

## OBJECTIVES

After reading this chapter, the student will be able to understand:

- Pragmatic Analysis
- Discourse – reference resolution.
- Reference phenomenon.
- Syntactic & semantic constraints on coreference

## 1. Pragmatic analysis

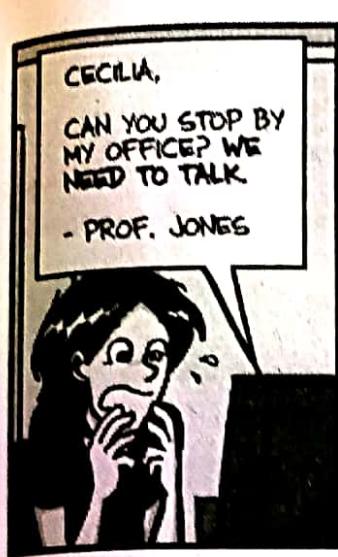
Pragmatics is a subfield of linguistics that studies the ways in which context contributes to meaning. Pragmatics encompasses speech act theory, conversational implicature, talk in interaction and other approaches to language behaviour in philosophy, sociology, linguistics and anthropology. Unlike semantics, which examines meaning that is conventional or "coded" in a given language, pragmatics studies how the transmission of meaning depends not only on structural and linguistic knowledge (e.g., grammar, lexicon, etc.) of the speaker and listener, but also on the context of the utterance, any pre-existing knowledge about those involved, the inferred intent of the speaker, and other factors. In this respect, pragmatics explains how language users are able to overcome apparent ambiguity, since meaning relies on the manner, place, time, etc. of an utterance.

Pragmatics deals with using and understanding sentences in different situations and how the interpretation of the sentence is affected. The ability to understand another speaker's intended meaning is called pragmatic competence.

Pragmatics is different than semantics, which concerns the relations between signs and the objects they signify. Semantics refers to the specific meaning of language; pragmatics, by contrast, involves all of the other social cues that accompany language. Pragmatics focuses not on what people say but how they say it and how others interpret their utterances in social contexts. Utterances are literally the units of sound you make when you talk, but the signs that accompany those utterances are what give the sounds their true meaning. Ref

Example : You invited your friend over for dinner. Your child sees your friend reach for some cookies and says, 'Better not take those, or you'll get even bigger.' You can't believe your child could be so rude."

In a literal sense, the daughter is simply saying that eating cookies can make you gain weight. But due to the social context, the mother interprets that same sentence to mean that her daughter is calling her friend fat. The first sentence in this explanation refers to the semantics—the literal meaning of the sentence. The second and third refer to the pragmatics, the actual meaning of the words as interpreted by a listener based on social context.



Some Example :

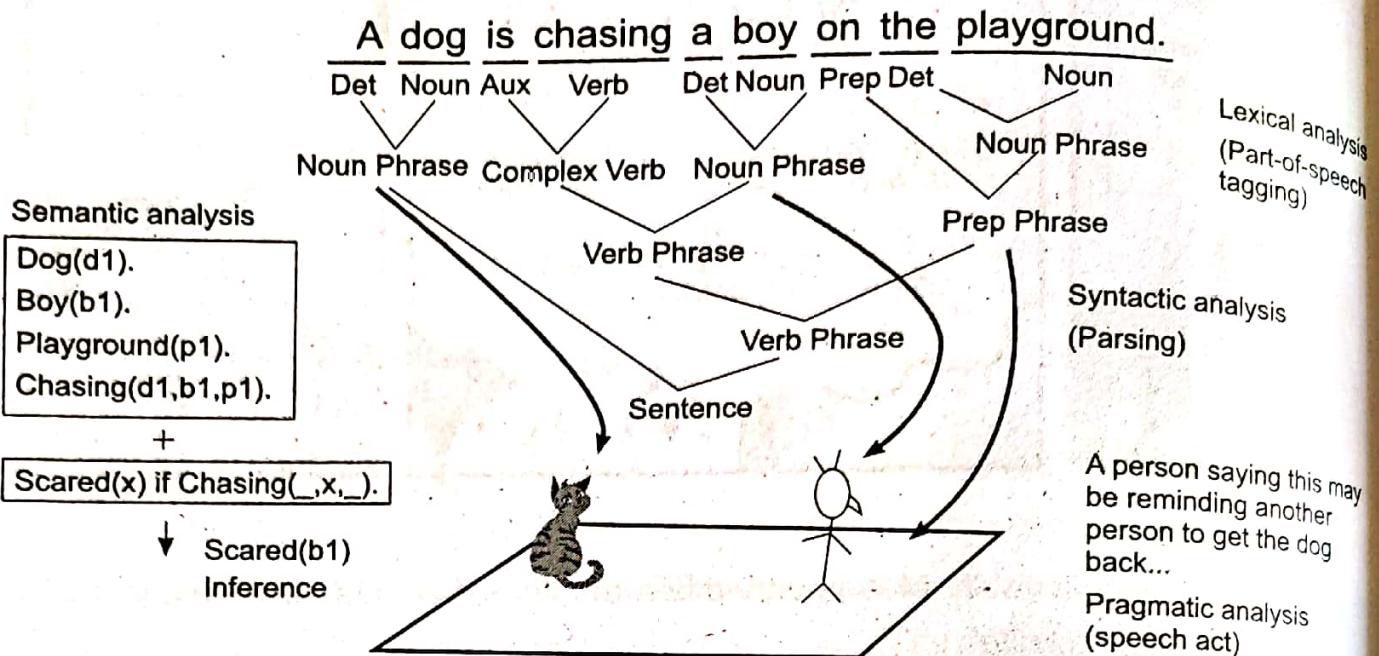
"The question 'can I cut you?' Means very different things if I'm standing next to you in line or if I am holding a knife".

"Is that water?" The action to be performed is different in a chemistry lab and on a dining table

If you go to your editor and ask her to suggest a better sentence structure for a line, her immediate question to you will be, "What's the context?" Most of the time, due to flexibility of the natural language, complexities arise in interpreting the meaning of an isolated statement. Ref.

Pragmatic analysis uses the context of utterance—when, why; by who, where, to whom something was said. It deals with intentions like criticize, inform, promise, request, and so on. For example, if I say "You are late," is it information or criticism? In discourse integration, the aim is to analyze the statement in relation to the preceding or succeeding statements or even the overall paragraph in order to understand its meaning. Take this one: Chloe wanted it. ("It" depends on Chloe). Pragmatic analysis interprets the meaning in terms of context of use unlike semantics. Ref.

## An Example of NLP



Pragmatics can be defined as :

**"It is the study of speaker meaning"**

It is concerned with the study of meaning as communicated by speaker and interpreted by the listener.

**"It is the study of contextual meaning"**

It involves interpretation of what people mean in a particular context and how the context influences what is said.

**"It is the study of how more gets communicated than is said"**

This type of study explores how great deal of what is unsaid is recognized as part of what is communicated.

**"It is the study of the expression of relative distance"**

On the assumption of how close and distant the listener is speakers determine how much needs to be said.

# Five aspects of pragmatics

## Deixis:

Deixis concerns the ways in which languages encode or grammaticalized features of the context of utterance or speech event, and thus also concerns ways in which the interpretation of utterances depends on the analysis of that context of utterance. Thus the pronoun this does not name or refer to any particular entity on all occasions of use; rather it is a variable or place-holder for some particular entity given by the context (e.g. by a gesture). In short Deixis is methods of directly encoding context into language. Consider, for example, finding the following notice on someone's office door:

"I'll be back in an hour"

Because we don't know when it was written, we cannot know when the writer will return.

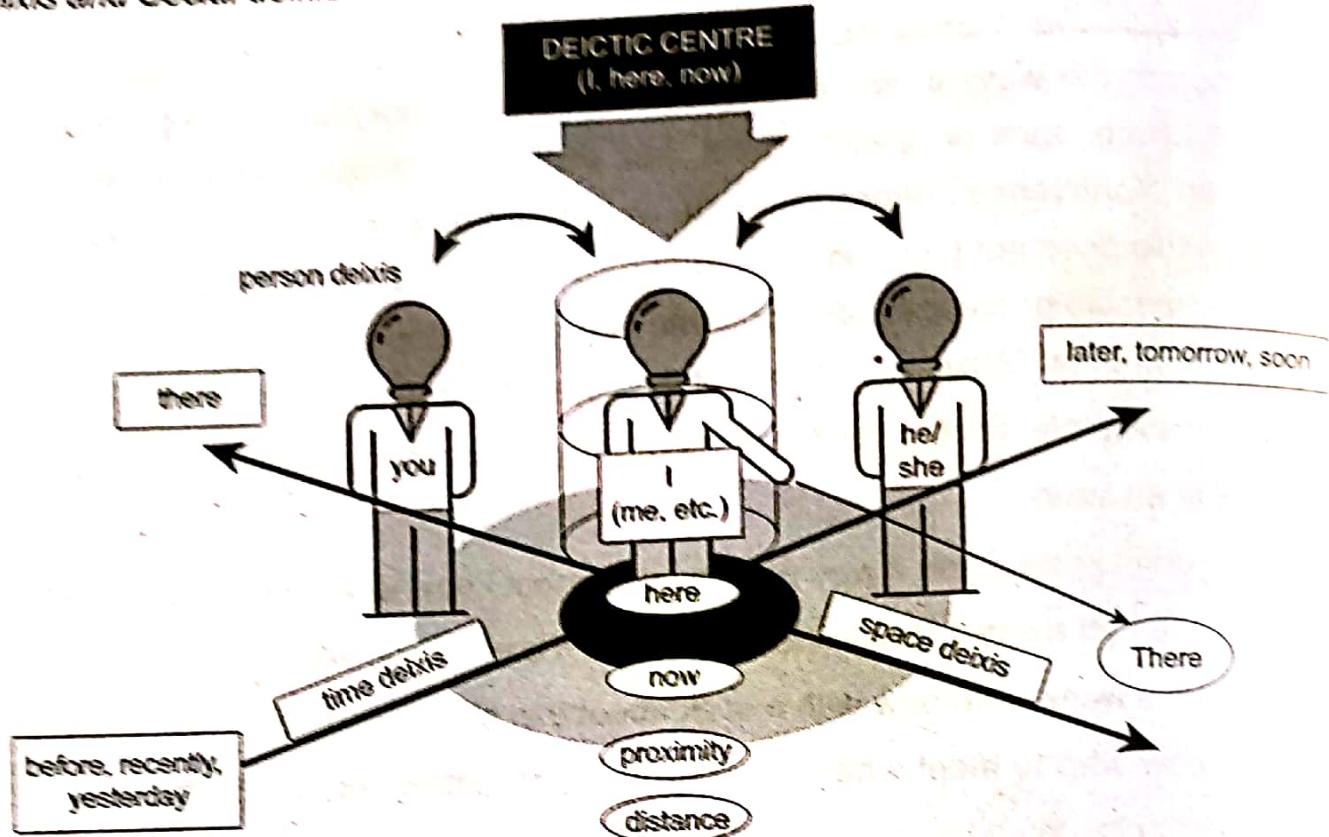
Or, suppose we find a bottle in the sea, and inside it a message which reads

"Meet me here a week from now with a stick about this big"

We do not know who to meet where or when to meet him or her, or how big a stick to bring

Deixis refers to words and phrases, such as "me" or "here", that cannot be fully understood without additional contextual information—in this case, the identity of the speaker ("me") and the speaker's location ("here"). Words are deictic if their semantic meaning is fixed but their denotational meaning varies depending on time and/or place. Words or phrases that require contextual information to convey any meaning—for example, English pronouns—are deictic. Deictic pronouns are pronouns that reference speaker- and hearer-known context.

Types of deixis are : Person deixis, Time deixis, Place deixis or Spatial deixis. Discourse deixis and Social deixis



## Implicature

**Implicature:** It means more being communicated than is said.

**Conversational implicature:** a meaning or message that is implicated in a conversation

When people oversay (or say more of) or undersay (say less of) something, they produce certain extra meaning or meanings beyond the literal meanings of words and sentences. This extra meaning is conversationally dependent, hence conversation implicature.

An implicature may also be seen as an indirect way of expressing oneself.

### Example 1:

A: Where is the fish?

B: The cat looks very happy.

### Example 2:

A: Did you invite John and Mary?

B: I invited John

### Example 3:

A (to passer by): I am out of gas.

B: There is a gas station around the corner.

Here, B does not say, but conversationally implicates, that the gas station is open, because otherwise his utterance would not be relevant in the context

Conversational implicatures are classically seen as contrasting with entailments: They are not necessary consequences of what is said, but are defeasible (cancellable). So, B could continue without contradiction:

B: But unfortunately, it's closed today.

An example of a conventional implicature is "Donovan is poor but happy", where the word "but" implies a sense of contrast between being poor and being happy

An important contribution made by the notion of implicature is that it provides some explicit account of how it is possible to mean (in some general sense) more than what is actually 'said' (i.e. more than what is literally expressed by the conventional sense of the linguistic expressions uttered).

Consider, for example:

A: Can you tell me the time?

B: Well, the milkman has come

Grice's theory says that a speaker should: be cooperative, be truthful (quality), be informative (quantity), be relevant, and be perspicuous (manner: avoid obscurity and ambiguity, be brief and orderly). This theory is insufficient, but useful. Implicature also includes notions of quantification (perhaps, some, many, etc.) and metaphors.

## Presupposition

Presupposition is something the speaker assumes to be the case prior to making an utterance. It roughly describes that which is immediately inferable but not the new information in an utterance.

Examples of presuppositions include:

Jane no longer writes fiction. Presupposition: Jane once wrote fiction.

Have you stopped eating meat? Presupposition: you had once eaten meat.

Have you talked to Hans? Presupposition: Hans exists.

Example:

"Mary's brother bought three horses"

Presuppositions:

- 1: Mary exists
- 2: She has a brother
- 3: She has only one brother
- 4: He has a lot of money

Eg., "Sue cried before she finished her thesis" presupposes that Sue finished her thesis, but this is not the new information (which is that she cried). There are both semantic and pragmatic presuppositions; the latter involve shared knowledge between speaker and hearer. A presupposition must be mutually known or assumed by the speaker and addressee for the utterance to be considered appropriate in context. It will generally remain a necessary assumption whether the utterance is placed in the form of an assertion, denial, or question, and can be associated with a specific lexical item or grammatical feature (presupposition trigger) in the utterance. Crucially, negation of an expression does not change its presuppositions: I want to do it again and I don't want to do it again both presuppose that the subject has done it already one or more times

## Speech Acts

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In linguistics, a speech act is an utterance defined in terms of a speaker's intention and the effect it has on a listener. Essentially, it is the action that the speaker hopes to provoke in his or her audience. Speech acts might be requests, warnings, promises, apologies, greetings, or any number of declarations. As you might imagine, speech acts are an important part of communication. Ref

A speech act is a statement that does something rather than just one that says something (eg., "I declare war on Zanzibar.") The basic question of speech acts seems to be that of identifying them and understanding how they differ from normal statements. A speech act in linguistics and the philosophy of language is something expressed by an individual that not only presents information, but perform an action as well. For example, the phrase "I would like the mashed potatoes, could you please pass them to me?" is considered a speech act as it expresses the speaker's desire to acquire the mashed potatoes, as well as presenting a request that someone pass the potatoes to them.

Another example The boss utters "You are fired" Performs an act of ending the employment Speech acts can be Command, apology, complaint, compliment, invitation, promise, request etc. "The tea is really cold!" Complaint during winter Compliment during summer.

"You're fired!" expresses both the employment status of the individual in question, as well as the action by which said person's employment is ended.

"I hereby appoint you as chairman" expresses both the status of the individual as chairman, and is the action which promotes the individual to this position.

"We ask that you extinguish your cigarettes at this time, and bring your tray tables and setbacks to an upright position." This statement describes the requirements of the current location, such as an airplane, while also issuing the command to stop smoking and to sit up straight.

"Would it be too much trouble for me to ask you to hand me that wrench?" functions to simultaneously ask two questions. The first is to ask the listener if they are capable of passing the wrench, while the second is an actual request

"Well, would you listen to that?" acts as a question, requesting that a listener heed what is being said by the speaker, but also as an exclamation of disbelief or shock

## Conversational Structure

analysis of the sequential (and anti-sequential) nature of conversations, interruptions, etc.

## Application that demands pragmatic understanding :

- IR and IE also seem impervious to the pragmatic hammer. QA might benefit, "Did Sue finish her thesis?"
- Even summarization seems fairly robust to a lack of pragmatic understanding, although the "new/old" issue is important here. Perhaps what is old in the real discourse is not new for the reader of the summary.
- Sentiment Analysis

## 2. Discourse - reference resolution

Language does not normally consist of isolated, unrelated sentences, but instead of collocated, related groups of sentences. Such a group of sentences as a discourse. Monologues are characterized by a speaker (a term which will be used to include writers, as it is here), and a hearer (which, analogously, includes readers). The communication flows in only one direction in a monologue, that is, from the speaker to the hearer. A conversation with a friend about it, which would consist of a much freer interchange. Such a discourse is called a dialogue. In this case, each participant periodically takes turns being a speaker and hearer. Unlike a typical monologue, dialogues generally consist of many different types of communicative acts: asking questions, giving answers, making corrections, and so forth. Finally, computer systems exist and continue to be developed that allow for human-computer interaction, or HCI. HCI has properties that distinguish it from normal human-human dialogue, in part due to the present-day limitations on the ability of computer systems to participate in free, unconstrained conversation. A system capable of HCI will often employ a strategy to constrain the conversation in ways that allow it to understand the user's utterances within a limited context of interpretation. While many discourse processing problems are common to these three forms of discourse, they differ in enough respects that different techniques have often been used to process them.

Language is rife with phenomena that operate at the discourse level. John went to Bill's car dealership to check out an Acura Integra. He looked at it for about an hour. What do pronouns such as he and it denote? Can we build a computational model for the resolution of referring expressions?

Algorithms for resolving discourse-level phenomena are essential for a wide range of language applications. For instance, interactions with query interfaces and dialogue interpretation systems like ATIS frequently contain pronouns and similar types of expressions.

I'd like to get from Boston to San Francisco, on either December 5th or December 6th.  
It's okay if it stops in another city along the way.

It denotes the flight that the user wants to book in order to perform the appropriate action.  
IE systems must frequently extract information from utterances that contain pronouns

First Union Corp is continuing to wrestle with severe problems unleashed by a botched merger and a troubled business strategy. According to industry insiders at Paine Webber, their president, John R. Georgius, is planning to retire by the end of the year. Text summarization systems employ a procedure for selecting the important sentences from a source document and using them to form a summary.

## Reference Resolution

In this section we study the problem of reference, the process by which REFERENCE speakers use expressions like John and he in passage (John went to Bill's car dealership to check out an Acura Integra. He looked at it for about an hour) to denote a person named John. Our discussion requires that we first define some terminology. A natural language expression used to perform reference is called a referring expression, and the entity that is referred to is called the referent. Thus, John and he in passage (John went to Bill's car dealership to check out an Acura Integra. He looked at it for about an hour) are referring expressions, and John is their referent. (To distinguish between referring expressions and their referents, we italicize the former.) As a convenient shorthand, we will sometimes speak of a referring expression referring to a referent, e.g., we might say that he refers to John. However, the reader should keep in mind that what we really mean is that the speaker is performing the act of referring to John by uttering he. Two referring expressions that are used to refer to the same entity are said to corefer, thus John and he corefer in passage. There is also a term for a referring expression that licenses the use of another, in the way that the mention of John allows John to be subsequently referred to using he. We call John the antecedent of he. Reference to an entity that has been previously introduced into the discourse is called anaphora, and the referring expression used is said to be anaphoric. In passage .the pronouns he and it are therefore anaphoric. Natural languages provide speakers with a variety of ways to refer to entities. Say that your friend has an Acura Integra automobile and you want to refer to it. Depending on the operative discourse context, you might say it, this, that, this car, that car, the car, the Acura, the Integra, or my friend's car, among many other possibilities. However, you are not free to choose between any of these alternatives in any context. For instance, you cannot simply say it or the Acura if the hearer has no prior knowledge of your friend's car, it has not been mentioned before, and it is not in the immediate surroundings of the discourse participants (i.e., the situational context of the discourse).

The reason for this is that each type of referring expression encodes different signals about the place that the speaker believes the referent occupies within the hearer's set of beliefs. A subset of these beliefs that has a special status form the hearer's mental model of the ongoing discourse, which we call a discourse model (Webber, 1978). The discourse model contains representations of the entities that have been referred to in the discourse and the relationships in which they participate. Thus, there are two components required by a system to successfully produce and interpret referring expressions: a method for constructing a discourse model that evolves with the dynamically-changing discourse it represents, and a method for mapping between the signals that various referring expressions encode and the hearer's set of beliefs, the latter of which includes this discourse model. We will speak in terms of two fundamental operations to the discourse model. When a referent is first mentioned in a discourse, we say that a representation for it is evoked into the model. Upon subsequent mention, this representation is accessed from the model. The operations and relationships are illustrated in Figure below

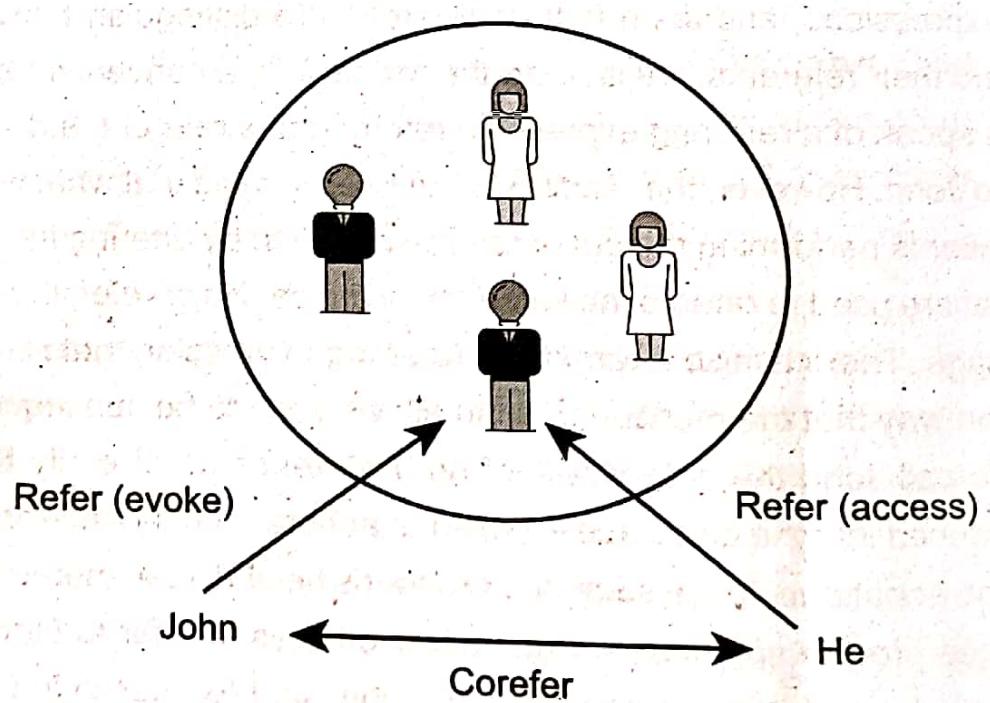


Figure 1: reference operation and relationships

We will restrict our discussion to reference to entities, although discourses include references to many other types of referents. Consider the possibilities in example:

According to John, Bob bought Sue an Integra, and Sue bought Fred a Legend.

- a. But that turned out to be a lie.
- b. But that was false.

- c. That struck me as a funny way to describe the situation.
- d. caused Sue to become rather poor.
- e. That caused them both to become rather poor. The referent of that is a speech act in (a), a proposition in (b), a manner of description in (c), an event in (d), and a combination of several events in (e). The field awaits the development of robust methods for interpreting these types of reference.

### 3. Reference Phenomenon

The set of referential phenomena that natural languages provide is quite rich indeed. Five types of referring expressions: indefinite noun phrases, definite noun phrases, pronouns, demonstratives, and one-anaphora. Three types of referents that complicate the reference resolution problem: inferrables, discontinuous sets, and generics.

**Indefinite Noun Phrases:** Indefinite reference introduces entities that are new to the hearer into the discourse context. The most common form of indefinite reference is marked with the determiner a (or an), as in A, but it can also be marked by a quantifier such as B or even the determiner this C.

- A. I saw an Acura Integra today.
- B. Some Acura Integras were being unloaded at the local dealership today.
- C. I saw this awesome Acura Integra today.

Such noun phrases evoke a representation for a new entity that satisfies the given description into the discourse model. The indefinite determiner a does not indicate whether the entity is identifiable to the speaker, which in some cases leads to a specific/non-specific ambiguity. Example A only has the specific reading, since the speaker has a particular Integra in mind, particularly the one she saw. In sentence D, on the other hand, both readings are possible.

- D. I am going to the dealership to buy an Acura Integra today.

That is, the speaker may already have the Integra picked out (specific), or may just be planning to pick one out that is to her liking (nonspecific). The readings may be disambiguated by a subsequent referring expression in some contexts; if this expression is definite then the reading is specific (I hope they still have it), and if it is indefinite then the reading is nonspecific (I hope they have a car I like). This rule has exceptions, however; for instance definite expressions in certain modal contexts (I will park it in my garage) are compatible with the nonspecific reading.

**Definite Noun Phrases** Definite reference is used to refer to an entity that is identifiable to the listener, either because it has already been mentioned in the discourse context (and thus is represented in the discourse model), it is contained in the hearer's set of beliefs about the world, or the uniqueness of the object is implied by the description itself. The case in which the referent is identifiable from discourse context is shown in . S1 : I saw an Acura Integra today. The Integra was white and needed to be washed.

**Pronouns** Another form of definite reference is pronominalization, illustrated in example I saw an Acura Integra today. It was white and needed to be washed. The constraints on using pronominal reference are stronger than for full definite noun phrases, requiring that the referent have a high degree of activation or salience in the discourse model. Pronouns usually (but not always) refer to entities that were introduced no further than one or two sentences back in the ongoing discourse, whereas definite noun phrases can often refer further back.

A . John went to Bob's party, and parked next to a beautiful Acura Integra. b. He went inside and talked to Bob for more than an hour. c. Bob told him that he recently got engaged. d. ?? He also said that he bought it yesterday. d.' He also said that he bought the Acura yesterday. By the time the last sentence is reached, the Integra no longer has the degree of salience required to allow for pronominal reference to it. Pronouns can also participate in cataphora, in which they are mentioned before their referents are, as in example (S2). S2 Before he bought it, John checked over the Integra very carefully. Here, the pronouns he and it both occur before their referents are introduced. Pronouns also appear in quantified contexts in which they are considered to be bound, as in example (S3). BOUND (S3) Every woman bought her Acura at the local dealership. Under the relevant reading, her does not refer to some woman in context, but instead behaves like a variable bound to the quantified expression every woman. We will not be concerned with the bound interpretation of pronouns in this chapter.

**Demonstratives:** Demonstrative pronouns, like this and that, behave somewhat differently than simple definite pronouns like it. They can appear either alone or as determiners, for instance, this Acura, that Acura. The choice between two demonstratives is generally associated with some notion of spatial proximity: this indicating closeness and that signalling distance.

Spatial distance might be measured with respect to the discourse participants' situational context, as in (S4). (S4) [John shows Bob an Acura Integra and a Mazda Miata] Bob (pointing): I like this better than that. Alternatively, distance can be metaphorically

interpreted in terms of conceptual relations in the discourse model. For instance, consider example (S5). (S5) I bought an Integra yesterday. It's similar to the one I bought five years ago. That one was really nice, but I like this one even better. Here, that one refers to the Acura bought five years ago (greater temporal distance), whereas this one refers to the one bought yesterday (closer temporal distance).

**One Anaphora:** One-anaphora, exemplified in (S6), blends properties of definite and indefinite reference. (S6) I saw no less than 6 Acura Integrals today. Now I want one. This use of one can be roughly paraphrased by one of them, in which them refers to a plural referent (or generic one, as in the case of (S6), see below), and one selects a member from this set (Webber, 1983). Thus, one may evoke a new entity into the discourse model, but it is necessarily dependent on an existing referent for the description of this new entity. This use of one should be distinguished from the formal, non-specific pronoun usage in (S6), and its meaning as the number one in (S7). (S6) One shouldn't pay more than twenty thousand dollars for an Acura. (S7) John has two Acuras, but I only have one.

**Inferables:** Now that we have described several types of referring expressions, we now turn our attention to a few interesting types of referents that complicate the reference resolution problem. First, we consider cases in which a referring expression does not refer to an entity that has been explicitly evoked in the text, but instead one that is inferentially related to an evoked entity. Such referents are called inferables (Haviland and Clark, 1974; Prince, 1981). Consider the expressions a door and the engine in sentence (S8). (S8) I almost bought an Acura Integra today, but a door had a dent and the engine seemed noisy. The indefinite noun phrase a door would normally introduce a new door into the discourse context, but in this case the hearer is to infer something more: that it is not just any door, but one of the doors of the Integra. Similarly, the use of the definite noun phrase the engine normally presumes that an engine has been previously evoked or is otherwise uniquely identifiable. Here, no engine has been explicitly mentioned, but the hearer infers that the referent is the engine of the previously mentioned Integra. Inferables can also specify the results of processes described by utterances in a discourse. Consider the possible follow-ons (a-c) to sentence (S9) in the following recipe (from Webber and Baldwin (1992)): (S9) Mix the flour, butter, and water.  
a. Knead the dough until smooth and shiny. b. Spread the paste over the blueberries.  
c. Stir the batter until all lumps are gone. Any of the expressions the dough (a solid), the batter (a liquid), and the paste (somewhere in between) can be used to refer to the

result of the actions described in the first sentence, but all imply different properties of this result.

**Discontinuous Sets:** In some cases, references using plural referring expressions like they and them (see page 10) refer to sets of entities that are evoked together, for instance, using another plural expression (their Acuras) or a conjoined noun phrase (John and Mary): (S10) John and Mary love their Acuras. They drive them all the time. However, plural references may also refer to sets of entities that have been evoked by discontinuous phrases in the text: (S11) John has an Acura, and Mary has a Mazda. They drive them all the time. Here, they refers to John and Mary, and likewise them refers to the Acura and the Mazda. Note also that the second sentence in this case will generally receive what is called a pairwise or respectively reading, in which John drives the Acura and Mary drives the Mazda, as opposed to the reading in which they both drive both cars.

**Generics:** Making the reference problem even more complicated is the existence of generic reference. Consider example (S12). (S12) I saw no less than 6 Acura Integras today. They are the coolest cars. Here, the most natural reading is not the one in which they refers to the particular 6 Integras mentioned in the first sentence, but instead to the class of Integras in general

## 4. Syntactic and Semantic Constraints on Coreference

Having described a variety of reference phenomena that are found in natural language, we can now consider how one might develop algorithms for identifying the referents of referential expressions. One step that needs to be taken in any successful reference resolution algorithm is to filter the set of possible referents on the basis of certain relatively hard-and-fast constraints. We describe some of these constraints here.

**Number Agreement** Referring expressions and their referents must agree in number; for English, this means distinguishing between singular and plural references. A categorization of pronouns with respect to number is shown in Figure A

Singular	Plural	Unspecified
she, her, he, him, his, it	we, us, they, them	you

Figure 2: Number agreement in the English pronominal system.

The following examples illustrate constraints on number agreement.

1. John has a new Acura. It is red.
2. John has three new Acuras. They are red.
3. John has a new Acura. They are red.
4. John has three new Acuras. It is red.

## Person and Case Agreement

English distinguishes between three forms of person: first, second, and third. A categorization of pronouns with respect to person is shown in Figure B. The following examples illustrate constraints on person agreement. S13 You and I have Acuras. We love them.

	First	Second	Third
Nominative	I, we	you	he, she, they
Accusative	me, us	you	him, her, them
Genitive	my, our	your	his, her, their

Figure 3: Person and case agreement in the English pronominal system

## Coreference

In linguistics, coreference, sometimes written co-reference, occurs when two or more expressions in a text refer to the same person or thing; they have the same referent, e.g. Bill said he would come; the proper noun Bill and the pronoun he refer to the same person, namely to Bill. Coreference occurs when one or more expressions in a document refer back to the entity that came before it/ them.

Coreference is the main concept underlying binding phenomena in the field of syntax. The theory of binding explores the syntactic relationship that exists between coreferential expressions in sentences and texts. When two expressions are coreferential, the one is usually a full form (the antecedent) and the other is an abbreviated form (a proform or anaphor). Linguists use indices to show coreference, as with the i index in the example Billi said hei would come. The two expressions with the same reference are coindexed, hence in this example Bill and he are coindexed, indicating that they should be interpreted as coreferential. Ref

## Coreference distinctions

When exploring coreference, there are numerous distinctions that can be made, e.g. anaphora, cataphora, split antecedents, coreferring noun phrases, etc. When dealing with proforms (pronouns, pro-verbs, pro-adjectives, etc.), one distinguishes between anaphora and cataphora. When the proform follows the expression to which it refers, anaphora is present (the proform is an anaphor), and when it precedes the expression to which it refers, cataphora is present (the proform is a cataphor).

These notions are illustrated as follows:

### Anaphora

- a. **The music**, was so loud that **it**, couldn't be enjoyed. – The anaphor *it* follows the expression to which it refers (its antecedent).
- b. **Our neighbors**, dislike the music. If **they**, are angry, the cops will show up soon. – The anaphor *they* follows the expression to which it refers (its antecedent).

### Cataphora

- a. If **they**, are angry about the music, **the neighbors**, will call the cops. – The cataphor *they* precedes the expression to which it refers (its postcedent).
- b. Despite **her**, difficulty, **Wilma**, came to understand the point. – The cataphor *her* precedes the expression to which it refers (its postcedent)

### Split antecedents

- a. **Carol**, told **Bob**, to attend the party. **They**, arrived together. – The anaphor *they* has a split antecedent, referring to both *Carol* and *Bob*.
- b. When **Carol**, helps **Bob**, and **Bob**, helps **Carol**, **they**, can accomplish any task. – The anaphor *they* has a split antecedent, referring to both *Carol* and *Bob*.

### Coreferring noun phrases

- a. **The project leader**, is refusing to help. **The jerk**, thinks only of himself. – Coreferring noun phrases, whereby the second noun phrase is a predication over the first.
- b. **Some of our colleagues**, are going to be supportive. **These kinds of people**, will earn our gratitude. – Coreferring noun phrases, whereby the second noun phrase is a predication over the first.

mention	John told Sally that she should come watch him play the violin.
antecedent	John told <u>Sally</u> that she should come watch him play the violin.
coreferent	John told Sally that she should come watch him play the violin.
cluster	John told Sally that she should come watch him play the violin.
anaphoric	John told Sally that <u>she</u> should come watch him play the violin.
non-anaphoric	John told Sally that she should come watch him play the violin.

## Coreference resolution

Coreference resolution is the task of clustering mentions in text that refer to the same underlying real-world entities. Coreference resolution, is the task of finding all expressions that are coreferent with any of the entities found in a given text. Coreference resolution is the task of resolving noun phrases to the entities that they refer to. Coreference resolution finds the mentions in a text that refer to the same real-world entity. For example, in the sentence, "Andrew said he would buy a car" the pronoun "he" refers to the same person, namely to "Andrew".

I voted for obama because he was most aligned with my values", she said.

"I", "my", and "she" belong to the same cluster and "Obama" and "he" belong to the same cluster.

In computational linguistics, coreference resolution is a well-studied problem in discourse. To derive the correct interpretation of a text, or even to estimate the relative importance of various mentioned subjects, pronouns and other referring expressions must be connected to the right individuals. Algorithms intended to resolve coreferences commonly look first for the nearest preceding individual that is compatible with the referring expression. For example, she might attach to a preceding expression such as the woman or Anne, but not to Bill. Pronouns such as himself have much stricter constraints. Algorithms for resolving coreference tend to have accuracy in the 75% range. As with many linguistic tasks, there is a trade-off between precision and recall.

A classic problem for coreference resolution in English is the pronoun it, which has many uses. It can refer much like he and she, except that it generally refers to inanimate objects (the rules are actually more complex: animals may be any of it, he, or she; ships are traditionally she; hurricanes are usually it despite having gendered names). It can also refer to abstractions rather than beings: "He was paid minimum wage, but didn't seem to mind it." Finally, it also has pleonastic uses, which do not refer to anything specific:

- a. It's raining.
- b. It's really a shame.
- c. It takes a lot of work to succeed.
- d. Sometimes it's the loudest who have the most influence.

## Approach to coreference resolution

### Coreference Resolution in Two Steps

#### 1. Detect the mentions (easy)

"[I] voted for [Nader] because [he] was most aligned with [[my] values]," [she] said  
mentions can be nested!

#### 2. Cluster the mentions (hard)

"[I] voted for [Nader] because [he] was most aligned with [[my] values]," [she] said

### Mentions Detection

Mentions : span of text referring to some entity

Three kinds of mentions:

- Pronouns : I, your, it, she, him, etc. Use a part-of-speech tagger
- Named entities : People, places, etc.. Use a NER system
- Noun phrases : "a dog," "the big fluffy cat stuck in the tree" Use a constituency parser

Filter things that look referential but, in fact, are not – e.g.

- geographic names, the United State
- pleonastic "it", e.g. it's 3:45 p.m., it was cold –
- non-referential "it" , "they" , "there" e.g. it was essential, important, is understood, they say, there seems to be a mistake

All noun phrases (both indef. and def.) are considered potential referent candidates. – A referring phrase can also be a referent for a subsequent referring phrases, Example: He had 300 grams of plutonium 239 in his baggage. The suspected smuggler denied that the materials were his. (chain of 4 referring phrases) – All potential candidates are collected in a table collecting feature info on each candidate.

## Features

Define features between a referring phrase and each candidate

– Number agreement: plural, singular or neutral

- He, she, it, etc. are singular, while we, us, they, them, etc. are plural and should match with singular or plural nouns, respectively
- Exceptions: some plural or group nouns can be referred to by either it or they IBM announced a new product. They have been working on it ...

– Gender agreement:

- Generally animate objects are referred to by either male pronouns he, his) or female pronouns (she, hers)
- Inanimate objects take neutral (it) gender

– Person agreement:

- First and second person pronouns are "I" and "you"
- Third person pronouns must be used with nouns

– Binding constraints

Reflexive pronouns (himself, themselves) have constraints on which nouns in the same sentence can be referred to:

John bought himself a new Ford. (John = himself)

John bought him a new Ford. (John cannot = him)

- Recency

Entities situated closer to the referring phrase tend to be more salient than those further away And pronouns can't go more than a few sentences away

- Grammatical role / Hobbs distance

Entities in a subject position are more likely than in the object position

- Repeated mention

Entities that have been the focus of the discourse are more likely to be salient for a referring phrase

#### -Parallelism

There are strong preferences introduced by parallel constructs Long John Silver went with Jim. Billy Bones went with him. (him = Jim)

#### -Verb Semantics and selectional restrictions

Certain verbs take certain types of arguments and may prejudice the resolution of pronouns John parked his car in the garage after driving it around for hours.

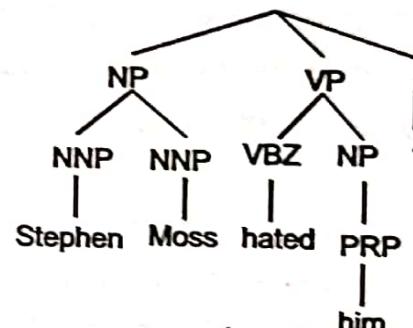
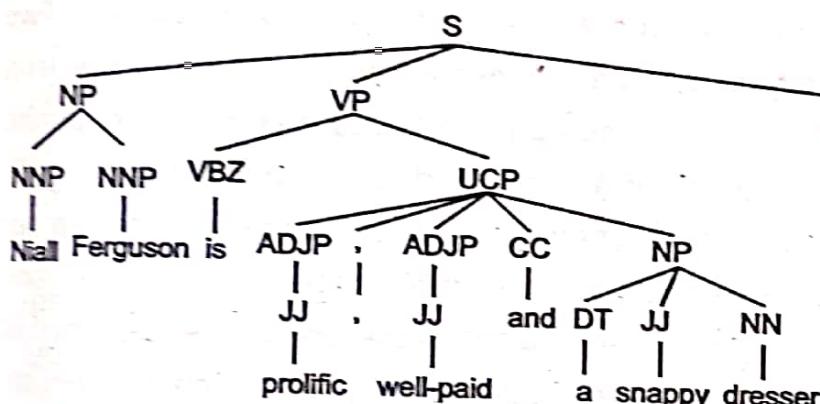
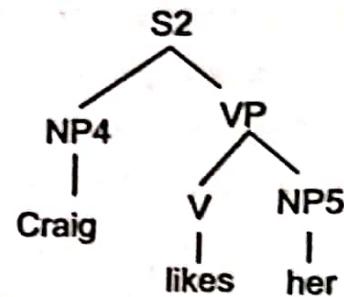
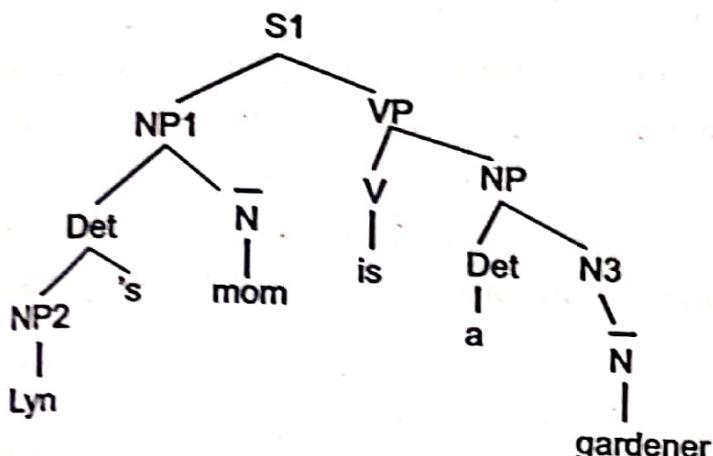
### **Hobbs' Algorithm**

Hobbs' algorithm was one of the earliest approaches to pronoun resolution. The algorithm is mainly based on the syntactic parse tree of the sentences. It makes use of syntactic constraints when resolving pronouns. First, intra-sentential antecedents are proposed. the syntactic tree of the current sentence is searched in a breadth-first left to-right fashion to find antecedents. The contra-indexing constraint is taken care inside the algorithm, by making sure that the path from the NP to the S node of the syntactic tree has at least one another NP on the way. If there are higher-level nodes in the current sentence, then antecedents resulting from a breadth-first left-to-right search of each subtree, are proposed. Then, parse trees of previous sentences in reverse chronological order are searched in the same fashion to propose antecedents. In essence, Hobbs' algorithm prefers entities that are within the same sentence, and entities that are closer pronoun in the same sentence. Depending on the position of the pronoun in the sentence, different entities in a sentence may become more relevant. When looking for antecedents in previous sentences, the antecedents that occur (or are realized) in the subject position are more salient, since a breadth-first left-to-tree search is performed starting at the root S node of the sentence. Depth of a node in the syntactic tree is thus a very important factor to determine discourse prominence. Ref

1. Start with target pronoun
2. Climb parse tree to S root
3. For each NP or S
  - a. Do breadth-first, left-to-right search of children
  - b. Restricted to left of target
  - c. For each NP, check agreement with target

#### 4. Repeat on earlier sentences until matching NP found

Example



## Why Coreference Resolution is Hard

Entities can be very long and coreferent entities can occur extremely far away from one another. A greedy system would compute every possible span (sequence) of tokens and then compare it to every possible span that came before it. This makes the complexity of the problem  $O(T^4)$ , where  $T$  is the document length. For a 100 word document this would be 100 million possible options. If this does not make it concrete, imagine that we had the sentence

\*Arya Stark walks her direwolf, Nymeria.\*

Here we have three entities: Arya Stark, her, and Nymeria. As a native speaker of English it should be trivial to tell that her refers to Arya Stark. But to a machine with no knowledge, how should it know that Arya and Stark should be a single entity rather than two separate ones, that Nymeria does not refer back to her even though they are arguably related, or

even that that Arya Stark walks her direwolf, Nymeria is not just one big entity in and of itself?

For another example, consider the sentence

\* Napoleon and all of his marvelously dressed, incredibly well-trained, loyal troops marched all the way across Europe to enter into Russia in an ultimately unsuccessful effort to conquer it for their country. \*

The word their is referent to Napoleon and all of his marvelously dressed, incredibly well trained, loyal troops; entities can span many, many tokens. Coreferent entities can also occur far away from one another.

## Coreference vs. Anaphora

Coreference resolution is often confused with the task of anaphora resolution. Two noun phrases are said to be co-referring to each other if both of them resolve to a unique referent (unambiguously). However, a noun phrase A is said to be the anaphoric antecedent of a noun phrase B, if and only if A is required for the interpretation of B. Thus, coreference is an equivalence relation, whereas anaphora is neither reflexive nor symmetric (nor transitive). Every speaker had to present his paper. Here, if "his" and "every speaker" are said to co-refer (i.e., considered the same entity), the sentence is interpreted as "Every speaker had to present Every speaker's paper" which is obviously not correct. Thus, "his" here is an anaphoric referent and not coreferential

A number of coreferential links could be anaphoric relations but some anaphora relations such as bound anaphora are not coreference links. For example, sentences like the following contain bound anaphora: a. Every dog has its day. b. The man who gave his paycheck to his wife was wiser than the man who gave it to his mistress. where the anaphor and the antecedent are not coreferent. Further, there could be other anaphoric relations like the following: The boy entered the room. The door closed automatically. where the relation between the room and the door is that of meronymy/holonomy. In these cases, the two noun phrases do not refer to a single entity. Other contentious cases exist such as concepts that vary with time such as the President of a nation, the price of a stock, etc. The problem with defining coreference resolution this way is the inappropriate use of the term "coreference" to cover semantic relations such as those involving temperature and price.

## Application of Coreference Resolution

The Coreference Resolution can be applied to multiple Natural Language Processing (NLP) tasks, such as name entity recognition (NER), translation, question answering and text summarization, in a meaningful way. For example, for name entity recognition (NER) task, the Coreference Resolution helps to detect the references between entities and pronouns. On the one hand, if pronouns are replaced by coreferred entities, the incremented frequency of entities in the document will enhance the accuracy of the NER model. On the other hand, it is not necessary to detect name entity word by word if we have already known all words that refer to the same real-world entity. Ref

Another example, in a French-English translation system, we have a sentence "Barack Obama a un chien. Son chien est grand." which in English is "Barack Obama has a dog. His dog is big." However, the translator may mis-recognize "his dog" as "her dog" because of the lack of gender information. If we introduce the Coreference Resolution into this translation system, then the translator can understand "son chien" is the dog of Barack Obama, and he is a man. Applying the Coreference Resolution to these NLP tasks, especially NLU tasks, can eventually increases their performances.