

# Lost Intuitions and Forgotten Intentions

Barbara Grosz\*  
Aiken Computation Lab  
Harvard University  
Cambridge, MA 02138 USA  
grosz@eecs.harvard.edu

Candace L. Sidner  
Lotus Development Corp.  
1 Rogers St.  
Cambridge, MA 02142 USA  
csidner@lotus.com

## 1 Overview

To provide context for the discussions of centering that appear in this volume, we review our previous research on global focusing and centering and discuss central unsolved problems in the theory of centering. This paper does not provide a comprehensive review of work on centering, as this volume in its entirety serves that purpose. Rather we present our view of the history of centering and our perceptions of the most important areas for future work. The paper begins with a description of the intuitions underlying our previous research, a statement of the intended properties of the attentional state models and proposed theories, and the major claims made. We then look to the future development of centering and argue briefly for additional empirical research, analysis of more complex types of discourse, and more detailed examination of the interaction of centering with other discourse processes at both the local and global levels.

## 2 Original Intuitions and Intentions

Grosz (1977a; 1977b) provided the framework that underlies subsequent computational linguistic research on the modeling of focusing of attention in discourse. This work established the context in which centering was formulated. It distinguished between two levels of focusing: immediate (or local) and global. While global focusing “is determined by the total discourse and situational setting of an utterance and influences . . . the overall interpretation of an utterance,” immediate focus “refers to the influence of a listener’s memory for the linguistic form of an utterance (the actual words and the syntactic structure) on his interpretation of a subsequent utterance” [(Grosz, 1977b), page 5].

Grosz (*op. cit.*) established two ideas fundamental to centering. First, immediate focus is a *local* level of processing in contrast to global focusing. It models utterance by utterance

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\*Partial support for the first author was provided by the National Science Foundation under Grants No. IRI-90-09018 and IRI-94-04756.

changes in the focus of attention as a discourse progresses. Second, the form of an utterance plays a role in the determination of immediate focus; “linguistic form” was taken to encompass the types of words used, the syntactic form of the utterance and intonation (cf. (Grosz, 1977b), page 157, footnote). This work, however, was largely directed at global focusing and did not address to any depth focusing at the local level; in particular, no details were provided of the relationship between utterance form and immediate focusing.

Sidner (1979; 1981; 1983) provided an algorithm for tracking focus of attention at the local level. This algorithm specified a way to establish the immediate focus; in addition, a series of rules were given that used immediate focus to identify the referents of third-person pronouns, demonstrative uses of “this” and “that” noun phrases and pronouns, verb-phrase anaphora of the “do-so” or “do-it” variety, and definite noun-phrase anaphora.

In this work, immediate focus was intended to model the sense of “aboutness” of utterances in discourse and thereby to establish a means of determining the coherence of discourse. Sidner conjectured that aboutness could be used to reduce the number of inferences needed to establish the coherence of discourse. Because pronouns, and other anaphora, establish coherence through linguistic form, immediate focus was intended to provide an anchor for the inference required by reference resolution; it would thus reduce the number of inferences necessary to interpret anaphoric expressions. The immediate focus rules specified a preference order for interpretation in which the immediately focused entity was most highly preferred, followed by other entities in the preceding utterance, and then by globally focused entities. Inference was used to filter out unreasonable choices high in the preference order.

Sidner’s work was in marked contrast to contemporaneous computational research by Winograd (1971), Charniak (1973), Rieger (1974), and Hobbs (1979), in which open-ended inference was applied to logical-form like representations in which pronouns were represented by free variables. These approaches provided no constraints from linguistic information on the cognitive processing required. By contrast, the immediate focusing algorithm and rules relied on linguistic information, from both the discourse level and the utterance level, to significantly constrain inference in cognitive processing. Immediate focusing also differed from theoretical linguistic approaches, such as Lasnik’s (1976) and Reinhart’s (1976), which sought purely syntactic explanations of pronoun reference.

Thus, Sidner’s (*op. cit.*) work provided much needed algorithmic detail for immediate focusing. However, the algorithm’s combined use of pronoun interpretation as the marker of immediate focus with the use of immediate focus as a tool for pronoun interpretation led many to assume a narrow view of centering as a process for pronoun interpretation only. In particular, by conflating the manner in which the immediate focus was *realized* (in the sense defined by Grosz, Joshi, and Weinstein (1995), as discussed below) with pronoun resolution, it led researchers to presume that pronouns alone determined immediate focus, and that immediate focusing alone could determine pronoun reference. Neither conclusion is correct.

Joshi and Weinstein (1981) introduced the terms “backward-looking center” and “forward-looking center.” About these they said: the Cb “determines how the [sentence] is going to be incorporated in the preceding discourse and thus incrementally augments the current discourse model.” The Cf “determines how [the sentence] will get linked up to the succeeding discourse” [(Joshi and Weinstein, 1981), page 385]. They assumed that the Cb was a singleton entity, and that the Cf was a set. However, they provided no argument for these choices.

From their brief presentation, the Cf appears to be equivalent to Sidner’s potential foci list and the Cb equivalent to Sidner’s discourse focus or expected focus (Sidner, 1981; Sidner, 1983), although the use to which these constructs are put was different. In particular, Joshi and Weinstein addressed questions about complexity of inference; to integrate a sentence [their term] into the discourse, the Cb of the current sentence had to be a member of the Cf of the previous sentence. Discourses without this relationship were still considered to be interpretable, but more difficult to comprehend. In addition, Joshi and Weinstein argued that the size of the Cf and the total numbers of centers in a discourse would affect the complexity of comprehension.

Certain of our original intuitions were captured by Sidner’s and Joshi & Weinstein’s early work. First, it established the relationship between immediate focus (or centering) and the aboutness of utterances. Second, it used immediate focus (or centering) to constrain the inferential processing in discourse. However, it blurred the distinction between the use of immediate focus (or centering) in the interpretation of natural-language expressions (not just pronouns, but all anaphora and various elliptical forms) and the use of certain linguistic expressions to mark immediate focus in discourse.

Subsequently, Grosz, Joshi, and Weinstein (1983; 1995)<sup>1</sup> hereafter referred to as **GJW**, attempted to integrate these three pieces of previous work, and to clarify the terminology and uses of the local level of focus of attention. To distinguish more clearly the process of centering from the use of centers, they made several claims and conjectures central to centering theory. They defined a *realization* relation between linguistic expressions and semantic interpretations (entities); description, reference and denotation are examples of realization relations. **GJW** claimed that the manner of the realization of the centers had to be distinguished from the entities that were centers. Following previous work on immediate focusing and centering (Sidner, *op. cit.*, and Joshi and Weinstein, *op. cit.*), they argued for a single Cb and an ordered set as the Cf; however, they allowed for the possibility that the Cf ordering was only partial. Finally, they conjectured that the ordering of Cf was determined by a range of factors, including the syntactic form of the utterance, intonation, and the realization of the Cb.

The primary claims of the centering theory in **GJW** are given in two proposed centering rules: Rule 1 establishes constraints on the realization of entities mentioned in an utterance; Rule 2 claims a difference in inference load among different centering transitions between utterances. Thus, the three most fundamental innovations in **GJW** were (1) distinguishing centers from their realizations; (2) the use of centering to provide constraints on realization; and (3) specification of types of transitions of centers across utterances depending on the Cb and on the Cf order.

Cross-linguistic and empirical research has addressed a variety of issues raised by this initial work. Kameyama (1985; 1986) investigated the applicability of the initial centering proposals (Grosz, Joshi, and Weinstein, 1983) to Japanese, arguing that the interpretation of zero anaphora in Japanese depends on centering in a manner analogous to pronoun in-

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<sup>1</sup>There are three relevant papers. After the appearance of Grosz, Joshi, and Weinstein (1983), a draft paper that extended the original ideas (Grosz, Joshi, and Weinstein, 1986) was circulated. The extended version was published in 1995. We refer to the papers together for the collection of the ideas now more clearly presented in the 1995 paper.

terpretation in English. She also argued that the Cf ordering depends on grammatical role, rather than thematic role which Sidner (1981) had used. Additional research on centering in Japanese (Walker, Iida, and Cote, 1993) and Italian (Eugenio, 1990) further supports that centering is, as we had conjectured, not just a phenomenon of English discourse. Hudson–D’Zmura’s experimental research (Hudson-D’Zmura, 1988) and Passoneau’s (Passoneau, 1993) corpus-based research provided empirical support for the role of centering in language comprehension; subsequent empirical work (Gordon, Grosz, and Gillom, 1993; Brennan, 1995) provides further support as well as initial information about factors affecting the identification of Cb and the ranking of elements of Cf.

In summary, this subsequent research has verified several claims of GJW and suggests the need to modify others. The major results include the following:

- There is a single Cb; there are multiple, ranked members of Cfs.
- Syntactic role, rather than thematic role, affects Cf ordering and the identification of the Cb.
- Surface order affects Cf ordering, but not Cb identification.
- Centering can be used to explain the interpretation of a variety of linguistic devices in different languages (e.g., zeros in Japanese, pronouns in English); other linguistic constructions, such as topic markers, function in part to determine the center.

### 3 Theory Development

A number of questions about the centering framework remain unresolved, and centering theory requires expansion and testing. We consider the following three research areas most critical for the further development of centering theory:

- A determination of the full set of utterance features that affect the determination of the Cb and the Cf ordering. Cross-linguistic studies are needed to determine the ways these vary across languages.
- Specification of the ways in which centering affects processing load; i.e., how does centering restrict the number and kinds of inferences needed in the interpretation of utterances?
- Identification of the role inferential processes play in determining Cb and Cf.

Progress in these areas depends upon more extensive empirical research on certain features of utterances and discourses both to establish the facts of the matter and to test theoretical proposals aimed at explaining those factors. This empirical work should complement previous studies along several dimensions. First, future empirical work must examine utterances with more complex syntactic structures and semantic categories (for verbs) than those studied to date. Second, it should investigate centering transitions within a discourse segment as a whole, not just the transitions as they apply to pairs of utterances. Finally,

it should consider interactions between centering and global focus of attention. In the remainder of this article, we first discuss some methodological issues and then briefly outline research along each of these dimensions.

## **Empirical Work: Methodological Issues**

To date, a number of different methods have been used in centering work, including the following: naturally occurring examples from text or conversations; constructed examples, especially minimal pairs of utterances; preference judgments on example pairs (Walker, Iida, and Cote, 1993); standard empirical psychological experiments (Hudson-D'Zmura, 1988; Gordon, Grosz, and Gillom, 1993; Brennan, 1995); and corpus-based statistical analyses (Passoneau, 1993). Although each of these methods can contribute to theory formulation, it is important to separate out the roles each can play. In particular, it is now time to increase efforts on those methodologies that enable direct tests of theory.

Both naturally occurring examples and constructed ones play a valuable role in suggesting the phenomena that need to be explained as well as in motivating a particular theoretical stance. However, neither serves as a way to test theoretical proposals, nor can they be used to establish properties of human processing in any detail. Corpus-based statistical analyses can offer empirical results about the shape of broad classes of phenomena. The use of acceptability judgments on preference pairs provides a more rigorous test of proposals. However, to be useful for testing centering theory, the application of this methodology must be controlled carefully. In particular, the number of examples used with informants, the size of the informant pool, and the specific judgments of test examples affect the reliability of acceptability claims. As theories of interpretation become richer, researchers need such information to evaluate the fit between theoretical claims and the data being used to support those claims.

It is often argued that the empirical methodologies of psychology are difficult to apply to discourse theories because these methodologies require fine-grained hypotheses. However, centering theory makes just such fine-grained claims. Its arguments about processing behavior can, in the end, only be validated by empirical investigations of properties of human processing. Such testing can be quite difficult to undertake because it requires construction of a large number of discourses of varying types. Even so, more experimental psychological work directed at issues raised in the remaining sections is needed both to help extend and to test centering theories.

## **Extensions to Sentential Phenomena**

Most work on centering has considered only limited semantic issues and simple sentence constructions, especially SVO sentences in English. Theoretical proposals require examination of more complex syntactic types and a greater variety of semantic forms in utterances. For example, the interpretation of pronouns in successive clauses is affected by the type of connective between the clauses. Kehler (1993a), who proposes a combined focusing and coherence approach in processing pronouns, illustrates the effect of connectives on pronouns with the contrast pair in (1). He proposes that some sentential connectives (such as *but* and

*because*) trigger a coherence-based integration of the potential referents into the discourse model, so that when the pronouns are processed, a semantically-based resolution process is used. Other connectives (such as *and*) need not trigger integration of the referents, and centering would then constrain pronoun interpretation.

- (1) (a) Steve<sub>i</sub> blamed Frank<sub>j</sub> because he<sub>j</sub> split the coffee.  
(b) Steve<sub>i</sub> blamed Frank<sub>j</sub> and he<sub>i</sub> spilt the coffee.

Examples like (1) suggest that the interaction between centering and semantic processing should be further investigated. In addition, the interaction of centering with other discourse processes must be more completely specified. Centering theory, and Rule 1 in particular, accounts only for some pronoun uses. In utterances with multiple pronouns, additional factors constrain the interpretation. For instance, centering theory alone cannot explain the oddness caused by the object pronoun in (2b) [from Kehler (1993b)]. Because the subject pronoun refers to Terry who is the highest-ranked member in Cf(2a), Rule 1 is satisfied, and centering theory does not constrain the interpretation of the object pronoun.

- (2) (a) Terry<sub>i</sub> has been getting harassed by Sandy<sub>j</sub> at school.  
(b) Her<sub>i</sub> father told her<sub>i/j</sub> to stop it.

Verbs of perception and dialogue also challenge current centering proposals and require further investigation. They exhibit properties much like the empathy properties in Japanese explored by Kameyama (1985; 1986). Thus, in the examples below, *see* and *look* verbs appear to affect centering differently.

- (3) She<sub>i</sub> saw Mary<sub>j</sub>. “she” = Jane = Cb  
(a) ? She<sub>i</sub> was wearing thick glasses.  
(b) ? She<sub>j</sub> was wearing thick glasses.

- (4) She<sub>i</sub> looked at Mary<sub>j</sub>. “she” = Jane = Cb  
(a) # She<sub>i</sub> was wearing thick glasses.  
(b) She<sub>j</sub> was wearing thick glasses.

- (5) Jim glanced down past McCoy, Sulu and Matlock toward Lt. Kerasus, raising an inquiring eyebrow at her. She glanced back, shaking her head ever so slightly. [(Duane, 1984) as quoted by Sirote (Sirote, 1991)].

Verbs of saying and telling also appear to affect the Cf list in different ways. For example, because indirect discourse reports lend themselves to dialogue turn-taking interpretations, the pronoun in (6b) could refer to Harry (e.g., “He<sub>j</sub> said he<sub>j</sub> expected them to.”) as easily as to John (e.g., “He<sub>i</sub> said they’d arrive on time.”).

- (6) (a) He<sub>i</sub> told Harry<sub>j</sub> that the plans were going well. “He” = John = Cb  
(b) He said ...

## Global Focusing and Centering

Research on centering has almost exclusively concerned linguistic phenomena that can be explained at the local level of discourse structure using centering ideas. However, some phenomena appear to require an appeal to both global focusing and centering. For example, right dislocation (RD) phenomena, discussed in the Grosz and Ziv article in this volume, provide a means to introduce situationally evoked entities to the discourse, to re-introduce discourse entities to the discourse so that they become highest ranked in the Cf, or to introduce implicitly focused entities directly for use as the highest-ranked element of Cf. The contrast between (7) and (8), discussed by Grosz and Ziv (this volume), illustrates the re-introduction function of RD. In (8), B's last utterance is acceptable in the discourse context (which is not true of B's utterance in (7)); it re-introduces "this article" as the most highly focused member of the Cf in the segment that continues with the last utterance of (8).

- (7) A: I asked you to read this/the article for today.  
B: # It's much too difficult, this/the article.

- (8) A: I asked you to read this article for today.  
B: I know. I tried to very hard, but I was quite busy. I had guests from abroad who I had to entertain and I had nobody to help me. Besides, it is much too difficult for me, this article.

Both centering and global focusing also appear to be required to explain the function of the *wa* topic-marking of Japanese. Kuno (1989) pointed out that straightforward application of centering theory incorrectly predicts reading 10(c) is preferred to reading 10(b) in the sequence below. Nakatani (1993) argues for the use of a full proposition in global focus to account for the distinctions in acceptability of these alternatives.

- (9) Taroo-wa Hanako-ga suki da.  
Taroo-TOP Hanako-NOM fond-of is.  
Taroo likes Hanako.

- (10) Jiroo-wa kirai da.  
Jiroo-TOP hating is.

- (a) (Taroo) dislikes Jiroo.  
(b) Jiroo dislikes (Hanako).  
(c) \* Jiroo dislikes (Taroo).

Finally, centering theory has yet to address a general question about the interaction of global and local attentional state: how do transitions in the forward-looking centers and the backward-looking center vary with the type of segment boundary?

The discourse model of Grosz and Sidner (1986) allows three types of transitions that are relevant for centering at segment boundaries; these are illustrated in Figure 1. A *sibling*

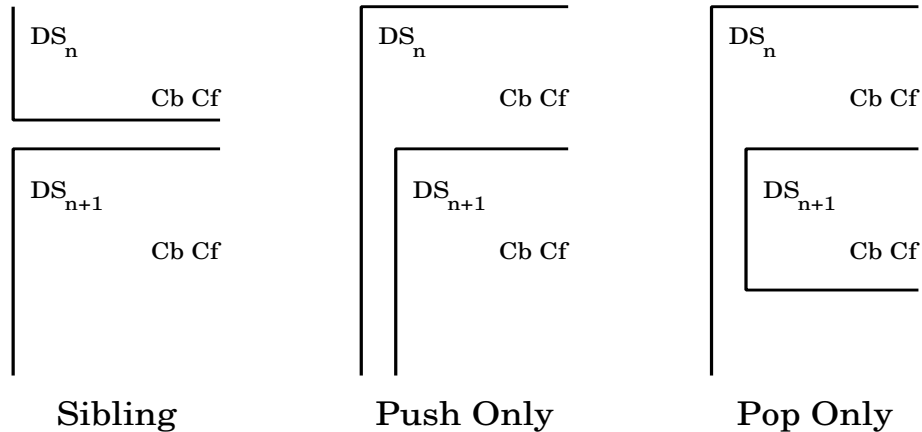


Figure 1: Segment Transitions Associated with Attentional State Changes

*transition* occurs when a popped space in the focus space stack is followed by a push so that the segment corresponding to the pushed space is at the same level of embedding as the segment corresponding to the space at the top of the stack after the pop. A *push-only transition* pushes a space onto the stack where the new space corresponds to a segment that is embedded relative to the preceding segment, which corresponds to the old top of the stack. A *pop-only transition* occurs when a space is popped from the stack and thereby leaves as the top of the stack a space that corresponds to a segment that is less embedded than the segment for which the pop occurred. In each of these cases, the forward- and backward-looking centers could either be carried along, dropped, or made less accessible.

Sidner’s (1979) implementation exhibited two features of accessibility: (1) *memory*: the immediate focus of a segment was “remembered” when a space for a new segment was pushed onto a stack, so that the immediate focus was ready again for use when the space for the new segment was popped; and (2) *clear break*: the immediate focus of a new segment was started anew when a new space was added to the stack. Neither of these features seems quite right. The memory feature presumes that a local attentional property is recorded for an indefinite time. Work subsequent to Sidner’s (1979) implementation revealed discourses for which the clear-break feature makes the wrong prediction. Because at the global level, different types of changes are occurring at the boundary with each of the three types of segment transitions, we expect different centering behavior to occur with each as well. Research that varies the availability of centers for different kinds of segment transitions is needed to determine an account of the transitions in centers at segment boundaries.

### Centering transitions

In GJW three types of transitions for centers across utterances are defined. Rule 2 claims that differences in inference load in discourse interpretation, and thus in coherence, result from using different sequences of transitions. Although Rule 2 is written in terms of sequences of utterances, all uses of this rule in language processing systems (beginning with the work of Brennan, Friedman, and Pollard (1987)) have adapted the rule by restricting it to pairs of utterances. These uses of Rule 2 miss the essential intuition that what matters to coherence



are centering transitions throughout a segment, not only between pairs of utterances. It is, of course, more difficult to evaluate coherence over a whole segment than between a pair of utterances. To determine the extent to which Rule 2 is true will require empirical data from studies in which texts like the two below (adapted from **GJW**) are compared. The first discourse contains only one change of center, whereas in the second the center changes from the store to John, and then back and forth several times.

- (11) John went to his favorite music store to buy a piano.  
He had frequented the store for many years.  
He was excited to be going to the store to actually buy a piano.  
It was the biggest music store in the area.  
It had just the kind of piano that he wanted.  
It was closing just as John arrived.
- (12) John went to his favorite music store to buy a piano.  
It was a store John had frequented for many years.  
He was excited to be going to the store to actually buy a piano.  
It was the biggest music store in the area.  
He knew that it had just the kind of piano that he wanted.  
It was closing just as John arrived.

## 4 Conclusions

We had a number of questions in mind when formulating the research program that led to the centering framework and theory: how does discourse aboutness change over a sequence of utterances, how do people interpret anaphoric expressions, how does aboutness constrain inference, what discourse-contextual constraints are there on pronoun use, how do discourses divide into subunits, and what linguistic cues link or divide these units?

Our original intuitions about focusing concerned the local nature of certain linguistic processing, especially definite anaphora, and the aboutness of local focus of attention. Likewise, we held that local attentional state played a key role in constraining inferential processing to make discourses easier to understand. These intuitions still form the core of centering theory. Many of the details about the ways centering operates to affect processing load and about the features of utterances that determine centers remain to be formulated. Further exploration of these matters will need to draw on empirical work using complex sentence types and a greater range of semantic categorization of verbs. Computational linguistic research must address, in addition, the interaction of global and local focusing. Such research will enable a more complete model of local attentional state, one that satisfies our original intuitions while realizing our forgotten intentions. Most important, it will help answer fundamental questions about the nature of discourse processing.

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