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Fass, Dan

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# Semantic Relations, Metonymy, and Lexical Ambiguity Resolution : A Coherence-Based Account

**Dan Fass**

**Rio Grande Research Corridor**
**Computing Research Laboratory**
**New Mexico State University**
**Box 30001, Las Cruces, NM 88003.**
**CSNET: dan@nmsu**

## Abstract

An account of coherence is proposed which tries to clarify the relationship between semantic relations, metonymy, and the resolution of lexical ambiguity. Coherence is the synergism of knowledge (synergism is the interaction of two or more discrete agencies to achieve an effect of which none is individually capable) and plays a substantial role in cognition. In the account of coherence, semantic relations and metonymy are instances of coherence and coherence is used for lexical ambiguity resolution. This account of coherence, semantic relations, metonymy and lexical ambiguity resolution is embodied in Collative Semantics, which is a domain-independent semantics for natural language processing. A natural language program called meta5 uses CS; an example of how it discriminates a metaphorical relation is given.

## 1 Introduction

An account of coherence is proposed which attempts to unpick the relationship between semantic relations, metonymy, and the resolution of lexical ambiguity. Coherence is defined as the synergism of knowledge, where synergism is the interaction of two or more discrete agencies to achieve an effect of which none is individually capable. In the account, semantic relations and metonymy are instances of coherence and coherence is also used in resolving lexical ambiguity. This account of coherence, semantic relations, metonymy and lexical ambiguity resolution is embodied in Collative Semantics, hereafter CS. CS is a semantics for natural language processing which extends the ideas of Preference Semantics (Wilks 1973, 1975a, 1975b, 1978; Fass and Wilks 1983).

To explain our account of coherence, we establish two sets of relationships that involve coherence and then unify those relationships. Section 2 establishes the first relationship which is between coherence, semantic relations, and metonymy. We take the general conception of coherence used in theories of discourse and extend it downwards from the discourse level to the sentence level to argue that semantic relations and metonymies in sentences are instances of coherence.

Section 3 establishes a second relationship which is between coherence and the resolution of lexical ambiguity. We develop a conception of coherence that is grounded in properties of semantic networks which are a common kind of knowledge representation scheme. Two basic kinds of coherence are distinguished that are termed "inclusion" and "distance." This general conception of coherence is extended upwards and it is argued that inclusion and distance underlie two of the main approaches to lexical ambiguity resolution.

The last part of section 3 integrates the two sets of relationships to produce the skeleton of our account of coherence, which is that [1] basic notions of coherence are founded on principles of knowledge representation, [2] semantic relations and metonymy within sentences are instances of coherence, [3] coherence is used for lexical ambiguity resolution, and [4] discourse phenomena are instances of coherence.

Section 4 connects [1] to [2] and [2] to [3] by describing the four components of CS and their interrelationships. The four components are "sense-frames," "collation," "semantic vectors," and "screening." CS is embodied in a natural language program called meta5. An example sentence is given that meta5 analyses. The sentence contains a metaphorical relation and illustrates the interactions between the components of CS. Section 5 provides a brief summary.

## 2 Coherence, Semantic Relations, and Metonymy

This section selectively surveys the literatures on coherence, semantic relations, and metonymy, and argues that semantic relations and metonymy are cases of coherence.

Coherence is a central notion in theories of discourse (e.g., Van Dijk 1977, Chapter 4; de Beaugrande and Dressler 1981, Chapter V; Van Dijk and Kintsch 1983, Chapter 5; Myers et al, pp.6-8) and truth (e.g., Rescher 1973). In discourse theories, coherence refers to how a discourse "hangs together," "makes sense," or is "meaningful." Discourse theories view the coherence of a discourse as amalgamated from the coherence relations between sentences in that discourse (e.g., Van Dijk, 1977). Little attention is paid by discourse theories to coherence relations that exist within parts of sentences. The coherence relations within a sentence determine the coherence of that sentence. These coherence relations include semantic relations and metonymy.

In our view, semantic relations between terms are complex systems of mappings between descriptions of those terms within some context. This view of semantic relations draws from definitions of metaphor as systems of relationships or "implicative complexes" (Black 1979), mappings (Carbonell 1981), correspondences between domains (Tourangeau and Sternberg 1982), and selective inferences (Hobbs 1983).

Next, we develop some terminology for describing semantic relations. The two terms in a semantic relation are called the **"source"** and the **"target"** (Martin 1985). The source initiates and directs the mapping process, the target has mappings laid upon it, and there is direction from the source towards the target.

We distinguish six types of semantic relation. These are termed literal, metaphorical, anomalous, redundant, inconsistent, and novel relations. Brief definitions of the six semantic relations are now given, together with an example sentence for each relation. These sentences assume a null context in which there are no complicating effects from prior sentences or the pre-existing beliefs of producers or understanders. The definitions of literal, metaphorical, and anomalous semantic relations develop the observation by Katz, Wilks and others that a satisfied selection restriction or preference indicates a literal semantic relation whereas a violated restriction indicates a metaphorical or anomalous semantic relation. The description of redundant, inconsistent, and novel semantic relations is an expansion of Katz and Fodor's ideas on "attribution" (1964, pp.508-509), which were a development of some ideas by Lees (1960). The meta5 program analyses all six sentences.

**(1)** "The man drank beer."

There is a literal relation between 'man' and 'drink' in (1) because 'drink' prefers an animal as its agent (it is animals that drink) and a man is a type of animal so the preference is satisfied.

**(2)** "The car drank gasoline." (adapted from Wilks [1978])

By contrast, the semantic relation between 'car' and 'drink' in (2) is metaphorical because 'drink' preferred an animal as its agent but a car is not a type of animal so the preference is violated. However, there is an analogy between animals and cars that is relevant in the context of a sentence about drinking, such as (2). The relevant analogy is that animals drink potable liquids as cars use gasoline.[1]

**(3)** "The idea drank the heart."

In (3), the semantic relation between 'idea' and 'drink' is anomalous because 'idea' is not an preferred agent of 'drink' and no relevant analogy can be found.

**(4)** "His wife is married."

The semantic relation between 'wife' and 'married' is semantically redundant in (4) because a wife is by definition a married women so the information that a wife is married is not new information.

**(5)** "His wife is unmarried."

In (5), the semantic relation between 'wife' and 'married' is inconsistent because the information added by 'unmarried' is incompatible with 'married' in the definition of a wife as a married woman. In out terminology, inconsistent semantic relations include contradictory and contrary ones.[2]

**(6)** "His wife is young."

Finally, (6) contains a novel semantic relation between 'wife' and 'young' because the information that a wife is young is new information.

Semantic relations are manifestations of coherence because they are the synergism of knowledge. Synergism, remember, is the interaction of two or more discrete agencies to achieve an effect of which none is individually capable. Consider, for example, the metaphorical relation observed in (2) and the relevant analogy that is central to its recognition. The analogy arises from the interaction of three agencies that are 'car' (the surface subject), 'animal' (the expected agent), and 'drink' (the relevant context; also the main sentence verb). The analogy is an effect achieved of which none of the three agencies is individually capable. The analogy is a synergism of knowledge and the metaphorical relation as a whole is a more complex synergism of knowledge.

Another form of coherence apart from semantic relations is metonymy. Metonymy is a nonliteral figure of speech in which the name of one thing is substituted for

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[1] It has been frequently claimed that the critical match in a metaphorical relation is some analogy or correspondence between two properties (e.g., Wilks 1978; Ortony 1979, p.167; Tourangeau and Sternberg 1982, pp.218-221; Gentner 1983). The importance of relevance has been argued by Tversky (1977) and Hobbs (1983).

[2] Contrary relations exist between terms gradable on some scale, e.g., hot/cold and big/small whereas contradictory relations exist between ungradable terms, e.g., female/male, single/married (Lyons 1963, pp.460-469; Lehrer 1974, p.26). This difference is compatible with the standard philosophical distinction between contraries and contradictories (Lyons 1977, p.272).

that of another related to it (Lakoff and Johnson 1980, pp.35-40). Lakoff and Johnson group individual cases of metonymy into seven general "metonymic concepts" (1980, pp.38-9). One of those metonymic concepts, with example sentences, is :

PRODUCER FOR PRODUCT
"He bought a *Ford.*"
"I hate to read *Heidegger.*"

Our treatment of metonymy distinguishes it from semantic relations but that treatment can only be described very briefly here. Metonymy is treated as a type of inference and metonymic concepts are encoded as **"metonymic inference rules."** Four types of metonymic concepts are currently represented. These are **Part for Whole, Container for Contents, Artist for Artform,** and **Co-Agent for Activity**

This section has developed a conception of coherence that includes semantic relations and metonymy. The next section develops another conception of coherence that is used as a means of resolving lexical ambiguity.

## 3 Coherence and Lexical Ambiguity Resolution

This section discusses two well known approaches to the resolution of lexical ambiguity and attempts to show how they utilise coherence. We call these approaches the **"inclusion-based"** and **"distance-based"** approaches. Inclusion-based approaches include Katz's semantic theory (Katz and Postal 1964; Katz 1972), Preference Semantics, message passing (Rieger and Small 1979; Small and Rieger 1982), and CS. Distance-based approaches include schemes for spreading activation (Quillian 1968) and marker passing (Charniak 1983; Hirst 1983). Both approaches use semantic networks. Our contention is that each approach is founded on two different basic notions of coherence that exist in semantic networks, that we call **"inclusion"** and **"distance."**

A semantic network is a network with nodes organised as a taxonomy of genus and species terms linked by arcs that have labels denoting class inclusion.[3] In a semantic network, a path between any pair of nodes has two intrinsic properties that are the two basic notions of coherence.

One intrinsic property is the semantic distance, or number of arcs traversed, between the two nodes. For example, 'vehicle' and 'car' have a small distance between them whereas 'animal' and 'car' have a much greater distance between them.

The other intrinsic property is the inclusion relation between the two nodes. For example, the path between network nodes for 'vehicle' and 'car' denotes inclusion because a car is a type of vehicle; on the other hand, the path between 'animal' and 'car' denotes exclusion because a car is not a type of animal.

Both distance and inclusion describe kinds of conceptual relatedness. A short distance indicates close conceptual relatedness (i.e., 'vehicle' and 'car') whereas a long distance indicates remote conceptual relatedness (i.e., 'animal' and 'car'). Inclusion

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[3] The genus is the name of a class that includes subordinates called the species. A species is distinguished from other species of the same genus by its differentia. Take for example

Car : a vehicle that carries passengers.

The word 'vehicle' serves as the genus term while "that carries passengers" differentiates cars from other species such as buses and motorbikes.

signifies conceptual relatedness (i.e., a 'vehicle' is a 'car') whereas exclusion signifies conceptual unrelatedness (i.e., a 'car' is not an 'animal').

Note that these basic notions of coherence (distance and inclusion) are not explicit in a semantic network but instead that they are a by-product of path building between nodes in that network. In other words, this new conception of coherence is the synergism of knowledge, as was the conception of coherence in section 2. Synergism, once again, is the interaction of two or more discrete agencies to achieve an effect of which none is individually capable. The agencies here are network nodes, the interaction is path building, and the effect achieved is the basic kinds of coherence, i.e., distance and inclusion. Next, it is shown how these two basic kinds of coherence underlie inclusion-based and distance-based approaches to lexical ambiguity resolution.

Inclusion-based approaches to lexical ambiguity resolution are based on the satisfaction and violation of selection restrictions which are called expectations in message passing and preferences in Preference Semantics and CS.[4] The notions of "satisfaction" and "violation" are based on inclusion, which is one of the two basic kinds of coherence. Satisfied selection restrictions, preferences and expectations are all paths denoting inclusion through a semantic network. Conversely, violated selection restrictions, preferences and expectations are all paths denoting exclusion. For example, if a selection restriction was for 'vehicle' then 'car' would satisfy the restriction because a car is a type of vehicle; but if the restriction were for 'animal' then 'car' would cause a violation because a car is not a type of animal.

Distance-based approaches all seek the path with the shortest distance between two nodes in a semantic network, i.e., the second basic kind of coherence. Search is unconstrained except for the ruling out of certain path sequences (Charniak 1983, 1986) and the use of mathematical functions for limiting the length of network paths (Hirst 1983; Charniak 1986).

The conception of coherence developed in this section is grounded in properties of semantic networks. It is argued that distance and inclusion are basic kinds of coherence that are emergent from network paths and underpin two of the main approaches to lexical ambiguity resolution. If this conception of coherence is combined with the conception of coherence from section 2 then our account of coherence is that

[1] basic notions of coherence are founded on principles of knowledge representation (from section 3),

[2] semantic relations and metonymy in sentences are instances of coherence (from section 2),

[3] coherence is used for lexical ambiguity resolution (section 3), and

[4] discourse phenomena are instances of coherence (section 2).

What is missing is the links between [1], [2], [3], and [4]. Section 4, which is on CS (Collative Semantics), attempts to supply the missing links between [1], [2], and [3].

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[4] The terms 'preference' (Wilks 1975a) and 'expectation' (Schank 1975) highlight different aspects of the use of selection restrictions. Wilks emphasises that selection restrictions may or may not be satisfied, hence the word 'preference' Schank stresses that selection restrictions are used for top-down prediction, hence the term 'expectation'

## 4 Collative Semantics

CS has four components which are **"sense-frames,"** **"collation,"** **"semantic vectors,"** and **"screening."** Sense-frames are the knowledge representation scheme and represent individual word-senses. Collation matches the sense-frames of two word-senses, finds any metonymies, and discriminates the semantic relations between the word-senses as a complex system of mappings between their sense-frames. Semantic vectors represent such systems of mappings produced by collation and hence the semantic relations encoded in those mappings. Screening chooses between two semantic vectors by applying rank orderings among semantic relations and a measure of conceptual similarity, thereby resolving lexical ambiguity.

CS has been implemented in the meta5 program. The meta5 program is written in Quintus Prolog and consists of a lexicon containing the sense-frames of 460 word-senses, a small grammar, and semantic routines that embody collation and screening, the two processes of CS.[5] An example sentence shows how semantic relations are discriminated by meta5, and hence by CS.

(2) "The car drank gasoline."

There is a metaphorical relation between 'car' and 'drink' in (2). Figure 1 shows the sense-frames for car1, drink1, and animal1 which is the agent preference of drink1. Sense-frames are composed of other word-senses that have their own sense-frames, much like Quillian's (1968) planes. There are no semantic primitives in the sense of Schank's (1975) Conceptual Dependency or Wilks' Preference Semantics.[6]

```
sf(drink1,
   [[arcs,
      [[supertype, ingest1]]],
    [node2,
     [[agent,
        [preference, animal1 ]],
      [object,
        [preference, drink1]]]]]).

sf(car1,
   [[arcs,
      [[supertype, motor_vehicle1]]],
    [node0,
      [[it1, carry1, passenger1]]]]).

sf(animal1,
   [[arcs,
      [[supertype, organism1]]],
    [node0,
      [[biology1, animal1],
       [it1, drink1, drink1],
       [it1, eat1, food1]]]]).
```

*Figure 1.* Sense-frames of car1, animal1, and drink1 (verb).

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[5] Meta5's grammar is adapted from the grammar of XTRA (Huang 1985), an English-Chinese machine translation program also written in Prolog. XTRA is the latest in a succession of programs that originate from Boguraev's (1979) natural language analyser that was written in LISP. Huang's and Boguraev's programs use versions of Preference Semantics.

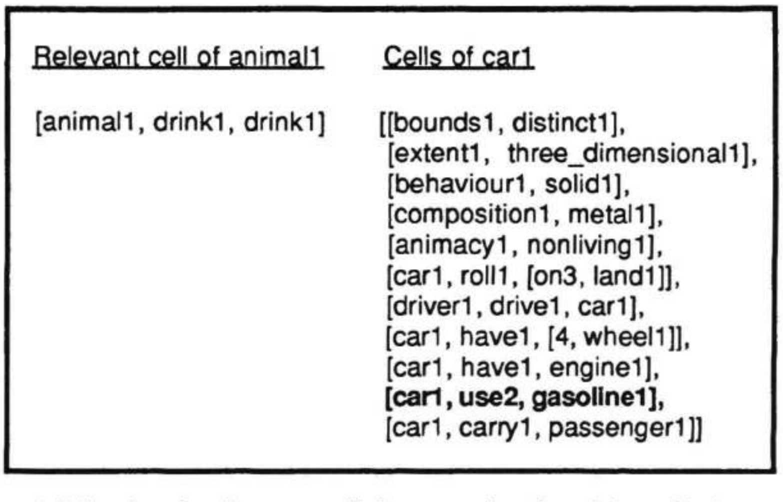
[6] One of the main claims of CS to be a semantics is its treatment of semantic primitives. See Fass (1986) for details.

The node part of a sense-frame is the differentia that provides a description of the word-sense represented by the sense-frame that differentiates it from other word-senses. Sense-frame nodes for nouns (node-type 0) resemble Wilks' (1978) pseudo-texts. They contain lists of two-element and three-element lists called **"cells."** Each cell expresses a piece of functional or structural information and can be thought of as a complex semantic feature or property of a noun.

The arcs part of a sense-frame contains a labelled arc to its genus term (a word-sense with its own sense-frame). The most common arc labels describe types of class inclusion such as 'supertype' that denotes membership of a class of individuals by a class of individuals and 'superinstance' that denotes membership of an individual within a class of individuals. Together, the arcs of all the sense-frames comprise a densely structured semantic network of word-senses called the **"sense-network."** This general architecture of a semantic network with frame-like structures as nodes is similar to many frame-based and semantic network-based systems, such as Quillian's (1968) memory model, schema theory (Norman and Rumelhart 1975), KRL (Bobrow and Winograd 1977), FRL (Roberts and Goldstein 1977), KLONE (Brachman 1979), and frail (Wong 1981).

Collation is the second component of CS. In (2), collation matches what was expected (animal1) against what is there in the sentence (car1) so the sense-frames of animal1 and car1 are matched together. Collation finds a system of multiple mappings between those sense-frames, thereby discriminating the metaphorical relation between animal1 and car1. Collation contains a graph search algorithm and a frame-matching algorithm. The graph search algorithm distinguishes five types of sense-network path. Two path-types denote inclusion; three denote exclusion. These path-types are the basic mappings produced by collation. The frame-matching algorithm matches the sets of cells from two sense-frames. Seven types of cell match are distinguished. These cell matches are more complex mappings that are built from sense-network paths and hence also embody inclusion.

First, collation finds a preference or expectation violation : a car is not a kind of animal. Next, collation matches the inherited cells of animal1 and car1. What is "relevant" in the present context is the action of drinking because that is what (2) is about. Collation then inherits the cells of animal1 down the sense-network and searches those cells for one that refers to drinking.



| Relevant cell of animal1 | Cells of car1 |
|---|---|
| [animal1, drink1, drink1] | [[bounds1, distinct1],<br>[extent1, three_dimensional1],<br>[behaviour1, solid1],<br>[composition1, metal1],<br>[animacy1, nonliving1],<br>[car1, roll1, [on3, land1]],<br>[driver1, drive1, car1],<br>[car1, have1, [4, wheel1]],<br>[car1, have1, engine1],<br>**[car1, use2, gasoline1],**<br>[car1, carry1, passenger1]] |

*Figure 2.* Match of relevant cell from animal1 with cells from car1

It finds a relevant cell [animal1, drink1, drink1] and seeks a match for that cell against the list of inherited cells for car1 (see figure 2). It finds a match with [car1, use2, gasoline1] (highlighted in figure 2) which is the relevant analogy that animals drink potable liquids as cars use gasoline. This relevant analogy is crucial to recognising the semantic relation between car1 and the drink1 as metaphorical.

| Non-relevant cells of animal1 | Non-relevant cells of car1 | Cell matches |
|---|---|---|
| [[bounds1, distinct1],<br>[extent1, three_dimensional1],<br>[behaviour1, solid1], | [[bounds1, distinct1],<br>[extent1, three_dimensional1],<br>[behaviour1, solid1], | 3 identical cell matches |
| [composition1, flesh1],<br>[animacy1, living1], | [composition1, metal1],<br>[animacy1, nonliving1], | 2 sister cell matches |
| [animal1, eat1, food1],<br>[biology1, animal1]] | | 2 distinctive cells of animal1 |
| | [car1, roll1, [on3, land1]],<br>[driver1, drive1, car1],<br>[car1, have1, [4, wheel1]],<br>[car1, have1, engine1],<br>[car1, carry1, passenger1]] | 5 distinctive cells of car1 |

*Figure 3.* Matches of non-relevant cells from animal1 and car1.

Finally, collation matches together the remaining non-relevant cells of animal1 and car1 (see figure 3) because such matches may figure in the aptness of a metaphor.[7] The cell [car1, use2, gasoline1] has been removed to prevent it from being used a second time. All of these matches made by collation are recorded in a semantic vector which figure 4 shows.

```
[preference,
   [[path_type,                         First array :
      [0, 0, 0, 0, 1]],                 exclusive sense-network path
    [cell_matches,
      [[relevant,                       Second array :
         [0, 0, 1, 0, 0, 0, 10]],       analogical match of relevant cell
        [non_relevant,                  Third array :
         [0,  3,  2, 0, 0, 2,  5]]]]]]  matches of non-relevant cells
```

*Figure 4.* Semantic vector for a metaphorical semantic relation.

Semantic vectors are the third component of CS. Semantic vectors are a form of representation, along with sense-frames; but sense-frames represent knowledge, whereas semantic vectors represent coherence. Semantic vectors are therefore a kind of "**coherence representation.**" A semantic vector is a data structure that contains

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[7] Tourangeau and Sternberg (1982) have claimed that the more distance between the conceptual domains of the source and target, the better the metaphor. We have developed a measure that tests this claim.

nested labels and ordered arrays structured by a simple dependency syntax. The columns of the arrays record different kinds of mapping between sense-frames.

The crucial elements of the metaphorical relation in (2) were the preference violation and the relevant analogy. In figure 4, the preference violation has been recorded as the 1 in the first array (fifth column) and the relevant analogy is the 1 in the second array (third column). The aptness of a metaphor may be determined by the matches of non-relevant cells. In figure 4, those matches are recorded in the third array (compare with figure 3). Other semantic relations have different semantic vectors.

Together, the labels and arrays of a semantic vector specify the synergistic interaction of sources of knowledge in a semantic relation; in other words, the labels and arrays represent coherence. To see this, recall once again that we define coherence as the synergism of knowledge, and that synergism is the interaction of two or more discrete agencies to achieve an effect of which none is individually capable. In the semantic vector of figure 4, the discrete agencies are three knowledge sources ([1] the surface subject car1; [2] the agent preference animal1; and [3] drink1, the relevant context and also the sense of the main sentence verb), the interaction of those sources is the systems of mappings, and the effect achieved is the metaphorical semantic relation in (2).

The fourth component of CS is the process of screening. During analysis of a sentence constituent, meta5 computes a semantic vector for pairwise combinations of word-senses. These word-sense combinations are called "**semantic readings**" or simply "readings." Each reading has an associated semantic vector. Screening chooses between two semantic vectors and hence their attached semantic readings. Rank orderings among semantic relations are applied. In the event of a tie, a measure of conceptual similarity is applied.

The detail can now be supplied for the missing links from our skeleton account of coherence in section 3. The first missing link was from [1] to [2], namely how inclusion is used in the recognition of semantic relations and metonymy (distance is not used in CS). Our explanation is that collation discriminates semantic relations and performs metonymic inferencing by finding multiple sense-network paths between two sense-frames.

The second missing link was from [2] to [3], which is how semantic relations and metonymy are used in the resolution of lexical ambiguity. Our explanation is that semantic relations are represented in semantic vectors as systems of mappings and that screening uses those mappings to apply rank orderings of semantic relations and, if necessary, a measure of conceptual similarity to choose between semantic readings and thereby resolve lexical ambiguity (metonymy helps to establish semantic relations and does not figure directly in lexical ambiguity resolution).

The missing links between [1] and [3] are filled by the four components of CS. What unifies our account of coherence is the treatment of semantic relations that collation discriminates ([1] to [2]) and semantic vectors represent ([2] to [3]).

## 5 Summary

This paper has attempted to describe the relationship between semantic relations, metonymy, and lexical ambiguity resolution. Coherence was used as an explanatory concept that organised that relationship. CS was introduced as a theoretical framework in which the role of coherence in the relationship between semantic relations, metonymy, and lexical disambiguation was made more concrete. Finally, an example from meta5 was used to make the description of CS and the relationship between all four phenomena (coherence, semantic relations, metonymy, and lexical disambiguation) more concrete still.

Coherence is the main theoretical focus of CS, together with semantic primitives. Collation produces coherence, semantic vectors represent coherence, and screening uses coherence. In CS, the representation and processing of knowledge (sense-frames and collation) are distinguished from the representation and processing of coherence (semantic vectors and screening).

There are many phenomena that a coherence-based approach such as CS can explore. We have argued that semantic relations and metonymy are manifestations of coherence. Coherence exists between linguistic structures of all sizes. We have argued that coherence exists within sentences and is prominent in approaches to lexical ambiguity resolution. Coherence also exists between sentences -- it is basic to theories of discourse. Coherence merits thorough investigation as it appears to play a substantial role in cognition, not just semantic relations, metonymy and lexical ambiguity resolution.

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