Even though the explicit *A* cases are correctly understood, the recovery is lowered from 1.00 to 0.70 in the illustrative task.

Therefore, a study should estimate the meaning priors and responses to the candidate expressions by the readers. The answer for the test item should not be used as the basis for the prior estimation but rather the independent audience information. Convention learning can be tested repeatedly during the exposure, but not learning performance during the initial comprehension.

There are methods for modeling less deterministic reasoning in probabilistic pragmatics (Frank & Goodman, 2012; Goodman & Frank, 2016). A graded message choice and a probabilistic interpretation can be substituted for exact best responses in an extension. This can't be done by adding noise to the example without consistency analysis, since adding noise doesn't automatically maintain the perfect bayesian equilibrium.

5.2. Candidate generation and pragmatic selection

A language model in the computational translator could provide semantically acceptable alternatives and a reader model could provide an estimate of interpretation. The attention model is one of the essential architectures for current translation modeling (Riadhusin et al., 2025). The proposed game would be a selection or analysis layer and the intention would be that it would not select wording which would change the meaning of the source.

The translator's presumed knowledge is a strong requirement. When the source itself has multiple readings, this should be maintained in candidate generation. A system shouldn't create a desired result just to employ the two-type game. Likewise, the same cost shouldn't be applied to all language pairs without taking account of the morphology, the register and the acceptability of explicit phrasing.

5.3. Testing semantic recovery alongside translation quality

A short study on selective versus all-explicit translations of source passages, with a clear distinction drawn by the source text, might be compared to an empirical study of short versus all-explicit translations of the same source passages. The recovered meaning would be given to readers to choose and/or explain. Semantic recovery, subgroup errors, reading time, perceived naturalness and translator's production or editing effort should be noted in the study.

BLEU is an automatic translation metric that has been already developed (Vaswani et al., (2017) while COMET is a learned metric based on source and target language information (Sharma & Das, 2024). These scores are meant to supplement the study, but are not meant to take its place in assessing the difference modeled by the game. A short translation and an overt paraphrase can convey the same intended content, but in different ways of having surface overlap.

Next, contextual expert error analysis of machine-translation evaluation is shown to be useful by Papineni et al., (2002). Right sense selection, missing distinctions, over-explicitation and harm to style should all be differentiated in an appropriate assessment. Automatic scores, expert assessment and reader understanding must be reported separately. Here no BLEU, COMET or human-evaluation score is provided since these experiments were not conducted.

6. Interpretive boundaries and concluding argument

6.1. When ambiguity belongs to the source

However, not all ambiguous expressions need to be resolved. A passage from literature can intentionally have many meanings, while a source author might avoid specifying a family relation. In such situations, the goal of the target task is preserving the ambiguity and not making an attempt to uncover the true but hidden meaning. The presented game is valid only when there is enough information for making the determination. The more complex framework could consider a set of acceptable translations, or alternatively could reward preservation of semantic alternatives, or incorporate costs related to reader effort or stylistic loss. These alterations to the payoff structure would lead to a different translation convention. Therefore, the presented conclusion can be considered as a conditional explanation of the observed phenomenon.

6.2. Limits of a shared-interest game

This model takes into account two meanings, three truthful messages, prior knowledge, and common goals in recovering information. Incomplete knowledge of the source, unreliable decoding of messages, cultural differences in interpreting information, and the need to influence or hide certain information are not considered here.

There is another problem in forecasting, which is related to multiple equilibria. The low-cost convention does exist, but existence does not imply the coordination of the sender and the receiver on this convention. Learning conventions, different audiences, and different knowledge of the target language should be verified. Payoffs created by the author cannot prove any behavior of the system.

Conclusion

Translation-based semantic interpretation can be considered a sequential coordination problem in which the translator chooses language based on an anticipated inference from the reader, and the reader decodes the language choice based on expectations regarding the translator. Under two-meanings signaling game, a fully informative equilibrium exists when the more common meaning is implicit and the less common meaning is explicit, if the cost of clarification does not exceed the value of successful recovery to the translator. For instance, the fully informative strategy gives the probability of recovery equal to 1.00 and the utility of the translator 0.94, whereas both-explicit strategy gives 0.80 and pooling strategy gives 0.70. This conditional solution helps to understand how selective explicitness can lower the cost of communication at the same time revealing the necessity of conventions among readers.

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