A presupposition-satisfaction model of lexical disambiguation

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Spring Junior Paper
April 28, 2003
Abstract

When we hear and read, we don't notice that most words have several meanings, and because of that most sentences have thousands of potential meanings. But, people figure out what meaning is intended for each word with ease. Lexical ambiguity is a problem awaiting an answer. Herein, what is needed to successfully disambiguate sentences is considered and a model of disambiguation is proposed. The priming effect and semantic selection, for instance, are shown to be insufficient tools for disambiguation. The model proposed uses sentence presuppositions to resolve lexical ambiguity in an indirect route. Senses of words are considered through how the sentence it is a part of would be interpreted. Interpretations of sentences are judged by whether the presuppositions they make have already been established. Interpretations with unsatisfied presuppositions are weighed against, causing the word senses in those interpretations to be less likely to be selected as the meanings for the words. The hypothesis makes several predictions in other areas of comprehension, but only by testing the model over a large set of examples can its true usefulness be determined.
Introduction

What makes us human, our unique ability to use language, is also one of the least understood aspects of cognitive psychology. Natural language is riddled with problems that have yet to be understood, from the level of discriminating phonemes in a stream of raw audio to maintaining a mental representation of the topic at hand. In the middle, however, is the problem of lexical ambiguity: words have many meanings. A classic example is the river bank/investment bank ambiguity. If I walked to “the bank,” to which type of thing did I go? Lexical ambiguity poses a problem for the speech listener (or reader), for how does his mind determine which meaning of every word was intended by the speaker (or writer)? This paper will investigate what computational processes in the mind can and cannot contribute to lexical disambiguation.

The problem of lexical ambiguity is even more intriguing when considering that people don't realize just how astronomical the problem can be. Most words have several meanings. In a sample of 423 short articles from TIME Magazine, the average word had 3.7 meanings (Krovetz & Croft, 1992). If each word in a ten-word sentence could have one of four meanings, then the sentence has $4^{10} = 1,048,576$ possible meanings. Miller (2001) multiplied out the number of possible meanings of Robert Frost's “But I have promises to keep / And miles to go before I sleep.” and found it could have over three trillion meanings if the parts of speech of each word is not known and as many as 9,660 if the parts of speech are known. The human mind must have some method to reduce
thousands, or trillions, of possibilities to 1.

It depends on the context, of course — at least, that is what one would say before seeing how unhelpful such a hypothesis is. One must figure in the mental/emotional context of the listener, the surrounding situational context, the context within a sentence, the context within a discourse, and perhaps other types of contexts as well. If all of these factors play a role, a useful hypothesis must define how they come together to solve the problem. It is tempting to organize the factors into some ordered set of modules, but ultimately a working hypothesis will be shown to only be found in one that explains how discourse context is applied.

Lexical ambiguity is a difficult problem to correctly pose, as words can be ambiguous in several ways. Bank is ambiguous, as above, because it has two unrelated semantic meanings, whereas open is ambiguous because it can be used to mean a variety of related things (to open a can versus to open a computer file). The former type of ambiguity is called homonymy, and the latter polysemy (Klepousniotou, 2002). (Words can also be ambiguous in their part of speech, called syntactic ambiguity, such as in to open a door and to hold an open ballot. For the purposes of this paper, it will be assumed that the part of speech of a word is known ahead of time.) Evidence exists for a mental distinction between the two types of ambiguity (Klepousniotou, 2002) as well as against polysemous meanings sharing a core meaning (Klein & Murphy, 2001), so the present discussion stays out of the debate by recognizing the difference but not making a further distinction between homonymy and polysemy.

A second problem to posing the question is that ambiguity resolution is neither always achieved nor always desired. Imagine standing in front of a door, on the other
side of which there is something labeled “success” that will make you successful. Now, open the door to success, no pun intended. Does it matter which meaning I meant? Nerlich and Clarke (2001) point out that ambiguity is also often used purposefully in irony, metaphor, jokes, and explicit double meanings, something we all know but easily forget when thinking about the problem. As important to humanity as these circumstances are, I will focus on only the cases when one is expected to arrive at a unique meaning.

Lexical ambiguity is also not always resolved immediately. Information at the end of a sentence can change how one interprets the start. For instance, *I cut the panel in half because we had too many experts in the room.* The sentence seems at first as if it were talking about a physical, flat panel, but by the end the word's meaning switches to a group of experts. Sometimes one has to consciously think about the meaning of the word to understand it. Waters and Caplan (1996) argued that “unconscious, on-line language comprehension” — that is, normal language comprehension — is distinct from “conscious, controlled, and verbally mediated processes,” such as explicit reasoning. Along those lines, I will be careful to exclude from consideration any hypotheses that rely on an obvious intervention of conscious thought.

But this approach differs from how models of comprehension are often considered in the literature. Sereno (1995), for instance, in comparing various models of lexical resolution through an eye-movement study, focused on what meanings of ambiguous words are activated during comprehension. The selective access, multiple access, reordered access, and integration models of lexical ambiguity resolution were characterized only by the level at which context is invoked and whether words have
dominant meanings. The present paper is not concerned so much with what meanings are activated when, but instead looks at what mental processes contribute to disambiguation, what hypotheses cannot help disambiguation, and what must be computed to achieve disambiguation.

Knowing what method the mind uses to solve this ambiguity has implications in many areas of student: for psychology by furthering our understanding of language comprehension, for education by guiding how vocabulary should be taught, and for medicine by shedding light on the nature of language deficits. Understanding lexical resolution also has applications in computing. Internet search engines like www.Google.com, and document retrieval systems in general, which search the Internet for webpages that match a text query, return documents that contain the words used in the query. They work on the false assumption that words each only have one meaning, and consequently often return unrelated documents that contain a homonym of a word in the query. Searching by word meaning could greatly improve these tools (Krovetz & Croft, 1992), but it is not done in practice, in part, because no computerized system can disambiguate words as good as a human can. Speech recognition systems also suffer from the same problem, unable to distinguish between homophones despite the presence of context. Understanding how people choose word meanings would allow computational linguistics to develop better methods for computers to deal with the same linguistics problems humans do.

The analysis here will start at the bottom with the most basic tools at the mind's disposal for lexical ambiguity resolution, and then it will work its way up to how understanding the discourse can and must be used to solve the problem.
Building blocks

There are several obvious, low-level factors that affect lexical disambiguation, including how often word senses are used, what the outside context is, and what word senses have been used recently. The simplest case of lexical resolution is understanding a single word in isolation, outside of any sentence, dialog, or scenario. Complete isolation can never occur, however, as experience affects how words are understood. The frequency with which one has heard word senses plays a role. Presented with the word *treat*, an idealized English speaker will think of the often-heard senses \textit{goody$_N$}, \textit{to provide with a gift}, or \textit{to provide treatment for}, but not \textit{to engage in negotiations}, which is never used in everyday speech. Parents who often ask their children if they would like a treat might lean toward the first or second sense, while doctors who often provide treatments will lean toward the third. Evidence in support of this hypothesis comes from studies that measured response times to words of different frequencies. In Ferreira, Henderson, Anes, Weeks, and Mcfarlane (1996), high-frequency words took 27 ms less time to process than did low-frequency words. Accordingly, one would expect high-frequency senses to be more salient than low-frequency senses.

Even in this isolated case, there are frequencies of four distinct events to take into consideration: hearing the word sense, speaking the word sense, thinking about the word sense's extension (it's meaning), and thinking about the word sense's intension (the word itself). Do each of these events, which often occur together, affect lexical resolution, and do they do so equally? Then there are four more events: hearing, speaking, and thinking about related word senses. If a parent uses \textit{candy} often but not \textit{treat}, and if \textit{treat} and
candy are related, will he still tend to resolve treat in the goody sense? All of these factors no doubt affect lexical disambiguation, but none get at the information needed to resolve ambiguity reliably.

Once situational context is brought in, the frequencies of past events seems a lot less important. A parent, who in isolation would take treat to mean goody, would in a hospital have the other reaction, taking it to mean to provide treatment. This conflict brings out the question of when situational context overrides past experiences.

Analyzing words in isolation is inherently awkward because lexical ambiguity is only interesting in the presence of other words. The next level above isolated words is pairs of words: how the presentation of one word affects the interpretation of a second, ambiguous word. One factor to consider at this level is the priming effect, where the presentation of one stimulus causes a particular response to be more or less likely, or to be faster or slower, through spreading neural activation in the brain's semantic networks. (See Joordens & Becker, 1997 for a review of semantic priming research.) In the case of lexical ambiguity resolution, one would expect word senses to cause other related word senses to be more likely selected. (Barn. Pen. The first word primes barn-related concepts, allowing the pig-pen interpretation of pen to win out over the writing implement interpretation.) Though priming may be important in keeping one's interpretations of words aligned with previously heard words, I will soon show that word relatedness is not very helpful for lexical disambiguation.

Ambiguity resolution can also be aided by the fact that some patterns of word senses are more common than others. For instance, eye of the storm more often contains
the storm-eye sense of *eye* than the ocular-organ sense. Furthermore, the “storm-eye of the weather-storm” interpretation is more common than the “storm-eye of the assault-on-a-stronghold” and “ocular-organ of the assault-on-a-stronghold” interpretations. Idioms are at the extreme. They are exclusively used to represent one concept. Thus, frequencies of word-sense patterns can help resolve lexical ambiguity in phrases in isolation.

A mere statistical analysis of the co-occurrence of word senses in sentences can yield not only information about what word sense patterns are likely but also what word senses are related. Landauer and Dumais (1997) showed the usefulness of the method by analyzing the co-occurrence of words (not senses) in sentences from a very large sample. Through a mathematical process called singular value decomposition, each unique word in the sample is assigned an n-dimensional vector such that words that occur in similar contexts are assigned nearby vectors. The authors assumed that words with similar meanings, such as *boat* and *ship*, appear in similar contexts (sentences with words like water, sinking, and passengers), though the two words do not themselves often appear in the same sentences.\(^1\) As a result, LSA would assign *boat* and *ship* nearby vectors. One could therefore use LSA to determine how similar words are. The model was shown to be effective when it performed at the level of humans on the Test of English as a Foreign Language's synonym section. Landauer and Dumais claimed LSA could explain the speed of language development, so one might expect it would be helpful in resolving lexical ambiguity.

\(^1\) The example is from a Apr. 14, 2003 lecture by Professor Ken Norman.
I have previously\(^2\) considered whether LSA, if it were implemented in the brain, could solve the problem of disambiguation. It could not. After training a modified LSA on concepts, as opposed to words as in Landauer and Dumais (1997), it was only marginally better than chance at disambiguating words given one sentence of context. The result was not surprising, as LSA ignores both the syntax and semantics of its input. As I will show, higher-level processing is necessary for disambiguation.

Semantics can play an important role at the phrasal level. Semantic selection, the process of filtering out word senses by how they're connected with other words in the sentence, is the intuitive but ultimately unhelpful solution to resolving lexical ambiguity. Senses of ambiguous verbs are easily ruled out based on argument structure. In *Fold the clothes*, the verb *fold* cannot mean to shut down (as in *The company folded*) because the latter meaning is intransitive but the sentence contains a direct object. But, semantic selection's usefulness ends here. For *We aimed for the eye of the storm*, semantic selection says that because storms do not have organs of sight, the speaker must have meant *eye* to mean the center of a storm. Semantic selection helps when the words in the sentence are used in their normal ways, but unusual events stump the system. Imagine, if you will, a science fiction movie in which *The government is starting a Frankenstein experiment*. *They are seeking arms*. When *arms* is read, semantic selection establishes that a government usually seeks weapons, and not appendages, and so the weapons interpretation is made. But, a person reading the dialog would arrive at the other interpretation or at least be confused. If semantic selection plays any role in disambiguation, it does so only in very limited circumstances.

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\(^2\) Fall 2002 junior report #2; Final project for LIN380, fall 2002.
There is also often not enough information in sentences for semantic selection to be useful in cases where one would think, intuitively, that it may help. The use of prepositions and possessives are two examples. For instance, *in* can be used to indicate location (*in the room*), direction (when it can be used like “into”), time frame (*in a minute*), or method (*in a rush*). As for possessives, the relation can connect owner to ownee (*his walkway*), do-er to do-ee (*his walk to the park*), and patient to action (*his walk*, meaning, for instance, the walk that a dog was taken on by his owner). The examples for each of the uses above shows that *his walk* could mean any of the three meanings. If semantic selection were to tackle the phrase, it would be unable to use a semantic relation between *his* and *walk* to come to any conclusions about the meaning of the phrase. Semantic relations are underspecified in syntactic relations, preventing semantic selection from being useful in disambiguation and comprehension.

The tools at our disposal for resolving ambiguity within phrases — use of word frequencies, situational context, semantic selection (perhaps), and word sense pattern frequencies — are not powerful enough to handle general speech. Word frequencies and word sense pattern frequencies are fixed across sentences, thus locking the listener into making the same interpretation of words over and over, despite where the discourse goes. Situational context, too, is fixed across sentences for as long as the external environment remains the same, further locking the listener into making particular interpretations in a particular setting. Semantic selection, if it is able to weed out senses at all, limits the

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3 In the sense of *his education*, meaning the education that he has received. (Adapted from an example in an Apr. 22, 2003 lecture by Professor Edwin Williams)
listener to very literal interpretations of phrases. But we know that any word sense can be used in any setting and still make sense, as long as it fits within the discourse. Other factors, at the level of the sentence and the discourse, must be at work.

**Priming & Syntax**

The act of reading words changes one's context. Can lexical disambiguation be explained by each word in a sentence priming interpretations of the words that follow? Consider these sentences:

*Though the sermon we heard resembled a waiter reading the specials, the service was nothing special.*

*Though the waiter read the specials like a sermon, the service was nothing special.*

*Sermon* and *waiter* will prime one of the meanings of *service*. If the priming effect were the dominating factor in disambiguating *service*, we would expect the last-read prime word to provide the meaning for *service*. In both cases, however, the left-most word was the one that disambiguated *service*, seemingly because that is where the topic of the sentence is determined.

Perhaps the priming model, and all of the tools discussed so far, can be upgraded to account for syntactic relations. For instance, allow words to prime later words only when the first word c-commands or is c-commanded by the second. (Word *a* c-commands word *b* if *b* is a member of the smallest phrase that contains *a*.) Such a model
would explain the previous example. In both sentences, the right-most prime word is more embedded within the first clause than the left-most prime word, so it would have less of a priming effect on the second clause. Thus, the left-most prime words' priming effects would rule. But, the following counterexample shows that even syntactic relations are not enough for disambiguation: *The waiter, who was in what he thought was a church, told us a day later his opinion of the service.* In this example, the disambiguating word, *church*, is deeply embedded in one phrase and the ambiguous word, *service*, is deeply embedded in another. The syntactic relations between the two are much more indirect than from *waiter* to *service*, but the sentence is understood properly anyway. Something above syntax, namely a model of the discourse, must be used to disambiguate words.

**Applying a model of discourse**

What is lacking in a theory so far is a way for sentences to flow from one to the next in a coherent discourse. The goal is to find a theory of comprehension, and therefore also disambiguation, that makes this possible. The last section showed that comprehension must consist of building some mental model of what is being talked about. Consider the following two pairs of sentences:

*We are administrators. Our strike went well.*

*We are paratroopers. Our strike went well.*

In the first, *strike* is taken to mean a work stoppage, while in the second it is taken to
mean a military action. There are several reasons why this could be the case: the perception of the words *administrator* and *paratrooper* primed the appropriate meaning of *strike* (and no semantic information was retained between the sentences), *administrator* and *paratrooper* were retained as the topic of the discourse and used later to constrain disambiguation (and nothing else was retained between the sentences), or information about the speaker gathered in the first sentence was used to constrain disambiguation in the second sentence. The first possibility seems unlikely, as for most people I don't believe *administrator* and *strike* (*work stoppage*) are semantically very related and so one word would not have a large priming effect on the other. It is also unlikely that the two words were uniquely held as the topics of the sentences, as more information than just a single-word topic could be needed to disambiguate words. (*There were both administrators and paratroopers in the room. Their respective strikes went well.*) Both words would have to be retained as a topic, making such a topic useless, without more information, for disambiguating the second sentence.) The explanation that remains is that all information about the discourse known to the listener must be available for disambiguation.

These sentences can only be disambiguated if a mental model of the discourse is built. As words are heard and understood, new propositions are integrated into a mental scene. Hearing *Though the sermon we heard . . .* should generated in the mind of the listener a mental scene of the speaker listening to a sermon in a church. When *the service* needs disambiguation, the mental model, which had been thinking about church services the whole time, causes the correct interpretation to be selected. This hypothesis of using a mental model of discourse requires an explanation for building the model,
which will not be discussed here, and an explanation of how it is applied in disambiguation.

Returning to the new example, when the reader gets to the word *strike*, he must be able to understand the relation between the word and the speaker (that the speaker is the subject and the word is the action). One possible explanation proceeds as follows. When the listener hears the ambiguous word *strike*, he calls in any information known about the lexical item: its syntactic relations to the other words in the sentence. *Strike* is modified by *our*, so whatever is known about the things related to *our* can be used to disambiguate *strike*. Resolving *our* poses the problem of anaphoric ambiguity, but as this is another problem entirely, I will assume the listener is able to call in all information that the pronoun refers to: in this case, the speaker's group. The particular relation invoked by possessives is ambiguous, however, just as I previously discussed with regard to semantic selection. All of the possible relations must be considered, and for each, each sense of *strike* must be considered. Nevertheless, at least now the listener has in mind only a small set of possible scenarios that *our strike* might refer to: the speaker refused to work or the speaker raided something. From there, however, a choice needs to be made.

Disambiguation can proceed based on which of the possible scenarios are compatible with the propositions in the mental model. Had the sentence been preceded by *We refused to work.*, then the listener would have already had in his mental model the proposition that the speaker refused to work. The work-stoppage interpretation (which makes the same proposition) would then be compatible with the mental model (more so than the other interpretation), and so that should be the interpretation chosen for the sentence. When the mental model already contains the information expressed in
sentences to be disambiguated, disambiguation is easy to explain. But if no interpretation is already in the mental model, another method for determining consistency must be used.

It could be that consistent disambiguations are those with the highest probability of making the interpretation true. The more probable of [administrators go on strike, administrators carry out raid] is the interpretation chosen for the first discourse. The probability of [the sentence about their strike is true] is greater if strike means work stoppage than a military action, and so work stoppage is the selected meaning. Selecting by probability works here, but it will not work elsewhere.

The model can also account for the comprehension of the Frankenstein experiment example. After the sentence is read, the mental model consists of the propositions [the government has a Frankenstein experiment, the government's Frankenstein experiment probably has something to do with assembling parts of a body]. The latter proposition boosts the probability that the government would be seeking appendages near or over the probability that it would be seeking weapons, and so interpreting arms as appendages is at least as likely as interpreting it the other way. This at least is close to the correct result. Unfortunately, the result is flaky because it necessitates that the listener actually believes there is a high probability that the government is doing something completely absurd, whereas real listeners are able to comprehend the sentence while still not believing it.

Other examples will show that while applying a mental model is necessary, choosing interpretations based on the probability of truth will not work. Consider disambiguating saw in the following pair of short discourses: Bill was sued. He saw a lawyer. and Bill looked through his binoculars. He saw a lawyer. In each discourse, saw
has a different (albeit related) meaning, and the meaning is determined by the content of the first sentence. To disambiguate the word using the above method, one calls in all knowledge about the word. In this case, both the subject and object of the word are known: Bill did something with regard to a lawyer. Is it more probable that, after being sued or after looking through binoculars, he would meet with a lawyer or would perceive a lawyer? Indeed being sued should increase the probability that one would meet with a lawyer, but the probability that one would meet with a lawyer must always be less than or equal to the probability of perceiving a lawyer, for the first entails the second. If in no case can the meet-with probability be greater than the probability of the other, then that sense could never be selected. Unfortunately, then, this model must be wrong.

One can see the model of choosing by probability is wrong because it cannot account for why a speaker would choose the words he does in constructing a sentence. Speakers presumably attempt to choose the least ambiguous way to express a concept (unless ambiguity is desired). Based on this probability principle, the word chosen to express a concept is the one for which of all of the word's senses, the one most probable to make the sentence true is the correct sense. Therefore, if one of a word's possible interpretations makes a sentence more probably true than the correct interpretation, then the word would not have been used in the sentence. This model implies that only the most probable of propositions are ever communicated. Clearly humans don't speak in truth values. Language is used to express novel situations that the listener does not already know and in many cases would not expect. And while some of those cases have very low probability, they are nonetheless understood. Probability is therefore not the deciding factor in choosing what propositions are compatible with the mental model of
the discourse.

Using a mental model is on the right track, but how to apply the mental model requires more discussion. The rest of this paper will work toward determining what factors do determine whether interpretations are consistent with the mental model by testing hypotheses with lexical disambiguation tasks. Factors that make correct predictions about hard cases of disambiguation, where no previous hypothesis did, are good candidates for being a part of language comprehension and disambiguation. Intention, expectation, presupposition, and activation will be considered as possible factors in determining the consistency of interpretations.

**Intended and expected meaning**

It seems on the surface that one interprets a sentence to match what one thinks the speaker intended it to mean: Interpretations are chosen to match what the listener thinks the speaker's intention is. For instance, in the last example, if the speaker says that Bill is in legal trouble, then he must have intended *He saw a layer* to mean that he sought the advice of a lawyer. After all, if he meant it to be literal, the speaker would have said so. Cues often exist in sentences that indicate where the discourse is going. Consider *I had second thoughts at the start. I said to myself, hold on to your heart.*\(^4\) After hearing *at the start*, which indicates the speaker no longer has second thoughts, one might think that the speaker is about to say how he got passed having second thoughts. That would bias

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\(^4\) From the lyrics of “The Longest Time” by Billy Joel
the interpretation of the metaphor that follows, such that *hold on to your heart* means to stick with the decision made by the heart. Conjunctions and adverbs, too, contribute. After hearing *The teacher didn’t give me credit for getting question 2 correct. She agreed I got it right, but wouldn’t.*, one expects the speaker to say that the teacher did not award the student any more points, and interpretations of what follows that are consistent with the expectation are going to be more likely selected. The trouble for scientifically outlining this model is determining how one knows what the speaker intended to say and how to judge what interpretations of sentences are consistent with the expected meaning.

Sometimes what the speaker intends to say is something other than what he says. The intended meaning can be consonant with the literal meaning, as in *Can you pass the salt?*, which intends the literal meaning and more. But, it can also intend the exact opposite. For instance, *I have a 9 am class tomorrow. It’s a good thing I don’t need to sleep.* does not mean anything that the second sentence says. Nerlich and Clarke (2001) hypothesized that the listener must understand and hold on to the literal meaning to get to the ironic meaning. If that is the case, then the literal meaning of each word in the sentence must be resolved before the intended meaning can be determined, and lexical ambiguity resolution need not be concerned with nonliteral intended meanings.

**Logical flow**

The purpose of language is to convey new information, as opposed to merely to represent truthful conditions, and so one should expect that language generation and
comprehension are based on principles of how best to express premises and conclusions. In English, premises and conclusions are expressed differently. Though both types of propositions have a logical entailment, the latter type of entailment is “asserted” while the former type is often “presupposed.” When something is presupposed by a sentence, the listener must believe that the speaker believes it to be true, and generally it must have already been established between the speaker and listener, regardless of the truth-value of the sentence itself. (Dryer, 1996; Fromkin, 2000; Dryer, 1996 calls this pragmatic presupposition.) Thus, even if the sentence is false, its presuppositions must still be true (or believed to be true, or established, etc.). Unestablished presuppositions seem to call for questions. *It's a good thing this paper is almost done.* might lead a listener who knows nothing about the paper to ask, *Oh, you're writing a paper?* The sentence *The previous sentence is false* presupposes that there was a previous sentence and then asserts that 1) some sentence is false, 2) the truth value of the previous sentence is under question, and 3) the previous sentence is one of the false sentences. (Assertions 1 and 3 are only stated explicitly here for comparison later.) If no sentence did precede it, then the sentence would not merely be false, it would not “make sense.” The listener would not accuse the speaker of lying, he would ask the speaker what he meant. In contrast to having a presupposition, *There is a previous sentence.* only asserts that there is a previous sentence. If there is not, the sentence still makes sense, though it is false. Parts of a sentence can also be forced into becoming a presupposition by adding emphasis to the assertion. *The previous sentence is false* both presupposes 1) that there is a previous sentence and 2) that some sentence is false, but it then asserts that the false sentence is the previous one. *The previous sentence is false,* on the other hand, presupposes 1) that
there is a previous sentence and 2) that the truth of the previous sentence is under question, but it only asserts the truth-value of the previous sentence. In each of the cases with emphasis, the assertion that lacked emphasis became a presupposition. (Dryer, 1996 pointed out that not all cases of added emphasis force the non-focused propositions into presuppositions. For instance, *Nobody saw John* does not presuppose that somebody *saw John.*) If language generation distinguishes between presuppositions and assertions, so should comprehension.

Presuppositions provide for the logical flow of discourse from one sentence to the next that has been missing from all of the aspects of comprehension discussed so far. A new logical-flow rule for judging an interpretation's compatibility with the mental model of the discourse is: an interpretation logically flows from the discourse if its presuppositions have already been established in the discourse. Good interpretations of sentences are those that are compatible with this rule. (Presuppositions that have not already been directly established might become implicitly established through accommodation, Lewis 1979, 1991 as cited by Dryer, 1996, in which the presupposition is implied. However, as far as this paper is concerned, the more indirect the implication, the less “good” the interpretation is. Thus if a presupposition can be implied from accepted general knowledge, then the interpretation may be “good,” but less “good” than interpretations for which the presupposition was directly established.) The rule provides a way for the discourse to affect disambiguation in a sensible way: The mental disambiguator can choose word senses that make the interpretation of the sentence most logically flowing.

The “logical-flow model” can handle the problematic examples of short discourse
from the last section. Both examples ended with *He saw a lawyer*. For the met-with interpretation, the sentence presupposes that the subject has a legal problem. (Lacking a formal listing of what presupposes what, determining presuppositions is a subjective process. I hope the reader bears with me on this.) Only following the sentence *Bill was sued*, which establishes the proposition that Bill has legal troubles, is the presupposition in the first interpretation satisfied. Because the presupposition would not be satisfied in the second discourse, that meaning is ruled out, which correctly explains the meaning chosen there. The saw-perceived interpretation, on the other hand, does not have any obvious presuppositions. But, in fact, it may. Outside of any context (guaranteeing no presuppositions are satisfied), *He saw a layer* might beg the question *Where were you when you saw the lawyer?*, indicating that *he was doing something at the time* might be a presupposition of the sentence. If that is the case, then that presupposition of the saw-perceived interpretation is not met in the first dialog, leaving only the other interpretation satisfied. Presupposition is a plausible way to determine what interpretations are consistent with the mental model.

The model can also explain the *We are administrators/paratroopers. Our strike went well.* example in a way that seems more intuitive than the probabilistic model. The work-stoppage interpretation presupposes that the subjects are unionized workers. If it has already been established that the subjects are administrators, the presupposition is easily implied and satisfied. On the other hand, paratroopers are very unlikely to be unionized, so the first meaning is correctly selected. The military strike interpretation presupposes that the subjects are acting as troops. If the subjects are paratroopers the presupposition is satisfied, whereas if the subjects are administrators the presupposition
has not been firmly established (though the interpretation could still be true). Since the first interpretation is more solid than the second, it is the interpretation selected.

The logical-flow model also disambiguates the Frankenstein experiment example in a more sensible way. Earlier I said that the mental model consists of [the government has a Frankenstein experiment, the government's Frankenstein experiment probably has something to do with assembling parts of a body]. The two interpretations of arms have different presuppositions. The weapons sense does not seem to presuppose anything that we would not expect of a government, so it is consistent with the model. The appendages sense, however, presupposes that the government is doing something diabolical. This too is consistent with the mental model. Since both interpretations are consistent, they are both possible interpretations, which again is the predicted result.

The logical-flow model also says something about how assertions are used, and it does so in, again, a sensible way. If the goal of communication is to convey new information, then assertions should not express something that has already been established in the discourse. Intuitively this seems correct. People have an aversion to redundancy. When assertions are not novel, the logical-flow model says the sentence's interpretation is less “good” than other interpretations. This contradicts what the probability-based model would say. If something has been established in the discourse, then the probability that the fact is true is unity. Thus, redundant assertions make for good interpretations. The difference should be testable through lexical ambiguity.

Given two possible interpretations of a sentence for which the presuppositions for each are satisfied, is an interpretation with a redundant assertion more or less likely to be selected than other interpretations? The logical-flow model says less, while the
probability model says more. Here is an example of such a case: *Despite the heat, supporters of the team filled the stadium's seats. There were many fans.* The two meanings of *fans*, the one that moves air around and the other that roots for a team, are both possible interpretations. And, ideally, they are both equally salient in their activations when *fans* is read. For both, whatever presuppositions are required by the second sentence are satisfied. But, one makes an assertion that has already been established in the discourse (that there were many fans in the stadium) and the other does not (it had not been established that many air-moving fans were present). Unfortunately, it does not appear that the redundant interpretation is immediately and unconsciously less “good” than the other interpretation. Possibly the logical-flow model does not contain such a rule about redundant assertions, and future research is necessary to come to a definite conclusion.

Logical flow may also help to quantitatively explain how expected intention can bias comprehension. *Immigrants who are coming in* is a peculiar phrase in that while *coming in* does not, on its own, indicate what the subject is entering, in that phrase the destination is implied to be a country. (This is not a case of lexical ambiguity, but it is related.) The implication can be explained in two ways, one using the mental model top-down and the other using the model bottom-up. In the top-down way, the semantic relation between *immigrants* and *coming in* is considered: an interpretation is good if it makes a good subject-verb fit. Immigrants are defined by the activity of entering a

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country, so if the verb had this meaning the subject-verb fit would be good. *Coming in* can fit the interpretation, so *entering a country* is selected. The draw-back to this explanation is that it makes no room for other interpretations in other contexts (*The no-entry sign did not stop the immigrants who are coming in [to the room]*), just as I concluded for semantic selection, so it would need to be arbitrarily weighed against all of the other factors in comprehension. Logical flow can make use of those other factors in comprehension to arrive at the same interpretation. Because immigrants are defined by the activity of entering a country, hearing *immigrants* will prime the concept of entering a country, making it readily available as a possible interpretation for future utterances. When the listener must interpret *coming in*, several meanings are available: entering the room or entering the country. The first interpretation presupposes that specific immigrants are present who might enter the room, but as the listener knows nothing about any specific immigrants, the presupposition is not valid. The second interpretation presupposes that there are immigrants who might enter the country. This presupposition is satisfied by definition of immigrants and the general knowledge that immigrants to the country exist. As the second interpretation is the only one with satisfied presuppositions, it is the one chosen. The drawback to the logical-flow explanation is that unexplained processes must be evaluating the discourse model to make expected meanings readily available for processing. Logical flow, without the aid of semantic selection, can explain how speaker intention can play a role in comprehension.

Dryer (1996) showed that another aspect of propositions in the mental model affects language: whether propositions are activated. The non-focused part of a sentence corresponds to the active propositions in the mental model (which are generally already
established and so are often also presuppositions of the sentence). For instance, *Is Clinton the vice-president?* activates the concepts Clinton and *is the vice-president.* A valid response will keep emphasis off of those concepts. Therefore, *No, Clinton is the president.* is acceptable, while *No, Clinton is the president.* is not. Whether emphasis is kept off of active propositions should be used along side whether presuppositions are established in the logical flow model to properly account for more uses of language.

Logical flow can also explain how in some circumstances ironic secondary meanings arise from sentences, though this may not contribute to lexical disambiguation. Whereas unestablished presuppositions weigh against an interpretation, presuppositions that saliently contradicts the mental model may indicate the presence of irony. Recall the example *I have a 9 am class tomorrow. It's a good thing I don’t need to sleep.* The second sentence presupposes that the speaker does not need to sleep, which saliently contradicts general knowledge. As a result, the listener is made aware that he should find an ironic meaning. Nerlich and Clarke (2001) retells the story of a taxicab passenger who says, *I love drivers who signal.* when her driver fails to signal before a turn. The statement's presupposition, that there exists drivers who signal, is established. But, part of the sentence's non-focused concept, signaling, is in opposition to a concept that is actually activated, failing to signal. This, too, may be a hint that irony is a foot. Contrast that sentence with *I love drivers who signal.* This sentence does not seem ironic, seemingly because activated propositions no longer contrast with non-focused propositions. These predictions may have only a marginal implication for lexical disambiguation, but they show that the components of this logical flow model make accurate predictions elsewhere in comprehension — a good hint that the hypothesis is
also valid for disambiguation.

The examples presented here have all been binary choices between two interpretations, a situation in which presuppositions can't go wrong. In literal speech, sentences' presuppositions are always met. If there are two interpretations and only one's presuppositions are satisfied, then the correct interpretation must be that interpretation. There are never cases when the correct disambiguation of a word causes a presupposition to be unsatisfied. Thus, it is impossible to find a counterexample to the logical flow theory in these cases. In these literal, binary choices, the true usefulness of presuppositions can only be determined by how much more often it successfully disambiguates words over other theories, which has yet to be tested. Logical flow must also be tested in cases of greater homonymy, in which each interpretation's presuppositions may be established to different degrees. Supportive evidence would be found if people choose each interpretation with a frequency in direct correlation to how satisfied its presuppositions are, though determining quantitative levels of satisfaction will no doubt be a subjective process.

A full account of this model requires some method to determine the presuppositions of an interpretation. It is easy to say that that-clauses are often made into presuppositions (such as I know that you have a dog, which presupposes that you have a dog, but not in the case I think that you have a dog, which doesn't make the presupposition.) But, was I right that He saw a lawyer. presupposes the subject is in legal trouble? And, it's certainly not obvious what I think he saw a lawyer. presupposes (perhaps it presupposes that the speaker believes that the subject is in legal trouble). Knowing when and where presuppositions are made, and how the structure of a sentence
mediates presuppositions, is needed to complete the model of logical flow.

**Conclusion**

Though comprehension is undoubtedly a function of a combination of processes, including the priming effect at the bottom and applying expectations at the top, only processes that apply knowledge of the discourse can account for the majority of correct disambiguations. Word sense and sense pattern frequencies, the priming effect, and situational context all bias how words are interpreted, but they do so irrespective of the semantic content of the discourse. A conversation might start off relevant to the situational context and then go off on an unrelated tangent, all the while situational context will continue to pull the interpretations back to a now-irrelevant initial interpretation. Even the information within a sentence may not be enough for disambiguation. Senses of verbs can be ruled out when it lacks the right argument structure, but little else can be gleaned from syntactic relations. Nevertheless, words are interpreted in ways that follow what is being talked about. Lexical disambiguation must make use of a model of the discourse.

Applying the mental model of the discourse to comprehension is the next step, but any number of methods could be used to determine whether a word sense matches the mental model. Interpretations of words should fit with the mental model, but interpretations cannot be limited to what is consonant with the model because that would preclude comprehending unexpected information. Presuppositions allow for a link between the mental model and new information without limiting what new information
there can be, ensuring a logical flow from one sentence to the next.

The logical-flow model is specific enough to make concrete predictions, unlike models based on expectations of speaker intention. What a sentence presupposes can be reliably determined by finding contexts in which the sentence cannot be meaningfully said. From there, whether an interpretation's presuppositions are satisfied can also be objectively determined by comparing them to what propositions have been established in the discourse or, if necessary, what can be inferred. A computer could be programmed to make such judgments, making it a very testable hypothesis. The model also may explain how irony is detected (in the absence of obvious cues). If these predictions hold up under other circumstances and with other examples, then the hypothesis should be considered a likely aspect of comprehension.

But because a correct interpretation's presuppositions are always satisfied, by definition, another system entirely may explain how the correct interpretation is determined and the correlation between satisfied presuppositions and correct disambiguations will remain. The logical-flow model must be tested in practice. If satisfied presuppositions alone can explain how correct interpretations are determined, then it is unnecessary to believe another system is at work. A computer program could be used to apply the model over a large corpus of text to see if it disambiguates words with better accuracy than other computational methods.

Without the right tools, finding the one right interpretation in 9,660 possibilities is an impossible task to do reliably. But as human language comprehension shows, lexical ambiguity is a problem that can be solved. The logical flow model presented here may be a key component of comprehension, and so it may explain how people handle lexical
ambiguity so successfully.
References


