

## A Survey of Studies of Bridging Anaphora

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### Abstract

This paper aims to review previous major studies of bridging anaphora resolution and generation in terms of their major views, advantages and inadequacies of each theory from the psychological, coherence-based, corpus-based, relevance-theoretic, cognitive, formal and computational perspectives. Then a critique of previous approaches to BA resolution and generation are made for future studies.

**Key words:** Bridging anaphora; Approaches to BA resolution and generation; Critique

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### INTRODUCTION

Anaphora plays a major role in accounting for cohesion and coherence in discourses and is an intriguing phenomenon under active study in both linguistic and computational academia. A broad range of approaches to anaphora resolution have been proposed in earlier literature. Most of these studies focus only on the coreference resolution and generation task. However, the algorithms for Bridging Anaphora (BA) resolution and generation have been much less explored. In comparison to direct anaphora, the resolution and generation of indirect anaphora (also, BA) is still a more difficult task because it is required to define the term BA properly

and also capture the wide variety of semantic relations it entails and the different knowledge structures it evokes. Diverse treatments of BA point to its complexity and multifacedness of the language phenomena, and its theoretical and practical significance in both linguistic and computational research.

## 1. APPROACHES TO BRIDGING ANAPHORA

### 1.1 Psychological Accounts

Many researchers have for long taken psychological approaches to BA resolution (Burkhardt, 2006; Clark, 1977; Garrod & Sanford, 1982; Garrod & Terras, 2000; Clark & Haviland, 1974, 1977; Singer, 1979). Among them, Clark (1977) is the first to use the term “bridging”. In the early studies of bridging reference, bridging is treated as one of the functions of the definite article. By contrast, Clark treats bridging implicatures as conversational implicatures in the Gricean sense. According to Clark, a bridging implicature is drawn when the “Maxim of Antecedence” (i.e., Try to construct your utterance such that the listener has one and only one direct antecedent for any given information and that it is the intended antecedent.) is deliberately violated. Clark is mainly concerned with the different ways in which new and given information are presented to the hearer. Clark and Haviland (1977) propose that the following Given-New Contract should be incorporated into Grice’s Cooperative principle:

#### Given-New Contract

The speaker agrees to try to construct the Given and New information of each utterance in context (a) so that the listener is able to compute from memory the unique Antecedent that was intended for the Given information, and (b) so that he will not already have the New information attached to the Antecedent (p. 9).

Whereas Clark accounts for bridging in terms of contracts and maxims of communication, Garrod and Sanford (1982) take a more psychological view. Garrod and Sanford propose a scenario-based account of text comprehension. A “scenario”, or “frame”, is a particular part of world knowledge activated in the course of interpretation. The information stored in a stereotypical scenario is then used for understanding BA. Besides, a scenario is made up of two different components: explicit and implicit focus. Explicit focus contains entities explicitly mentioned in the utterance while implicit focus contains slots for entities evoked by the current scenario for the interpretation of the utterance.

Garrod and Sanford explain the difference between explicit and implicit focus in terms of the organization of memory. “Explicit focus is a short-term store of limited capacity, and therefore, as new tokens are added, the activation of old ones will be gradually diminished until eventually they are no longer in focus” (p.162). By contrast, there is no capacity limitation for implicit focus partitioned in long-term memory. Garrod and Sanford assume that the reference domain includes not only explicitly mentioned items, but also some additional information retrieved from long-term memory which provides the setting for the text.

Garrod and Terras (2000) conducted an eye-tracking experiment to address whether the bridging relation between a verb and its anaphor was affected by the context in which the verb occurs, i.e., contextual account, or due to a purely lexical association between the verb and its role-filler, i.e., lexical account. Garrod and Terras’ experiment presented two main findings. First, first-pass reading times of the target sentence were slower after an implicit introduction of the thematic argument is made. However, there was no difference found between explicit and implicit antecedents for dominant verb-role pairs. Second, an early context effect emerged for the dominant rather than the nondominant verb-role pairs. Reading times were faster when appropriate contexts rather than inappropriate contexts were provided. Nondominant verb-role pairs were not affected by context appropriacy. Nevertheless, in the second-pass reading times on the noun, a strong context effect occurred both for dominant and nondominant targets.

Most of the studies presented before indicate that given information is integrated more easily in the discourse model than new information. In addition, Haviland and Clark (1974) and Singer (1979) found that the establishment of bridging relations involved more processing costs than direct identity relations. These studies are based on reading or comprehension time measures that can only be taken offline.

To overcome potential error sources in offline experiments, Burkhardt (2006) made an online experiment which can measure event-related brain potentials to study at what point real-time sentence processing inferential

knowledge affected how referring expressions are interpreted. It is found out that in ERP measurements, a negative deflection with a delay of around N400 emerges related to semantic implausibilities and contextual incoherence. A reduced N400 may occur with given noun phrases integrated into the discourse. Moreover, a positive deflection with a latency of around P600 can be analyzed indicating increased processing costs if new information is integrated into the discourse. Burkhardt held that bridging anaphora might comprise both new and given information.

To sum up, the interpretation of bridging NPs depends on the interpretation of both given and new information. Moreover, the need to establish a new discourse referent rather than to make complex inferences for a bridging relation, may account for the processing cost with the integration of bridging NPs displayed by the P600 effect.

## 1.2 Coherence-Based Approaches

Coherence can be defined according to a set of coherence relations between successive utterances in a discourse, i.e., Elaboration, Temporal Sequence, Cause-Consequence, etc.. The most important claim about reference assignment made within the coherence-based approach is that the recognition of coherence relations automatically solves the problem of reference assignment.

Hobbs (1979) maintains that reference resolution is a by-product of the search for coherence. This claim is significant in that it explicitly rejects the widely held view that co-reference is sufficient for coherence. Hobbs’ view can be summarized as follows: (a) assignment of reference is achieved in the course of identifying an appropriate coherence relation based on general knowledge; (b) an utterance will be judged unacceptable when no coherence relations can be assigned between two segments of discourse. Thus, according to Hobbs, success or failure of reference assignment is solely determined by whether a coherence relation is successfully identified or not. Nevertheless, the way of a proper coherence relation identified is not detailed enough to be fully usable and testable.

Sanders, Spooen, and Noordman (1992, 1993) share a similar view about how to define coherence relations. They explicitly aim at a psychologically plausible account of coherence relations. Their basic assumptions are as follows: (a) The set of coherence relations is ordered in terms of accessibility; (b) Readers use their knowledge of a few cognitively basic concepts to infer coherence relations. On the basis of these assumptions, Sanders et al. propose a taxonomy which classifies coherence relations in terms of cognitively salient primitives such as the type of relation, the source of the relation, the order of segments, the polarity of the relation. The four primitives are considered to satisfy their “relational criterion”.

There are many descriptive and theoretical limitations to the coherence-based approach. Just two of them are mentioned herein. In the first place, the hearer may be able to choose between two interpretations, both of which

would make the discourse coherent. A second problem is that an utterance may be interpreted in different ways, which may satisfy the same coherence relation.

### 1.3 Corpus Studies

Various empirical investigations into bridging anaphora have been made in the last decades (Fraurud, 1990; Gardent et al., 2003; Poesio & Vieira, 1998; Schwarz-Friesel, 2007). Most studies found out that definite noun phrases evoked bridging relation. However, indefinite noun phrases might convey a bridging relation in some context.

An important corpus study on the use of referring expressions was conducted by Fraurud (1990). She classified both definite and indefinite noun phrases based on a Swedish corpus based on written texts of various types. She found that 61% of definite descriptions were “first-mentioned” while 39% were “subsequent-mentioned”. As regards indefinite NPs, 85% are first-mentioned. Subsequent-mentioned NPs are direct anaphora, while first-mentioned NPs cover indirect anaphora. The important finding of this study is that the case of “first-mentioned” isn’t limited to indefinite NPs at all. The case of indirect anaphora evoked by definite descriptions is not rare.

Poesio and Vieira (1998) explored the use of definite NPs and proposed a classification based on native-speaker annotations with Class I identified with Fraurud’s “subsequent-mentioned” class, and the rest with “first-mentioned”, leading to very similar results. The study shows that only a quarter of all first-mentioned definite NPs is really unfamiliar or brand-new (class IV), while the NPs in class II and III are neither really “old” nor entirely “new”. This status of indirect anaphora is emphasized by Schwarz-Friesel (2007).

In another corpus annotation study, Gardent, Manuélian and Kow (2003) found a different number of cases of bridging definite descriptions. They distinguished between “first mention”, “coreferential” and “bridging” cases in a corpus of French newspaper articles. Number differences in general can be out of a number of reasons such as differences between spoken and written language, or between different discourse types underlying the corpora, or as a result of different postulations of classes.

Gardent et al. (2003) further differentiated between five classes of bridging relations: set membership, thematic, definitional, co-participants, and non-lexical. The set membership class accounts for 5.8% of their data. The thematic class accounting for 5.3% of their corpus matches Clark’s indirect reference. 83% of cases are subsumed into the definitional and co-participants classes with the semantic relation specified by lexicographic definitions.

To sum up, indirect anaphora enters into a majority of all occurrences of definite NPs as well as cases of indefinite NPs. Based on the studies mentioned above, it can be concluded that some kind of familiarity rather than uniqueness is essential to bridging inferences.

### 1.4 Relevance-Theoretic Approaches

This line of research has been carried out in many studies (Erku & Gundel, 1987; Irmer, 2011; Matsui, 2000; Wilson & Matsui, 1998). Early analyses of bridging are made within a largely Gricean pragmatic framework, with its machinery of Cooperative principle and maxims, maxim-violation, inferential intention-recognition, and so on. Early studies of bridging thus raise pragmatic questions on two quite different levels. That is, general pragmatic questions concerning the justification of an overall pragmatic framework and its consequences for the analysis of pragmatic processes; specific pragmatic questions about the felicity conditions on the use of particular constructions and the particular effects they intend to achieve.

Erku and Gundel (1987) argue that in the interpretation of bridging examples, considerations of relevance are decisive.

What we would like to suggest here is that the only thing which makes it possible for [bridging] expressions to be recognized as anaphoric is the maxim of relation, i.e. the expectation that the speech act performed in the use of some sentence be relevant to the context in which it occurs (p. 542).

However, they (1987) make no attempt to provide a theoretical definition of relevance, commenting merely that:

The importance of this notion [relevance] in the pragmatics of natural language has been noted in a number of works.... There has, however, been relatively little progress in making the notion explicit (p.543).

Wilson and Matsui (1998) maintain that Relevance Theory shares the Gricean assumption that hearers are looking for the overtly intended interpretation of an utterance. It differs from the Gricean approach in two main respects. First, it is not maxim-based: it contains no general communicative principles that speakers and hearers have to know and use. Second, it does not assume that communication is necessarily cooperative in Grice’s sense: that speakers and hearers have to share a common purpose over and above that of understanding and being understood. Its basic claim is that what is fundamental to communication is the pursuit of relevance.

The greater flexibility in the relations across utterances is what the coherence-based approach is lacking. Part of the appeal of the coherence-based approach relies on its use of relations such as Explanation, Temporal Sequence, Cause-Consequence and so on, holding between utterances in discourse. However, two problems with theoretical accounts of coherence relations have to be noted: first, the degree of fine-grainedness between the relations and the number of the relations a pair of utterances can enter into simultaneously; second, the inadequacy of coherence relations to account for arbitrary new relations.

Matsui (2000) further elaborates on several factors that may affect the hearer’s stylistic judgments:

- Plausibility of the bridge
- Shortness of the bridge
- Computability of the bridge
- Accessibility of candidate referents (“focus” or “topic”)
  - Accessibility of coherence relations

Matsui argues that none of the existing accounts is satisfactory as it stands. Matsui attempts to sketch an alternative account based on Relevance Theory, in which factors such as those mentioned above are considered to contribute to overall processing effort, which in turn affects acceptability.

Matsui makes the following hypothesis based on the definition of optimal relevance.

A hearer will find a given bridging reference stylistically infelicitous in the following conditions:

- When it is obvious that there is a better (i.e. more economical) way of achieving the intended effects;
- When it is possible for the hearer to decide what the intended effects are.

On the basis of the acceptability judgments for bridging reference, Matsui’s hypothesis is confirmed: when a bridging case is judged unacceptable, this is because the speaker is failing to achieve optimal relevance, either by asking the hearer to expend unjustifiable processing effort, or by failing to achieve adequate cognitive effects. It is also suggested that the speaker could increase the acceptability of such an utterance by making the intended set of contextual assumptions more accessible, or by creating a situation in which it is the most economical way of achieving the intended effects. Overall, Relevance Theory holds that utterance interpretation, including reference resolution, results from a trade-off between processing effort and cognitive effects.

However, Irmer (2011) suggests that Relevance Theory is very flexible and can account for a considerable range of bridging anaphora. However, it tends to give arbitrary explanations, which can be adapted to account for virtually any kind of example. Although the relevance-motivated reasoning gives many plausible answers for phenomena difficult to explain otherwise, it is questionable whether complex reasoning processes always play a decisive role in the resolution of indirect anaphora.

In a nutshell, pragmatic principles and constraints certainly play a critical role in anaphora resolution and can explain many anaphoric phenomena. However, these principles, as stated in pragmatic theories of anaphora interpretation, are far from being easily formalized or implemented.

### 1.5 Cognitive Accounts

There is now a rapidly growing body of research in cognitive linguistics which offers a new angle for anaphora study (e.g., Ariel, 1990; Fauconnier, 1994, 1997; Fauconnier & Turner, 1999, 2003; Langacker, 1996; Prince, 1981; van Hoek, 1992, 1995). The central claim

of this line of study is that anaphora can be resolved by recourse to different knowledge structures stored in the reader’s mental representations. Therefore, instead of simply making links between words in a text, a reader, through whose perspective the world and the text are construed, is supposed to make gap-bridging inferences about mental entities in cognitively-constructed worlds. What is tacitly bridged is typically some implicit information not structurally retrievable from either the sentence or discourse that triggers the inferential process. This provides great insights for bridging anaphora resolution and generation, reinforcing the cognitive linguistic position that “Language does not carry meaning, it guides it” (Fauconnier, 1994).

The accessibility model based on accessibility theory is best formulated by Ariel (1990), who argues that there exists a certain relationship between anaphoric expressions and mental entities that the expressions represent. Different referring expressions mark different levels of accessibility on a scale of accessibility marking, forms to the left signaling relatively higher accessibility and forms to the right signaling relatively lower accessibility listed as below:

#### The Accessibility Marking Scale:

Zero < reflexives < agreement markers < cliticized pronouns < unstressed pronouns < stressed pronouns < stressed pronouns+gesture < proximal demonstrative (+NP) < distal demonstrative (+NP) < proximal demonstrative (+NP) + modifier < distal demonstrative (+NP) + modifier < first name < last name < short definite description < long definite description < full name < full name + modifier

Ariel maintains that natural languages tend to code degrees of accessibility according to three coding principles: informativity, rigidity, and attenuation. The more informative the linguistic form is, the relatively lower accessibility it will code. The more rigidly (unambiguously) a form refers, the lower the accessibility it marks. The less attenuated the form (i.e., longer or louder, but with no added information), the lower the accessibility it marks. Lower accessibility markers occur in contexts where the antecedent is relatively less accessible to the addressee. Higher accessibility markers, on the other hand, tend to occur in contexts which assume a higher degree of accessibility of the antecedent to the addressee. According to Ariel, these accessibility markers, also called “context retrievers”, presumably have a one-to-one correspondence to the context type they evoke in the reader’s mind (e.g., definite descriptions, proper names—encyclopedic knowledge context, demonstrative expressions—physical context, pronouns and gaps—linguistic context).

The merit of accessibility model is that it can provide a cognitive explanation of why anaphora varies. However, some basic notions such as accessibility, retrieval, etc are not rigidly defined. In addition, Huang (2000) observes

there is still some counter-evidence against some of the hypothesis of accessibility theory. He points out that the correlation between cognitive status and anaphoric form does not correspond as satisfactorily as expected, some counter-examples exist in both directions. On the one hand, NPs can and even must be used for activated entities; on the other hand, pronouns may be used for inactivated entities. He concludes that “the cognitive contrast between activation and non-activation of a referent constitute neither a necessary nor a sufficient condition for the morphological contrast between reduced and full NPs” (p.163).

Also along this cognitive line is conceptual reference point model (van Hoek, 1992) to BA under Cognitive Grammar. Langacker (1996) suggests that a reference point (R) is a salient or accessible entity which the conceptualizer (C) invoke to establish mental contact with the target (T). And a reference point is anchored in a mental space, called dominion (D), where a set of interrelated entities can be approached via this reference point. As for reference resolution, the basic assumption is that all reference is resolved via access to or restructuring of domains of reference.

In sum, a cognitive account of BA provides a fresh perspective on the relation between cognitive linguist theories and BA, which may contribute to the development of models for BA resolution and generation. The advantage of a cognitive approach to BA lies in that by elevating words beyond surface structural level to mental entities, a wider and relaxed range of BA can be identified and accounted for than in previous accounts. However, cognitive oriented BA resolution models are mainly concerned with conceptualizer’s mental activities. Therefore, it is as hard to be formalized as a relevance-theoretic approach to BA resolution.

## 1.6 Formal Accounts

In Segmented Discourse Representation Theory, bridging inferences are seen as a byproduct of computing how the current sentence connects to the previous ones in the discourse (Asher & Lascarides, 1998). The resolution of bridging anaphora relies on four meta-rules:

- If possible use identity.
- Bridges must be plausible.
- Discourse structure determines bridging.
- Maximize discourse coherence.

The first rule concerns the tendency of the coreference of anaphora with an identical antecedent. This rule takes the priority; only if coreference fails to apply, the other rules may operate in the indicated order.

The second rule suggests that general world knowledge can offer certain plausible rationale to fill in the underspecified parameters.

The third rule means that if a rhetorical structure between discourse segments gives particular clues for resolving the anaphora, then this information is to be used.

The fourth rule, one of the most basic principles in Segmented Discourse Representation Theory, states that there is a preference for resolving bridging anaphora in a way that maximizes discourse coherence.

These meta-rules are the basis of the interpretation of bridging anaphora in Segmented Discourse Representation Theory.

Segmented Discourse Representation Theory offers an exact formulation of inferences in discourse interpretation which involves knowledge from diverse knowledge sources. Nevertheless, to match the antecedents of glue logic defaults world knowledge is supposed to be encoded in a proper manner. There are ways to express at least parts of domain and world knowledge in a constrained fashion. One possibility is to employ an extended view of lexical knowledge; another possibility is to use frame-based representations of stereotypical knowledge.

## 1.7 Computational Approaches

### 1.7.1 Focus Theory

Two topic/focus-based accounts of bridging reference will be considered here. According to Sidner (1981), speakers center their attention on a particular discourse element called the “focus”. Then a set of preference rules which govern the hearer’s choice of focus is given. The main factors governing this choice are the grammatical relations in a sentence. On her account, the focus will be:

#### The Expected Focus Algorithm

- a. The subject of a sentence if the sentence is a “is-a” or “there”-insertion sentence.
- b. The first member of a default expected focus list, ordered as follows:
  - Theme, unless the theme is a verb complement in which case theme from the complement is used.
  - All other thematic positions with the agent last.
  - Verb phrase.

Sidner argues that grammatical and thematic relations in a sentence play significant roles in selecting focus. The expected focus is most likely to be either the subject of a sentence, or the highest ranked member of the following default list:

Theme > all other thematic positions with the Agent last > the verb phrase

Sidner’s account is best characterized by focus as a default notion, i.e., the rejection of the expected focus and selection of an alternative candidate as focus if the interpretation does not correspond to either information from earlier discourse or to general knowledge.

Erku and Gundel (1987) assume that a referring expression is supposed to refer to the topic of the previous sentence; otherwise, the utterance which contains it is likely to be judged stylistically infelicitous. Erku and Gundel adopt Sidner’s algorithm to predict the topic of a sentence. However, unlike Sidner, they do not argue for the importance of plausibility; hence, they do not seem to allow for the possibility that general knowledge may override the choice of topic.

There are problems with their claim. First, there is no reason to assume that there is always at most one local topic/focus in a sentence. Second, non-stylistic factors affect accessibility. The position of the intonational nucleus instead of the syntactic structure of the sentence may be the indicators of topic/focus.

### 1.7.2 Centering Algorithms

Centering Theory, one of formally-oriented theories of anaphora resolution, has been paid a lot of attention by many researchers (e.g., Grosz, Joshi, & Weinstein, 1983; Joshi & Kuhn, 1979; Joshi & Weinstein, 1981; Miltsakaki, 1999, 2002, 2007; Strube & Hahn, 1999) and widely applied to diverse subfields of linguistics. Their studies are mostly devoted to pronoun or zero pronoun resolution and generation while less to BA resolution and generation. Given Centering's exact predictions for pronoun resolution, it can be well suited to handling BA as part of more comprehensive discourse theories. There are four major studies on this language phenomenon carried out within Centering.

#### Semantic Approach

Fais (2004) examines the inferrable centers in Japanese e-mail corpus within a Centering framework. The study shows that utilizing this type of center results in a high level of indeterminacy in labeling transitions and thus in characterizing the coherence of the corpus. The difficulty lies in the requirement of identity of discourse entities in the definitions of transition states. Lexical cohesion is

proposed as a well-defined notion to replace the intuitions captured by the use of inferrable centers. Based on lexical relatedness, two new transitions are used to supplement the standard Cb realizations for a more suitable characterization of coherence in this corpus.

Based on intuitions of native speakers, Fais claims that the level of coherence in the corpus is much higher than the centering account implies, primarily due to the fact that transitions involving inferrable entities are often difficult to specify. The major problem is derived from the identity requirement of standard Centering between discourse elements across adjacent utterances. Fais suggests that the crux of the problem lies in the application of standard centering processes to inferrable centers. What is required is a way to recognize a Cb in  $U_i$  not by virtue of its identity with a pre-established list of explicit and inferrable centers, but by virtue of a relationship, other than identity, with the explicit centers of  $U_{i-1}$ . The relationship of "lexical cohesion" developed by Halliday is posed to fulfill this function.

Fais discusses how semantic distance is established, a semantic similarity measure derived from the Gainen Base (Kasahara et al., 1996). He indicates how semantic distance can be used to define the notion of lexical cohesion as a crucial factor in devising two new types of transition: COHESIVE and COMPLETE SHIFT, which contribute to an adequate characterization of coherence in a corpus containing a high proportion of nonexplicit Cbs.

**Table 1**  
**Transition Definitions in Japanese E-mail Discourse**

$Cb(U_i) = Cb(U_{i-1})$ OR $Cb(U_{i-1}) = ?$ $Cb(U_i) \neq Cb(U_{i-1})$	$Cb(U_i) = ?$	and $Cb(U_i) \neq ?$		
$Cb(U_i) = Cp(U_i)$ $Cb(U_i) \neq Cp(U_i)$	CONTINUE RETAIN	SMOOTH SHIFT ROUGH SHIFT	COHESIVE COMPLETE SHIFT	$\exists Cf(U_i) \approx Cb(U_{i-1})$ $\sim (\exists Cf(U_i) \approx Cb(U_{i-1}))$

Table 1 defines two new types of shift to utterances that do not contain an explicit Cb. If there is at least one Cf in  $U_i$  having a high lexical cohesion value with some Cf (s) in  $U_{i-1}$ , then the transition from  $U_{i-1}$  to  $U_i$  is a COHESIVE transition. The transitions to these clauses are reidentified as COHESIVE.

The inclusion of COHESIVE and COMPLETE SHIFT in Centering Theory is derived from the necessity of specifying two identical entities across adjacent utterances to exhibit coherence of those utterances. The requirement of identity leads to the need to allow inferrable entities to play a part. However, it is often impossible to characterize transition states to utterances containing inferrable Cbs. By including the notion of COHESIVE transitions, the relatedness of two entities is captured without the need to invoke inferrable centers, and the apparent coherence in this corpus can be far better characterized.

Since COHESIVE transitions operate like CONTINUE transitions but replace the identity condition on Cbs with

a similarity condition, it is believed that they place only a slightly higher load on processing than CONTINUE transitions. Likewise, since COMPLETE SHIFTS shows an even greater discontinuity than ROUGH SHIFTS, a higher processing load is presumably imposed in the case of COMPLETE SHIFTS rather than ROUGH SHIFTS.

However, the lexical cohesion approach to inferrable centers is not without inadequacies. First, the COHESIVE transition should be refined. COHESIVE transition can be subdivided to capture coherence across utterances, i.e., a "CONTINUE COHESIVE," in which the  $Cp(U_i)$  has the highest similarity to  $Cf(U_{i-1})$ , and a "RETAIN COHESIVE," in which some other Cf has the highest similarity to  $Cf(U_{i-1})$ . Second, the implementation of this approach needs to be improved. Semantic distance as measured by the Gainen Base provides a feasible basis for how lexical cohesion is rigorously defined. However, two major areas need to be addressed. The first area concerns coverage. The lack of complete coverage of the corpus

by the Given Base makes it impossible to characterize cohesion over the corpus. The second area pertains to definitions of distance for each transition type. The study has examined semantic distances as relative strengths within messages; it would be useful to set definitive, independent levels for each transition type.

**Centering Optimality Theory Approach**

Some researchers approach BA by integrating Optimality Theory into Centering (e.g., Beaver, 2004; Mineur, 2006). A major property of Optimality Theory lies in that the interaction of principles operates on different levels. That is, the principles display properties across different levels. Their mode of operation is represented in the so-called tableau. What is to be represented is the way in which the existence and the ordering of certain principles affect the way in which input sentences are analyzed.

Beaver (2004) combines Centering Theory and Optimality Theory in order to account for the resolution of discourse anaphora. Beaver notes that this Rule 1 of Centering Theory does not have to be stated conditionally

once the OT framework is adopted, for now constraints are allowed to be violated. Beaver’s approach mentions bridging anaphora, however, focusing mainly on coreferential anaphora. Some of his constraints are immediately useful for an account of bridging. The most relevant ones are *Cohere*, *Align* and *ProTop*.

Beaver’s system is designed for coreferential anaphora, not for bridging anaphora. However, the phenomena are so much similar that the ordering of the constraints can be maintained to a great extent. Mineur (2006) has refined Beaver’s *Agree* to express its applicability to coreferential anaphora, and turned it into *Coref Agree*. Moreover, Mineur holds a different view on how definites should be handled. Rather than considering them to be familiar, as Beaver does, she considers them to be unique. She has added three new constraints: *Referential Economy*, *Accessible* and *Bridges are understood*. The following constraints defined by Mineur for the resolution of bridging anaphora (in alphabetic order) are listed as follows:

**Table 2**  
**Mineur’s Constraints for the Resolution of Bridging Anaphora**

Mineur’s Constraints	Resolution of Bridging Anaphora
Accessible	Antecedents must be accessible.
Align	The topic is in subject position.
AvoidF	Avoid Focus.
BaU	Bridges are Understood.
* Block Cohere	A form-meaning pair may not be dominated by another form-meaning pair in either direction of optimization in the tableau consisting of all constraints except * Block.
Cohere	The topic of the current sentence is the topic of the previous sentence.
Coref Agree	Coreferential anaphoric expressions agree with their antecedents in terms of number and gender.
Def-Uniq	Each definite noun phrase refers to a unique antecedent within a given context.
Disjoint	Co-arguments of a predicate are disjoint.
DOAP	Don’t Overlook Anaphoric Possibilities.
Pro-Top	The topic is pronominalized.
Referential Economy	reflexive < pronouns < R-expression

Based on some adjustments to Beaver’s scheme, Mineur suggests that bridging is a complex phenomenon deriving from several interacting principles, syntactic, scope-related, (lexico-) semantic as well as pragmatic. Optimality Theory serves very well to explain this phenomenon. Mineur also focuses on nominal anaphora, which falls into two major classes: pronouns and full noun phrases. Pronouns are typically used as an attenuated form to repeat an existing discourse referent. Thus, the pronoun co-refers with its antecedent. Whereas full noun phrases have independent semantic content, which can contribute to introducing a new discourse referent indirectly tied to another element in the discourse.

**Salience-Based Approach**

Poesio (2003) discusses the problems involved in identifying and annotating bridging descriptions in corpora of English, and presents results concerning the correlation between bridging descriptions and Centering by employing a reliably annotated corpus and automatic focus-tracking methods. The study Poesio conducts is motivated to address the following difficulties:

Poesio exploits a self-constructed corpus and some focus-tracking techniques to study the correlation between “salience” and bridging reference resolution, focusing on ASSOCIATIVE DESCRIPTIONS, i.e., bridging references realized as the-NPs, related to their anchor by a relation other than identity (Hawkins, 1978).

In the first place, the study develops a new annotation scheme on BA resolution. In order to be consistent about what is classified as “bridging reference”, Poesio develops, first of all, methods for marking both identity and associative semantic relations; Secondly, the NPs related by non-identity semantic relations with discourse entities last mentioned in the previous utterance are only classified as bridging references.

In the second place, marking up bridging references is quite hard. In Poesio and Vieira (1998), it is found that the subjects only agreed on about 5% of bridging descriptions. By limiting the types of relations annotators are supposed to mark up, and by specifying priorities, this problem is addressed. Annotators only annotate four types of relations, a subset of those proposed in the “extended relations” version of the MATE scheme (Poesio et al., 1999): identity (IDENT), set membership (ELEMENT), subset (SUBSET), and “generalized possession” (POSS), which also includes part-of relations.

In the third place, an investigation into the extent to which the interpretation of BAs depends on the salience of potential anchors is made. Poesio suggests that given near-perfect knowledge about focus, the first-mentioned entity of  $U_{i-1}$  is still significantly more likely to be the anchor of a bridging description than  $C_b(U_{i-1})$ . However, focusing information might still be useful provided that effective ways of filtering away implausible anchors are found, since 84.5% of anchors are previously Cbs.

The limitations of the study are first that annotators only annotated four types of relations, not all of them, and second that salience is not the necessary condition for BA resolution, the anchor of BA is sometimes related to a lower degree of salience.

### Functional Approach

Functional anaphora has not been paid much attention within Centering Theory. Compared to the more elaborated “direct realization” constraints for pronominal anaphora, its realization conditions are not duly treated.

Markert, Strube, and Hahn (1996) present an inference-based text understanding methodology for the resolution of functional anaphora within the Centering model. A more precise, formally-based notion of realization is devised for the analysis of functional anaphora under Centering Theory via a set of heuristic realization constraints on underlying inference processes. These include language-independent conceptual criteria and language-dependent information structure constraints. The postulated criteria contribute additional restrictions on the search space of possible referents and also direct inference processes to understand anaphoric utterances in the discourse. Thus, compared with the original Centering model, the advantage of this explanatory model for local coherence is the limitation of the resource demands for text understanding.

To identify and evaluate proper conceptual links of an antecedent with a functional anaphor, a path finder and a

path evaluator will be employed to make a unidirectional search in the domain knowledge base for well-formed paths between the two concepts and to select the strongest of the ensuing paths.

Paths between an antecedent  $x$  and a functional anaphor  $y$  may be computed to yield several types of well-formed paths, i.e., “plausible”, “metonymic” or “implausible”. Those different path markers are ranked in terms of their intrinsic conceptual strength for a proper selection. Based on this ranking, metonymic paths will be eliminated from a path list iff plausible paths are already viable while implausible paths will be ignored iff plausible or metonymic paths already apply. Hence, the ranking of path markers by conceptual strength is listed as follows:

“plausible”  $>_{str}$  “metonymic”  $>_{str}$  “implausible”

The edge of the proposed algorithm is that it presents a modular approach with precise and semantically motivated restrictions. It combines two equally general, multi-purpose modules, viz. a path finder and a path evaluator, which are also used in the parsing process, and a Centering mechanism which is applied to other forms of anaphora resolution problems as well. This algorithm has the advantage of a specific inference module with lucid triggering conditions.

The original Centering model does not address how to resolve functional anaphora. Grosz et al. (1995) just demonstrates the difference between the relations *directly realizes* and *realizes*. How to define both of them precisely rests with the semantic theory adopted (p. 209). Markert et al’s study has shown, however, that there are a lot of general constraints at the knowledge level which need not be covered by semantic theories at all.

In sum, in order to constrain the realization of functional anaphora in the Centering framework, two constraints are proposed. One is conceptual well-formedness and strength criteria for role chains in a terminological knowledge base, by which the plausibility of various possible antecedents as proper bridges to functional anaphora can be assessed. The other is information structure constraints on the underlying utterances in terms of topic/comment patterns contributing further inferential restrictions on proper antecedents for functional anaphora.

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## 2. A CRITIQUE OF PREVIOUS STUDIES OF BRIDGING ANAPHORA

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Bridging is a challenge for accounts of anaphora resolution and generation. Psycholinguistic approaches to bridging provide us with psychological considerations and empirical evidence of the role context plays in bridging resolution, but they fail to give some general rules to constrain bridging anaphora resolution. It relies too heavily on the role of linguistic information in selecting the appropriate domain of memory to activate,



and contextual factors are completely ignored. Therefore, it cannot address cases where there is more than one candidate for a plausible scenario or more than one candidate referent when the search domain is extended into the entire knowledge structures. The coherence-based approaches to bridging clearly define a set of coherence relations between successive utterances in a discourse, whereby some underspecified bridging anaphora is resolved. Coherence-based approaches raise descriptive questions about which coherence relations exist, and explanatory questions about why they exist and how they are acquired. Hobbs' version of the coherence-based criterion does not offer any mechanism for choosing one of several potential coherence relations, because it imposes no order of accessibility between them. A mechanism is provided in Sanders et al.'s account for selecting a unique coherence relation among all the possible ones. Nevertheless, their mechanism foregrounding the ordered accessibility of coherence relations is inadequate. Moreover, Sanders et al.'s proposal that there is a fixed order of accessibility for causal inferences seems to be too strong. Corpus studies on bridging anaphora mainly concerns the distribution, classification and annotation of definite NPs and indefinite NPs based on different corpora. However, no single rules are derived from these empirical studies. The relevance-theoretic approach is superior to the coherence-based approach on both descriptive and theoretical grounds: it applies to isolated utterances, and to longer stretches of discourse as well; it provides a comprehension procedure which spare the computation of all possible interpretations; it shows how expectations of relevance can affect the accessibility of candidate interpretations, and how accessibility can in turn affect acceptability; and it explains most of the intuitions of acceptability that coherence-based approaches are intended to explain. Nevertheless, although the idea that merely one underlying Principle of Relevance is assumed, from which all pragmatic inferences are derived, is intuitively appealing, a serious demerit for relevance-theoretic accounts of bridging is the lack of a formal implementation of mechanisms. The cognitive account of BA emphasizes the active and ubiquitous role humans have. Cognition is a lense, through which every entity in the world is projected on mental screen in a subjective fashion. Therefore, despite the widening of BA taxonomies, the difficulty in formalization is also obvious. Computational and formal accounts can formally express these inferences with the help of nonmonotonic reasoning. The formal account of bridging integrates grammar with context to show us a more satisfactory picture of bridging resolution. Segmented Discourse Representation Theory offers an exact formulation of inferences in discourse interpretation which involves knowledge from diverse knowledge sources. Nevertheless, to match the antecedents of glue logic defaults world knowledge is supposed to be encoded in a proper manner.

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