# Dynamic Centering

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## Abstract

It has previously been proposed that a Centering-style theory might be integrated with Dynamic Semantics, in a way that solves problems associated with strict and sloppy readings of pronouns. However, I show that this integration is in fact inconsistent with Centering. I trace the problem to an implicit assumption in Centering that coherence relations are primarily entity-based. I present a modified version of Centering, Dynamic Centering, in which this assumption is removed. This makes it possible to successfully integrate Centering with Dynamic Semantics. I show that this results in a simpler as well as more empirically successful version of Centering.

## 1 Background: Centering and Sloppy Identity

Consider the problem of strict and sloppy readings of pronouns, illustrated by (1):

(1)    $Ellen_i$ was talking to $Mary_j$ and $Susan_k$ about cats.

(2)    $Mary_j$ loves $her_j$ cat.

(3)    a. $Susan_k$ loves $her_j$ cat too. (*strict*)

     b. $Susan_k$ loves $her_k$ cat too. (*sloppy*)

     c. $Susan_k$ loves $her_i$ cat too. (*other*)

The terms *strict* and *sloppy* are originally due to (Ross, 1967), where they were applied to cases involving ellipsis. In the above example, the VP "loves her cat" can be elided. Whether "loves her cat" is overt or elided does not change the interpretive possibilities in this example. Although the analysis of the differences between elliptical sentences and their overt counterparts is an important area of research, I will ignore this issue in this paper, and assume that the ellipsis case is interpretively analogous to the above overt examples.

It is widely accepted that the strict and sloppy readings are equally acceptable, while the *other* reading is impossible. In a series of papers (Hardt, 1996; Hardt, 1999; Stone and Hardt, 1997; Hardt, 2003) I have previously suggested that Centering Theory might provide an account of this. These papers do not apply Centering in a systematic way. Rather, they rely on certain claims that are inspired by Centering. First, in sentences with a single pronoun, that pronoun must refer to the Center. Second, there is a preference that Center Shifts are associated with Subjects, or otherwise prominent NP's.

I employ the following notational conventions: a pronoun referring to the Center is notated with a * subscript, while an NP that shifts the Center is notated with a * superscript. This follows a well-established convention in dynamic semantics that superscripted indices indicate context change, while subscripts do not. The * is meant to indicate position 0 in the current state (or assignment function). All NP's also receive ordinary indices as well; this ensure that an individual remains accessible after it is no longer the Center.

The three readings are indexed as follows:

(4)    $Ellen^{*i}$ was talking to $Mary^j$ and $Susan^k$ about cats.

(5)    $Mary^*$ loves $her_*$ cat.

(6)    a. $Susan_k$ loves $her_*$ cat too. (*strict*)

     b. $Susan^*$ loves $her_*$ cat too. (*sloppy*)

     c. $Susan_k$ loves $her_i$ cat too. (*other*)

First, *Ellen* is established as the Center. Next, the Center shifts to *Mary*. Then for the strict reading, the Center remains Mary, while for the sloppy reading, it shifts to Susan. In both cases, the pronoun refers to the Center, as required since it is the only pronoun. For the *other*, the pronoun does not refer to the Center.

The Centering approach to strict/sloppy alternation is proposed as an alternative to semantic accounts (Sag, 1976) which rely on variable binding. I have argued that the variable binding account predicts that the antecedent for a sloppy pronoun ("Susan" in the above example) must be sister to a constituent containing the sloppy pronoun; the Centering account is somewhat more flexible; it involves a preference that the antecedent must be rather prominent, but does not impose a specific structural constraint. From this perspective, one would expect that sloppy identity is somewhat flexible concerning the structural position of the antecedent, as long as it is contextually prominent.

It has long been recognized that sloppy identity exhibits precisely this sort of flexibility. This poses a major problem for the variable binding account, and (Hardt, 2003) points out that a recent attempt (Tomioka, 1999) to solve this problem requires substantial complication of the syntax-semantics interface, and appears to encounter substantial empirical problems as well.

This proposal is attractive in that it imports independently required principles concerning the processing of pronouns. It arguably accounts for strict-sloppy alternation better than alternative accounts, and avoids any complications to the mechanisms of syntax and semantics.

## 2 The Problem

Unfortunately, there is a serious problem with this rosy scenario: Centering Theory as it is generally understood fails utterly to capture the facts in examples involving strict-sloppy alternation. While it is generally agreed that the strict and sloppy readings are both acceptable, and the "other" reading impossible, Centering only permits the strict reading, treating the sloppy reading on a par with the impossible "other" reading.

To show this, I will first give a brief presentation of Centering Theory.

- **Definitions:**
  - Cf(U): all entities realized in utterance U (the *forward-looking centers*)
  - Cp(U): the highest ranked element of Cf(U) (the *preferred center*)
  - Cb(U): highest ranked element of Cf(U-1) that is realized in U (the *backward-looking center*)

The ordering of the Cf list is an intensive area of research; here, I assume that ordering follows syntactic prominence, with the subject the most prominent.

- Constraint 1: All Utterances have exactly one Cb
- Rule 1: If anything is pronominalized, the Cb is
- Rule 2: Transition Preferences

|            | Cb(U) = Cb(U-1) | Cb(U) ≠ Cb(U-1) |
|------------|-----------------|-----------------|
| Cb(U) = Cp(U) | CONTINUE     | SHIFT           |
| Cb(U) ≠ Cp(U) | RETAIN       | ROUGH-SHIFT     |

CONTINUE is preferred over RETAIN, followed by SHIFT and ROUGH-SHIFT.

The above claims are instantiated in the BFP algorithm(Brennan et al., 1987). For purposes of comparison, it is convenient to use the formulation of (Beaver, 2002), COT. This is an OT (Optimality Theory) version of Centering, in terms of ordered constraints. Beaver shows that COT is equivalent to the BFP algorithm.

### 2.1 Beaver's COT

COT consists of the following ordered constraints:

- AGREE: Anaphoric expressions agree with their antecedents in terms of number and gender.
- DISJOINT: Co-arguments of a predicate are disjoint.
- PRO-TOP: The Cb is pronominalized.[1]
- FAM-DEF: Each definite NP is familiar.
- COHERE: The Cb of the current sentence is the Cb of the previous sentence.
- ALIGN: The Cb is in subject position.

The reader is referred to (Beaver, 2002) for details. The FAM-DEF constraint is not relevant to the issues discussed in this paper. Also, while ALIGN is described as a requirement that Cb be in subject position, it might better be expressed in somewhat more broad terms, for example, that the Cb is (syntactically) prominent. However, for simplicity I will leave ALIGN as defined by Beaver in this paper.

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[1] A note on terminology: Beaver uses the term "topic" instead of the standard term Cb, I often simply use the term Center.

To illustrate COT, I use the following example, taken from (Grosz et al., 1995)). After utterances (7) and (8), Grosz *et al.* consider four possible continuations ((9)a to (9)d below). They observe that there are preferences among these four continuations: (9)a is preferred to (9)b and (9)c is preferred to (9)d.

(7)  Susan$_i$ gave Betsy$_j$ a pet hamster.

(8)  She$_i$ reminded her$_j$ that such hamsters were quite shy.

(9)  a. She$_i$ asked Betsy$_j$ whether she liked the gift.

   b. Susan$_i$ asked her$_j$ whether she liked the gift.

   c. Betsy$_j$ told her$_i$ that she really liked the gift.

   d. She$_j$ told Susan$_i$ that she really liked the gift.

Let us see how these two preferences are captured by COT. We construct an OT tableau comparing readings (9)a and (9)b:

| | AGREE | DISJOINT | PRO-TOP | FAM-DEF | COHERE | ALIGN |
|---|---|---|---|---|---|---|
| ☞ (9)a | | | | | | |
| (9)b | | | * | | | |

Reading (9)a is preferred because it violates no constraints, while Reading (9)b violates PRO-TOP. This is because the Cb in (9)a and (9)b is Susan, and Susan is not pronominalized in (9)b. We now examine readings (9)c and (9)d:

| | AGREE | DISJOINT | PRO-TOP | FAM-DEF | COHERE | ALIGN |
|---|---|---|---|---|---|---|
| ☞ (9)c | | | | | | * |
| (9)d | | | * | | | * |

Here, both (9)c and (9)d violate ALIGN, since the Cb Susan is not subject. Reading (9)d violates PRO-TOP, since the Cb Susan is not pronominalized, while (9)c does not violate PRO-TOP. Thus reading (9)c is correctly preferred.

We return now to example (1), repeated here.

(10)  Ellen$_i$ was talking to Mary$_j$ and Susan$_k$ about cats.

(11)  Mary$_j$ loves her$_j$ cat.

(12)  a. Susan$_k$ loves her$_j$ cat too. (*strict*)

   b. Susan$_k$ loves her$_k$ cat too. (*sloppy*)

   c. Susan$_k$ loves her$_i$ cat too. (*other*)

We construct the following tableau:

| | AGREE | DISJOINT | PRO-TOP | FAM-DEF | COHERE | ALIGN |
|---|---|---|---|---|---|---|
| ☞ (a) - strict | | | | | | * |
| (b) - sloppy | | | * | | * | * |
| (c) - other | | | * | | * | * |

Reading (a), the sloppy reading, violates only ALIGN, since the Cb is not subject. The sloppy reading (b) and the *other* reading (c) have no Cb, since they do not refer to any entity from the preceding sentence. An utterance without a Cb necessarily violates PRO-TOP, COHERE and ALIGN, since all three of these constraints impose conditions on the Cb.

As noted above, it is widely agreed that the strict and sloppy readings should be grouped together as both completely acceptable, while the other reading is impossible.[2] Centering incorrectly predicts that the sloppy reading is impossible.

## 3  The Solution: Dynamic Centering

The characterization of discourse coherence is a primary element of Centering theory. The preferences defined on transition types can be viewed as a claim about relative coherence of utterance sequences: a sequence in which the Cb remains the same is more coherent than when it changes.

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[2]This basic observation can be found in many different works: some prominent examples are (Sag, 1976; Rooth, 1992; Tancredi, 1992; Fox, 2000).

Of course, there are many ways in which utterances can exhibit coherence, not all of which involve topic continuity. For example, Parallelism can obtain between utterances with or without topic continuity.[3] (Poesio et al., 2001) note that there is an implicit claim in Centering Theory that entity-based coherence is most important. To my knowledge, no evidence has been given for this claim, and I propose to remove it from Centering Theory. In COT, this is naturally accomplished by removing the COHERE constraint.

In addition I propose that Center shifting is processed incrementally, rather than across utterances. More specifically, I propose the following modified approach to Centering, which I call Dynamic Centering:

**Dynamic Centering**

- **Definitions:**

    - CENTER ESTABLISHER: an NP of the form NP* becomes the new CENTER.

    - CENTER: at any point in the discourse, CENTER is the most recently occurring CENTER ESTABLISHER

- **Constraints:**

    - PRO-TOP-INC: An utterance must contain a pronoun referring to the center.

    - ALIGN: Center establisher appears in Subject position

    - COHERE: eliminated

We return now to the problematic example, repeated below with indexing :

(13)     Ellen$^{i*}$ was talking to Mary$^{j}$ and Susan$^{k}$ about cats.

(14)     Mary* loves her$_*$ cat.

(15) a. Susan$_k$ loves her$_*$ cat too. (*strict*)

   b. Susan* loves her$_*$ cat too. (*sloppy*)

   c. Susan* loves her$_i$ cat too. (*other*)

We construct the following tableau:

[3]There is an extensive literature on Parallel and other coherence relations; cf. (Kehler, 2000; Asher, 1993).

| | AGREE | DISJOINT | PRO-TOP-INC | FAM-DEF | ALIGN |
|---|---|---|---|---|---|
| ☞ strict | | | | | |
| sloppy | | | | | |
| other | | | * | | |

Now the strict and sloppy readings violate no constraints. On the strict reading, the center remains Mary, while on the sloppy reading the center shifts to Susan (which is consistent with ALIGN). However, the "other" reading remains ruled out, since it violates PRO-TOP-INC.

The simplified version of Centering solves the above problem. Now I will show that it still makes the same correct predictions on several standard examples from the Centering literature.

Consider the following example (Poesio et al., 2001)[p 4]:

(16) a. Something must be wrong with John$^{i*}$.

   b. He$_*$ has been acting quite odd.

   c. He$_*$ called up Mike$^{j}$ yesterday.

   d. John$_i$ wanted to meet him$_j$ quite urgently.

   e. He$_*$ wanted to meet him$_j$ quite urgently.

| | AGREE | DISJOINT | PRO-TOP-INC | FAM-DEF | ALIGN |
|---|---|---|---|---|---|
| (d) | | | * | | |
| ☞ (e) | | | | | |

The (e) continuation is correctly preferred to (d). This is because (d) violates the constraint PRO-TOP-INC. In (e), the Center ($John_i$) is pronominalized, while it is not pronominalized in (d).

We also get the right results in the following widely discussed example (Grosz et al., 1995):

**Version 1**

(17)    John$^{i*}$ went to his$_*$ favorite music store$^j$ to buy a piano.

(18)    He$_*$ had frequented the store$_j$ for many years.

(19)    He$_*$ was excited that he$_*$ could finally buy a piano.

(20)    He$_*$ arrived just as the store$_j$ was closing for the day.

**Version 2**

(21)    John$^{i*}$ went to his$_*$ favorite music store$^j$ to buy a piano.

(22)    It$_j$ was a store John$_i$ had frequented for many years.

(23)    He$_*$ was excited that he$_*$ could finally buy a piano.

(24)    It$_j$ was closing just as John$_i$ arrived.

As (Grosz et al., 1995) point out, the first version is preferred to the second. We first show that (18) is preferred to (22).

| | AGREE | DISJOINT | PRO-TOP-INC | FAM-DEF | ALIGN |
|---|---|---|---|---|---|
| ☞ (18) | | | | | |
| (22) | | | * | | |

Version (22) violates PRO-TOP-INC, since the Center John$_i$ is not pronominalized. Since (18) violates no constraints, it is correctly preferred. We now compare (20) and (24):

| | AGREE | DISJOINT | PRO-TOP-INC | FAM-DEF | ALIGN |
|---|---|---|---|---|---|
| ☞ (20) | | | | | |
| (24) | | | * | | |

Again, the crucial factor is PRO-TOP-INC, which is violated by (24), while (20) violates no constraints.

## 4 Accessibility: a Semantic Constraint

There is an additional benefit to Dynamic Centering: by integrating Centering with a semantic framework, the system can take advantage of semantic constraints on pronoun reference; constraints that are not enforced in standard Centering. Consider the following:

(25)    Mary has had some unpleasant conversations with her aging husband.

(26)    She said that if she won the lottery, she'd get a new young husband.

(27)    He replied that the lottery is a waste of time.

In standard Centering, there is a strong preference for "he" in (27) to have the antecedent "a new young husband". In Dynamic Centering, this reading is ruled out, because "a new young husband" is embedded in a conditional, and is therefore not accessible. The Accessibility constraint is built into all versions of Dynamic Semantics, and thus is naturally inherited by Dynamic Centering. [4] It is therefore natural to add ACCESSIBLE as a highly ranked constraint in Dynamic Centering, since it plays a role analogous to the Binding Theory constraints of DISJOINT.

Consider now the two possible readings for (27), in standard Centering and in Dynamic Centering:

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[4]Indeed, it is not necessary to state it as a constraint, since even if "he" received the same index as "a new young husband", Dynamic Semantics would not permit a link to be established between them. The reader is referred to (Kamp and Reyle, 1993) for details of Accessibility: simply put, an antecedent embedded within a conditional, negation, or modal is not accessible to a pronoun which is not embedded.

| | AGREE | DISJOINT | PRO-TOP | FAM-DEF | COHERE | ALIGN |
|---|---|---|---|---|---|---|
| he=her aging husband | | | * | | * | |
| ☞ he=a new young husband | | | | | * | |

Standard Centering strongly prefers the impossible (b) reading "a new young husband". This is because the (a) reading violates PRO-TOP, since, for reading (a) there is no Cb, since no entity in the Cf list of (26) is mentioned in (27). Reading (b) only violates the lower ranked COHERE, since the Cb changes from Mary to "a new young husband".

Dynamic Centering solves the problem:

| | AGREE | DISJOINT | ACCESSIBLE | PRO-TOP-INC | FAM-DEF | ALIGN |
|---|---|---|---|---|---|---|
| ☞ he=her aging husband | | | * | | | |
| he=a new young husband | | | | * | | * |

Here, the (b) reading violates ACCESSIBLE, and thus the (a) reading is correctly preferred.

It has been proposed that discourse effects be integrated into Centering, for example using Discourse New as a preference factor in selecting pronoun antecedents. Consider for example the account of ((Strube, 1998)). Here, as in the proposed account, potential antecedents are processed incrementally, rather than sentence-by-sentence. For Strube, there is a single S-list of potential antecedents, ordered in terms of Informational Status, with discourse-new entities coming before discourse-old entities. Each pronoun simply searches the S-list in order, selecting the highest ranked element for which agreement and binding constraints hold. Thus, although Strube's account shares two key features with Dynamic Centering: an account of discourse (informational) status, and incrementality, it still fails to capture examples like (25).

## 5    Parallelism Theories and Centering

In this section, I make some remarks on the relation of Centering theory to other theories that deal with parallelism.

In Dynamic Centering, the COHERE constraint has been eliminated. This is not meant to deny that coherence plays an important role in pronoun resolution and other aspects of discourse interpretation: what I take issue with is the way that entity-based coherence is given special prominence in centering theory. In my view, Centering Theory must coexist with some general theories about parallelism and other coherence relations, as explored in works such as (Hobbs, 1979; Rooth, 1985; Asher, 1993; Prust et al., 1994; Asher et al., 2001). Indeed I am not aware of any proposal to eliminate general coherence or parallelism in favor of centering theory. Even if one takes the view that entity-based coherence is properly captured in Centering theory, there are surely forms of parallelism that are not entity-based, as illustrated by the following examples:

(28)    John said he was looking for a cat, and Bill also said he was looking for a cat.(adapted from (Chomsky, 1995)[p 203])

(29)    John told Mary to speak in the conference room, and Harry told her to speak in the office.

(Chomsky, 1995)[p 203] notes that the ambiguities in (28) must be resolved in parallel in the two conjuncts. In particular, if "a cat" receives a specific reading in the first conjunct, it receives a specific reading in the second as well. There is a similar parallelism effect in (29); in the first conjunct, "in the conference room" can modify either the telling or speaking event. This ambiguity must be resolved in parallel in both conjuncts. As far as I know, there is no known version of Centering that seeks to capture such parallelism effects.

On the other hand, the general theories of parallelism mentioned above can account for such effects. For example, Rooth's theory essentially requires semantic identity of non-focused elements in such structures. This provides a basis for accounting for non-entity parallelism effects.

A general parallelism theory combines with Dynamic Centering to impose important constraints on sloppy identity, as illustrated by the following example:

(30)    John talked to Fred about his problems, and Bill did too. [talk to Fred about his problems]

Dynamic centering by itself is insufficiently constrained with respect to such examples, since

it would incorrectly permit the following non-parallel reading:

(31)    John talked to Fred about Fred's problems, and Bill did too. [talk to Fred about Bill's problems]

A center shift from *Fred* in the first sentence to *Bill* in the second would give rise to the above, incorrect reading. However, it should be clear from the preceding discussion that such readings are to be ruled out by the general parallelism theory, which as I have argued, is independently needed. While space doesn't permit a detailed study of the integration of Dynamic Centering with a general parallelism theory, it seems clear that a theory such as Rooth's would naturally rule out the above reading: Rooth's theory requires non-accented material in the second sentence to semantically match corresponding material in the first sentence. It is clear that the above reading violates this requirement.

## 6   Conclusions

It has previously been proposed that Centering be integrated with Dynamic Semantics, to address the problem of strict-sloppy alternations in pronoun interpretation. However, Centering as currently formulated fails when applied to such examples. I have argued that this results from an assumption in Centering that entity-based coherence is more important than other aspects of coherence. I argue that this assumption is false, and I propose a version of Centering, Dynamic Centering, in which the CO-HERE constraint is removed from Centering. This makes it possible to integrate Centering with Dynamic Semantics. I show that this has several important empirical benefits over standard Centering.

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