Intrasentential Centering: A Case Study

Megumi Kameyama
Artificial Intelligence Center and
The Center for the Study of Language and Information,
SRI International
333 Ravenswood Ave., Menlo Park, CA 94025, U.S.A.
megumi@ai.sri.com

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1 Introduction

One of the necessary extensions to the centering model is a mechanism to handle pronouns with intrasentential antecedents. Existing centering models deal only with discourses consisting of simple sentences. It leaves unclear how to delimit center-updating utterance units and how to process complex utterances consisting of multiple clauses. In this paper, I will explore the extent to which a straightforward extension of an existing intersentential centering model contributes to this effect. I will motivate an approach that breaks a complex sentence into a hierarchy of center-updating units and proposes the preferred interpretation of a pronoun in its local context arbitrarily deep in the given sentence structure. This approach will be substantiated with examples from naturally occurring written discourses.

2 Centering Model

Centering (Grosz, Joshi, and Weinstein, 1983, 1986, 1995) synthesizes two lines of research. One is the *discourse centering model* (Joshi and Kuhn, 1979; Joshi and Weinstein, 1981) concerned with the issue of grammar-based control of discourse inference. The basic claim is that discourse has a *monadic tendency* — the tendency to be ‘about’ one thing at a time, which is indicated in utterance structures. The other is the *discourse focusing model* (Grosz, 1977; Sidner, 1979; 1983; Grosz and Sidner, 1986) concerned with the discourse structure and meaning associated with the discourse participants’ intentions, attentions, and linguistic choices.

Centering is part of an overall theory of discourse structure and meaning (Grosz and Sidner, 1986) that distinguishes among three components of discourse structure — a linguistic structure, an intentional structure, and an attentional state — and two levels of discourse coherence — global and local. *Attentional state* models the discourse participants’ focus of attention determined by
the intentional and linguistic structures at any given point in the discourse. It has global and local components corresponding to the two levels of discourse coherence. Centering models the local-level component of attentional state — how the speaker’s linguistic choices for representing propositional contents affect the *inference load placed upon the hearer* in discourse processing.

In centering, an utterance in discourse (not a sentence in isolation) has entities called *centers* that link the utterance with other utterances in the discourse segment. They are a set of *forward-looking centers* (Cf) partially ordered by relative prominence. One member of the Cf may be the *backward-looking center* (Cb) that connects with a member of the Cf of the previous utterance. The speaker’s linguistic choices define centering transitions that affect the local coherence of the discourse. In English discourse, pronouns and grammatical subjects are the main indicators of centering transitions (Grosz et al., 1983, 1986; Kameyama, 1985, 1986; Brennan, Friedman, and Pollard, 1987). *Unstressed* pronouns are primarily used to indicate the Cb in English-type languages, whereas it is the zero pronominals in Japanese-type languages according to the syntactic typology of pronominal forms (Kameyama, 1985: Ch.1).

### 2.1 The Basic Centering Model

The core insight of the centering model fits well into a general dynamic discourse processing architecture (Kameyama, 1992a, 1992b, 1996). In the following reformulation of centering within this architecture, I will make a crucial use of salience as a primitive notion underlying centering dynamics:

- **Discourse** is a sequence of utterances $U_1, \ldots, U_n$ produced by one or more discourse participants.

- Each utterance $U_i$ defines a transition between an *input context* $C_{i-1}$ and an *output context* $C_i$, where a context $C_k$ is a dynamically evolving cognitive information state (more or less) shared by the discourse participants.

- A component in context $C_k$ is the *attentional state* $A_k$ consisting of a set of currently “open” propositions with the associated entities. The entities in $A$ are partially ordered by salience (see below).

- The most salient subpart of $A_k$ is the centering state $CEN_k$ consisting of a set of propositions with associated entities called the *forward-looking centers* $Cf_k$.

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1. The dynamic discourse processing architecture here is in line with dynamic semantic theories such as by Kamp (1981), Heim (1982), and Groenendijk and Stokhof (1991).
2. Note that Constraint-3 and Rule-2 of the centering theory in the introduction of this volume are not assumed in this reformulation. These specifics are discussed in the next subsection.
3. The “open” propositions and entities in $A_k$ are those into which a new utterance content can potentially be integrated. $A_k$ corresponds to the *focus space stack* (Grosz and Sidner, 1986) whose internal structure is determined by the current position in the overall discourse structure.
• One of the entities in $C_{f_k}$ may be the backward-looking center $C_{b_k}$, or the Center, the central entity that the discourse is currently about. $C_{b_k}$ is also a member of $C_{f_{k-1}}$, but is not necessarily the same as $C_{b_{k-1}}$.

• With centering rules and constraints, each utterance $U_i$ defines a transition between an input centering state $CEN_{i-1}$ and an output centering state $CEN_i$ controlling the inferences involved in updating the context with each new utterance.

I will henceforth distinguish two kinds of input context $C_{i-1}$ for an arbitrary utterance $U_i$. It is an intersentential context when $U_{i-1}$ and $U_i$ belong to different “sentences” in the standard syntactic sense. It is an intrasentential context when $U_{i-1}$ and $U_i$ belong to the same sentence.

A discourse describes situations, eventualities, and entities, together with the relations among them. The attentional state $A$ represents a dynamically updated snapshot of their salience. I assume the property salient to be a primitive representing the partial order among a set of entities in $A$. Salience is gradient and relative. A certain absolute degree of salience may not be achieved by any entities in a given $A$, but there is always a set of maximally salient entities, which we can call the “Cm” for convenience. The Cm is often, but not necessarily, a singleton set. Note that the Cm differs from the existing centering notion of the Cb (or Cp), although they are related to one another. I argue that the property of the Cm, over and above that of the Cb (and Cp), elucidates the centering dynamics, as discussed in the remainder of this section.

Various factors affect salience dynamics — including utterance forms, discourse participants’ purposes and perspectives, and the perceptually salient objects in the utterance situation. The specification of salience dynamics is a crucial step toward a formal theory of discourse pragmatics, and centering focuses on the interrelations between the center dynamics and utterance forms.

Centering stipulates that the entities in the Cf are generally more salient than other entities in $A$, and if one of these entities is the Center (Cb), it is the most salient entity. We state this stipulation as a defeasible preference:

**CENTER** The Center is normally more salient than other entities in the same attentional state.

### 2.2 Linguistic Correlates of Salience

We can now state a set of linguistic correlates to salience dynamics in terms of additional defeasible preferences (Kameyama, 1996).

Two default linguistic hierarchies are crucial in centering dynamics — the grammatical function hierarchy (GF ORDER) and the nominal expression type hierarchy (EXP ORDER).

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4 Defeasibility is indicated by “normally”.

5 Both linguistic hierarchies are in fact recurrent in functional and typological studies of language. The GF ORDER closely resembles Keenan and Comrie’s (1977) Accessibility Hierarchy, Givon’s (1979) Topicality Hierarchy, and Kuno’s (1987) Thematic Hierarchy, all of which predict the preferred syntactic structure for describing the things that a sentence is “mainly about” within and across languages. The EXP ORDER resembles the linguistic correlates of Gundel, Hedberg, and Zacharski’s (1993) Givenness Hierarchy, which is closely related to Prince’s (1981) Familiarity Scale, which predicts the relative degrees of accessibility of referents. It is of interest that virtually the same hierarchies are relevant to the computational interest in how grammar controls inferences in language use.
**GF ORDER:** Given a hierarchy [SUBJECT > OBJECT > OBJECT2 > OTHERS], an entity realized by a higher-ranked phrase is normally more salient in the *output* attentional state.

**EXP ORDER:** Given a hierarchy [ZERO PRONOMINAL > PRONOUN > DEFINITE NP > INDEFINITE NP], an entity realized by a higher-ranked expression type is normally more salient in the *input* attentional state.

For each utterance $U_i$, EXP ORDER and GF ORDER predict the relative salience of entities in the *input* and *output* attentional states $A_{i-1}$ and $A_i$, respectively. GF ORDER in $U_i$ directly affects the *output* attentional state $A_i$. It corresponds to the major determinant of the Cf ordering in centering. EXP ORDER in $U_i$ is an assumption or presupposition about the *input* attentional state $A_{i-1}$. It generalizes the centering Rule-1. EXP ORDER also predicts the relative salience of entities in the *output* attentional state $A_i$ since these assumed salience levels are also often accommodated into the context (see Lewis, 1979).

Another centering stipulation is that at most one entity is given the Center status at any one attentional state. I propose the following defeasible preference as a specialization of EXP ORDER:

**EXP CENTER:** An expression of the highest-ranked type in EXP ORDER normally realizes the Center in the *output* attentional state.

EXP CENTER departs from Constraint-3 in defining what makes an entity a Cb. Constraint-3 relies on the Cf ordering, whereas EXP CENTER relies on EXP ORDER. The following example illustrates the difference:

(1) 1. John went to Jim’s party.
   2. *he* was very pleased to see John again.
   3. *he* had just recovered from a stressful week at work.

After (1)-2, EXP CENTER makes Jim the Cb, whereas Constraint-3 makes John the Cb. The preferred referent of *he* in (1)-3 is then Jim under the present approach due to GF ORDER and EXP CENTER whereas it is John under the centering algorithm due to the preference for CONTINUE over SMOOTH-SHIFT.

EXP CENTER also enables two choices in what expression types are associated with the Center status. The “highest-ranked type” in EXP CENTER can be interpreted as either relative to each utterance or absolute in all utterances. Under the relative interpretation, a nonpronominal expression type can also output the Center as long as there are no pronouns in the same utterance. Under the absolute interpretation, only the pronominals (either zero or overt, depending on the

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6There is a pragmatic difference between stressed and unstressed pronouns, which should be accounted for by an independent treatment of stress — for example, in terms of a preference reversal function (Kameyama, 1994). This paper concerns only unstressed pronouns.

7When an utterance contains more than one highest-ranked expression types, the Center is realized by either (1) the Cb-chaining one or (2) the one with the higher-ranked GF, in this preference order.
syntactic type of the language) can output the Center. I will take the absolute interpretation in this paper following Kameyama (1985, 1986), based on the rationale that the choice of the highest-ranked pronominal forms in a language should reflect a certain absolute sense of salience threshold.

This paper will focus on English centering. Since matrix subjects and objects cannot be omitted in the English-type language, the highest-ranked expression type that outputs the Center is the (unstressed) pronoun. From EXP ORDER, it follows that a pronoun normally realizes a *maximally salient entity* in the input attentional state. Since it is a defeasible preference, a pronoun may also realize a submaximally salient entity under certain conditions. Known such conditions fall under three classes:

1. Another overriding preference gives a different interpretation of the pronoun. Kameyama (1996), in motivating general preference classes with overriding relationships, points out that specific commonsense causal knowledge can generally override salience-based local coherence preferences. Garden-path effects of centering studied by Hudson D’Zmura (1988) show that this overriding can require a considerable effort when the salience-based preference is particularly “strong”.

2. The denotational range imposed by the pronoun’s grammatical features rule out the maximally salient entity. For instance, *he* would not resolve to a maximally salient female person entity.

3. Sortal constraints on the pronoun’s argument position coming from the verb rule out the maximally salient entity. For instance, in “I learned *it*”, the referent of *it* is sortally inconsistent with, say, a salient dog entity.

### 2.3 Centering Preference Interactions

One of the notable features of the present reformulation of centering is that the transition types per se play no role in determining the preferred interpretation of utterances. They are mere “labels” on centering transitions that result from the interactions of the centering preferences stated in CENTER, GF ORDER, EXP ORDER, and EXP CENTER. For instance, we can classify transitions into “establishing” and “chaining” (Kameyama, 1985,1986) as follows. The Center is “established” when a pronoun picks a salient non-Center in the input context and makes it the Center in the output context. It corresponds to both types of SHIFT in centering. It is “chained” when a pronoun picks the Center in the input context and makes it the Center in the output context. It corresponds to both CONTINUE and RETAIN in centering. The preference for CONTINUE over RETAIN is a consequence of the general preference for *determinate* maximal preference as discussed below.

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8 Except in a telegraphic register.
9 What I have previously called *retain* (Kameyama, 1985, 1986, 1988) is now called *chain*. 
(In)Determinate Maximal Salience

The interaction of CENTER, GF ORDER, EXP ORDER, and EXP CENTER accounts for canonical intersentential centering examples. A novel aspect of the present setup is that each centering state contains the set of maximally salient entities (Cm), and the Cm’s (in)determinacy predicts the corresponding (in)determinacy of the preferred interpretation of a pronoun. The Cm is determinate when it is a singleton set, and indeterminate when it is a set of two or more entities. The interpretation preference of a pronoun is determinate when it converges on a single maximal preference, and indeterminate when its maximal preference is a set of equally preferred entities. EXP ORDER states that a pronoun’s preferred interpretation is the Cm, so the (in)determinacy in the Cm predicts the (in)determinacy in a pronoun’s preferred interpretation (unless other overriding factors remove the indeterminacy).

This is how it works. There are two independent sources for the Cm, the highest-ranked GF defined in GF ORDER and the Cb. When they converge on the same entity, it is the single member of the Cm, but when they diverge on two different entities, both are in the Cm. In English centering, for instance, a subject Center achieves a convergence, and a nonsubject Center leads to a divergence in most cases. This is illustrated below.

1. Babar went to a bakery.
   \( A_1: [[\text{Babar} > \text{Bakery}]_{\text{CF}} \ldots] \)

2. *he* greeted the baker. \( he := \text{Babar} \)
   \( A_2: [[[\text{Babar}_{\text{Subj}} > \text{Baker}]_{\text{CF}} > \text{Bakery}] \ldots] \)

3. *he* pointed at a blueberry pie. \( he := \text{Babar} \triangleleft \text{Baker} \)

Example (2) shows the effects of determinate salience ranking (>) in terms of a chain of subject Centers. The preferred value of the pronoun *he* in (3)-3 is also determinate (indicated by determinate preference ordering <>) with a strong preference (\( \chi^2_{df=1} = 13, p < .001 \)) for 13 native English speakers. The next example shows the effects of indeterminate salience ranking:

1. Babar went to a bakery.
   \( A_1: [[\text{Babar} > \text{Bakery}]_{\text{CF}} \ldots] \)

2. The baker greeted *him*. \( \text{him} := \text{Babar} \)
   \( A_2: [[[\text{Baker} \triangleleft [\text{Babar}_{\text{Center}}]_{\text{CF}} > \text{Bakery}] \ldots] \)

3. *he* pointed at a blueberry pie. \( he := \text{Baker} \triangleleft \text{Babar} \)

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10 Discussions with Becky Passonneau helped clarify this perspective.
11 Hoffman (this volume) discusses the indeterminacy of RETAIN transitions.
12 Nonsubjects can be made more salient than subjects in special syntactic constructions such as clefting and topicalization.
In (3), the salience ranking in $A_2$ is indeterminate (<>), and the preferred value of he shifts to the baker, although this preference is weak ($\chi^2_{df=1} = 3.77, .05 < p < .10$) for 13 nonoverlapping speakers.

The notion of (in)determinate attentional preference is not entirely new to centering, but it has not been given appropriate recognition. If we call the highest-ranked GF in the GF ORDER the “preferred Center” ($C_p$) as in Brennan et al. (1987), we are talking about the convergence ($C_b=C_p$) and divergence ($C_b\neq C_p$) of the $C_b$ and $C_p$ in the input attentional state here. In the centering algorithm (Brennan et al., 1987; Walker, Iida, and Cote, 1994), the same convergence-divergence distinction takes on quite a different role. First of all, the distinction is in the output state of utterance interpretation, separating out CONTINUE and RETAIN on one hand, and SMOOTH-SHIFT and ROUGH-SHIFT on the other, and a fixed preference ordering among these transition states predicts the preferred interpretation of a pronoun. Second of all, the preferred pronoun interpretation is always determinate. The algorithm is defined so that no indeterminacy arises.

Parallelism Preference

The weak preference in (3)-3 comes from the interaction of centering preference and the separate preference for structural parallelism. In Kameyama (1996), it was hypothesized that when a determinate attentional preference and structural parallelism preference conflict, the former overrides the latter, but when the attentional preference is indeterminate, the parallelism preference kicks in to give rise to a weak parallelism preference. This parallelism preference is loosely stated in the following defeasible preference:

**PARA:** Two adjacent utterances in discourse seek maximal parallelism.

Integrating both monadic and parallelism effects is crucial for making accurate predictions about local coherence preferences based on utterance structures. The property-sharing constraint on centering (Kameyama, 1985, 1986) was a proposal for this integration. Here, the integration is achieved at a higher level of preference interactions.

Parallelism effects on local discourse coherence have been neglected in centering because centering focuses on orthogonal “monadic” effects. For example, the centering algorithm incorrectly predicts a definite preference for he := Babar in (3)-3 because CONTINUE ($C_b=C_p=Babar$) is preferred over SMOOTH-SHIFT ($C_b=C_p=Baker$) after (3)-2 ($C_b=Babar$, $C_p=Baker$). This example contradicts the claim made in support of the centering algorithm that “structural parallelism is a consequence of our ordering the CF list by grammatical functions and the preference for continuing over retaining” (Brennan et al., 1987, p.157).

The remainder of the paper addresses the issue of how to extend the existing intersentential centering model to discourses consisting of arbitrarily complex sentences.

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13 The only indeterminacy in their centering algorithm comes from “optional” rules such as the Zero Topic Assignment rule in Walker et al. (1994). It is unclear what the logical/cognitive status of these optional rules are. The best characterization is that their application is random.

14 For a specific definition of parallelism, see, e.g., Pruest (1992), Kameyama (1986).

15 See Passonneau (1993) for empirical supports for the property-sharing constraint.

16 See Suri and McCoy (1994) for a similar criticism.
3 Issues of Intrasentential Centering

The existing centering models say nothing explicit about how to analyze complex sentences. What are relative preferences for a pronoun to realize entities in the intersentential or intrasentential context? What counts as evidence? Does a centering model contribute to elucidating an aspect of intrasentential binding phenomena overlooked in purely syntactic approaches? In the rest of the paper, I will propose a centering model that makes an explicit claim about complex sentences, motivating it from theoretical and empirical grounds. All the example discourses in the remainder of the paper come from the Brown corpus (Francis and Kucera, 1982).

To substantiate the importance of intrasentential (pronominal) anaphora, I have compared the counts of intrasentential and intersentential anaphora with 3rd person pronouns in nineteen randomly selected seventeen-sentence discourses in the Brown corpus that contain numerous *he*-type pronouns. Among 255 3rd person pronouns in total, of which 184 (65.8%) are *he*-type pronouns, 149 (58.4%) have their antecedents in the same sentence, 100 (39.2%) have their antecedents in the immediately preceding sentence, and 6 (2.4%) have their antecedents in the second most recent sentence. All the antecedents precede the pronouns. There are thus more intrasentential than intersentential anaphoric dependencies in these naturally occurring written texts. I will now motivate a set of extensions to centering to handle complex sentences, and discuss a number of theoretical and computational issues.

3.1 Sentence-based Centering?

There is an approach to intrasentential centering that I am rejecting. It is to process a whole sentence at once, deciding for each pronoun whether it realizes an entity in the intersentential discourse context or something evoked within that sentence. I will henceforth call this approach the sentence-based centering. This approach first appears attractive because it would imply that a single input centering state functions as a control factor for a whole complex sentence. If this is indeed the case, it would not only give a further motivation to centering but also support the special status of a sentence as an atomic and autonomous unit that organizes a discourse. The following example, in fact, appears to support this sentence-based centering analysis:

(4) Example: Sutherland

1. CHAIN(Cb=Sutherland): Her entrance in Scene 2 Act 1 brought some disconcerting applause even before she had sung a note.

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17 Walker (1989) discusses the need for this extension to centering, and suggests several constraints.
18 So-called pleonastic *it* was excluded.
19 When a sentence has a set of coreferring pronouns, I have counted at most one of them to be intersentential anaphora. For instance, in “He said he was lucky,” there are one intersentential and one intrasentential anaphoric dependencies.
20 In subsequent examples, third person nonpleonastic pronouns appear in boldface, and each utterance ($U_k$) is labeled with a centering transition type discussed above — CHAIN ($Cb_{k-1}=Cb_k \neq NULL$), ESTABLISH ($Cb_{k-1} \neq Cb_k \neq NULL$), and NULL ($Cb_k=\text{NULL}$).
2. \text{CHAIN}(Cb=Sutherland): \text{Thereafter the audience waxed applause happy but discriminating operagoers reserved judgment as her singing showed signs of strain, her musicianship some questionable procedure, and her acting uncomfortable stylization.}

3. \text{CHAIN}(Cb=Sutherland): \text{As she gained composure during the second act her technical resourcefulness emerged stronger though she had already revealed a trill almost unprecedented in years of performances of Lucia.}

Discourse example (4) above consists of three complex sentences, each of which contains multiple she-type pronouns all referring to the same person, Sutherland. We can see these sentences to be all ‘centrally about’ Sutherland, and this “Cb” in the input \text{CEN} determines the uniform referent for all the pronouns in each sentence.

A sentence can contain multiple pronouns with different referents, however, and when these pronouns are all in the same type, their disambiguation is a nightmare. An example follows.

(5) \textbf{Example: Sarah}

1. \text{ESTABLISH}(Cb=Sarah): \text{And in all likelihood by now there was more than one person in the house who knew the terms of her marriage contract.}

2. \text{CHAIN}(Cb=Sarah): \text{There was no point either in telling herself again what a fool she had been.}

3. \text{CHAIN}(Cb=Sarah): \text{She went downstairs and received another curious shock, for when Glendora flapped into the dining room in her homemade moccasins, Sarah asked her when she had brought coffee to her room, and Glendora said she hadn’t.}

The sentence of interest is (3)-3 repeated below.

(6) input: \([Cb = \text{Sarah}_1] \]
\text{She}_1 went downstairs and received another curious shock, for when \text{Glendora}_2 flapped into the dining room in \text{her}_2 homemade moccasins, \text{Sarah}_1 asked \text{her}_2 when \text{she}_2 had brought coffee to \text{her}_2 room, and \text{Glendora}_2 said \text{she}_2 hadn’t.

Here, assuming that only the two most salient female entities, Sarah and Glendora, are involved, syntactic constraints on pronominal coreference and the explicit names in the sentence can help determine only 2 out of 6 pronoun references. Remaining ambiguities make \(2^4 = 16\) possible combinations for the sentence as a whole. Even if ellipsis resolution forces the two \text{she}_2 subjects to corefer, there are \(2^3 = 8\) possible combinations. It would be desirable if the complex sentence can be processed piece by piece, treating one or two pronouns at a time, reducing inferential spaces and combinatorics.
3.2 Computational Motivation

One might argue that sentence-based centering is not very complex because sentence grammar problems are more manageable than discourse grammar problems. However, attachment ambiguities in sentence grammar lead to exponential combinatorics, and processing long and complex sentences is computationally intensive. Moreover, discourse structure analyses (e.g., Polanyi, 1988; Hobbs, 1990) have shown that sentences in discourse do not form a flat structure but rather a tree-like structure, where sentences start at widely different depths. In short, we know a priori that sentence grammars are no better at handling intrasentential anaphora.

The approach to intrasentential centering that I will advocate here is to break a complex sentence into a structured sequence of subsentential units each of which is the “utterance” in intersentential centering. This approach is desirable from a computational ground. If a complex sentence can be processed piece by piece, then the computational load involved in utterance processing becomes more manageable. This occurs because the utterance processing complexity is predicted to increase exponentially with the number of references in the utterance that must be resolved with respect to the discourse context. This desire for resource boundedness to curtail the computational load is the original motivation of the centering model (Joshi and Weinstein, 1981).

3.3 Linguistic Motivation

As discussed in Section 2, there are parallel and monadic tendencies that govern intersentential local discourse coherence. Grammaticization of these tendencies in connecting clauses within a sentence would be the prime linguistic motivation for clause-based centering. Structural parallelism is known to govern the wellformedness of a number of ellipsis phenomena such as gapping and verb phrase ellipsis. Control phenomena involving unexpressed subjects in nonfinite (i.e., tenseless) clauses can be seen as an example of grammaticized monadicity. Syntactic “movements” observed in topicalization, left- and right-dislocation, and clefting also give prominence to a single entity, thus illustrating the monadic tendency. These tendencies should then also affect the preferential aspects of clause-to-clause transitions. We expect, however, stronger semantic, rhetorical, or causal constraints coming from explicit clausal connectives for conjunctions and subordinations in intrasentential processing because explicit event relations and rhetorical relations between clauses constrain inferences more strongly than implicit relations “between lines” in sentence-to-sentence discourse processing.

There is evidence that intrasentential anaphoric dependencies of pronominals in complement clauses are also controlled by an analogical interpretation of intersentential centering. The analogy here is between a linear sequence of utterances $U_1, \ldots, U_n$ and recursive embeddings of clauses (Kameyama, 1988). The preferred antecedent-pronoun pair shares a certain grammatical property such as SUBJECT and IDENT (grammaticized speaker’s point of view in Japanese, commonly called “Empathy”). From this perspective, given GF ORDER and PARA, in John told Bill that he ..., the preferred antecedent of he is John. These general preferences, however, can be overridden by commonsense inferences. For example, in John asked Bill when he ..., the commonsense preference leads to Bill as the preferred antecedent of he.
3.4 Intrasentential Centering Hypothesis

I will motivate the following top-level hypothesis:

(7) **Intrasentential Centering Hypothesis (ICH):** A complex sentence is broken up into a set of center-updating units corresponding to the “utterances” in intersentential centering.

This hypothesis still leaves open what structure the subsentential utterances form. It could be a flat sequence, a tree, or something more complex. If it is a flat sequence, there is always a single centering state, and the output center of a complex sentence is the output of the last subsentential unit. This *sequential intrasentential centering* is illustrated in Figure 2.

If it is a tree, we need to allow multiple centering states simultaneously active at different depths of embedding. This *hierarchical intrasentential centering* is illustrated in Figure 3. The set of simultaneously active CENs here lie on the “right open edge” of the evolving discourse structure. At this point, it is an open question which of the multiple input centering states is the most prominent.

In general, the ICH in (7) predicts the following:

(8) **Prediction from ICH:** After a complex sentence $S$, the subsequent discourse favors the input center to be the one that results from breaking up $S$ into a (structured) sequence of

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21 Of interest is the fact that something like this hypothesis has been taken for granted in the focusing approach (Grosz, 1977; Sidner, 1979; 1983; Grosz and Sidner, 1986). For instance, the following sequence of “utterances” is from Sidner (1983: D26):

1. Wilbur is a fine scientist and a thoughtful guy.
2. He gave me a book a while back which I really liked.
3. It was on relativity theory,
4. and talks mostly about quarks.
5. They are hard to imagine,
6. because they indicate the need for elementary field theories of a complex nature.
7. ... 

Note that 3–4 and 5–6 break up sentences into subsentential clauses each of which updates the local focus. No definition has been given anywhere in the literature, however, for what subsentential units count as independent utterances.
subsentential units rather than the one that results from S as a whole. In other words, the output center of a complex sentence is the output of the last (possibly nested) subsentential unit in the linear ordering rather than the output heavily influenced by the matrix clause of S alone.

The validity of this hypothesis depends on how a complex sentence is broken up into utterance units and what structure these utterance units form. A number of dimensions need to be considered for a full account: nominal versus clausal units, matrix versus subordinate clauses, the linear ordering of clauses, tensed versus untensed clauses, conjuncts versus adjuncts, adjuncts versus complements, direct versus indirect reports, and restrictive versus nonrestrictive relative clauses. For each dimension, we would like to know when and how the center is updated.

A central question here is the relation between the syntactic structure of a complex sentence and its discourse structure in terms of centering units. Do the centering units in a sentence form a flat sequence or a recursively embedded hierarchical structure? If they are hierarchical, are they isomorphic to the syntactic hierarchy?²²

²²These questions lead to a connection with the Linguistic Discourse Model (LDM) (Polanyi, 1988; Scha and Polanyi, 1988). In LDM, the elementary information unit in discourse is a discourse constituent unit (dcu) that mostly corresponds to a tensed or untensed clause. A discourse is a left-to-right growth of a complex tree-like structure with recursive embeddings of segments, each of which consists of a set of dcu’s. Sentences correspond to subtrees that may start from (or “attach to”) any level of embedding in the discourse tree. Of interest here is to what extent the LDM converges with an extended centering model that does both inter- and intrasentential updating. More specifically, is every dcu a center-updating unit, or vice versa?
In sum, the following questions are central in intrasentential centering:

1. What subsentential units update the center?
2. Are there some embedded updates “hidden” from the top-level centering?
3. How are the sentence structure and discourse structure related?

In the next section, I will state a number of specific hypotheses as partial answers to these questions, and motivate them with naturally occurring discourses.

4 Clause-based Intrasentential Centering

As a direct extension of intersentential centering, tensed clausal units are the best place to start carving out the mechanism of intrasentential centering, for the following reasons:

1. Untensed clauses are more grammatically integrated with superordinate clauses, leaving relatively less room for pragmatics (e.g., grammatically controlled unexpressed subjects in infinitives and gerunds).

2. Attentional state updating with tense and aspect as proposed by Kameyama, Passonneau, and Poesio (1993) can be unified with centering state updating with tensed clauses.

I have then obtained the distribution of the antecedents from the perspective of this tensed clause-based centering. Here, rather than the antecedent’s sentence location, we look at its tensed clause location. Henceforth, an utterance \( U \) is a tensed clause. Among the 255 third person pronouns in nineteen seventeen-sentence discourses above, (a) 83 (32.5%) have their antecedents in the immediately preceding utterance in the immediately preceding sentence, (b) 82 (32.2%) have their antecedents in the immediately preceding or superordinate utterance in the same sentence, and (c) 65 (25.5%) have their antecedents in the same utterance. These 230 local dependencies account for overwhelming 90.2% of all the pronouns in these corpora. Clause-based centering proposed here will make predictions about the (b) cases that existing centering has nothing to say about, and will refine the predictions about the (a) cases by focusing on the clause rather than entire sentence that immediately precedes the clause containing the pronoun in question. 45(69.0%) of the (c) cases are possessive pronouns that occur in tenseless clauses or nominal expressions as in its rejection, his estimate, and their revision.\(^{23}\) I propose that possessive pronouns are subject to an even tighter locality constraint than nonpossessive pronouns, and that their preferred antecedents lie nearer in their left within their utterance units regardless of their grammatical functions.\(^{24}\)

In this section, I will propose an initial classification of clausal relation types in terms of their association with either sequential or hierarchical intrasentential centering. Subsection 4.1 discusses sequential centering, and Subsection 4.2 discusses hierarchical centering.

\(^{23}\)The relative salience between the possessor and possessed still needs investigation.

\(^{24}\)Hobbs’s (1978) syntactic algorithm posits such a tight locality preference for all pronouns.
4.1 Sequential Intrasentential Centering

Tensed clauses of interest here are conjuncts and adjuncts. The reductionist view that I take is that tensed conjuncts and adjuncts define sequential centering structures. More specific hypotheses are stated with supporting examples below.

Conjuncts

The central hypothesis for tensed conjuncts is this.

(9) **Tensed Conjunct Hypothesis (TConj):** Tensed clausal conjuncts $C_l_1, ..., C_l_n$ break up into a sequence of utterances $U_1, ..., U_n$ at the level of embedding at which $C_l_1$ starts out in the given discourse structure. TConj Example 1:

1. CHAIN: *Her* mother was a Greer
2. CHAIN: *and her* father’s family came from the Orkney Isles.

TConj Example 2:

1. NULL: Happy but discriminating operagoers reserved judgment
2. ESTABLISH: *as her* singing showed signs of strain,
3. CHAIN: *her* musicianship of some questionable procedure,
4. CHAIN: *and her* acting of uncomfortable stylization.

Hypothesis TConj in (9) predicts that after an embedded conjunct segment closes, the input center to the subsequent discourse is the output of the last embedded unit rather than the output of the whole sentence. In the following example, Sutherland is established and chained as the Cb within an adjunct segment, and she is not mentioned at all in the top-level clauses. The next sentence simply chains Sutherland as the Cb, showing the natural flow from the more recent embedded segment than from the more distant matrix clauses.

(4) 1. CHAIN(Cb=Sutherland): *Her* entrance in Scene 2 Act 1 brought some disconcerting applause
2. CHAIN: even before *she* had sung a note.
3. NULL: *Thereafter* the audience waxed applause happy
4. NULL: *but* discriminating operagoers reserved judgment

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25 In the following centering analysis, I will annotate conjunction and subordination connectives between adjacent (sets of) utterances in italics. These connectives, such as *and*, *but*, *so*, *when*, and *because*, control utterance interpretation inferences by inducing rhetorical and discourse coherence relations. When no overt connectives appear, there is an implicit “and” between utterances. The interaction between these connectives and attentional dynamics is an area for future research.
5. ESTABLISH(Cb=Sutherland): as her singing showed signs of strain
6. CHAIN: her musicianship some questionable procedure
7. CHAIN: and her acting uncomfortable stylization.
8. CHAIN: As she gained composure during the second act
9. CHAIN: her technical resourcefulness emerged stronger
10. CHAIN: though she had already revealed a trill almost unprecedented in years of performances of Lucia

Under the present approach, tenseless clauses do not count as utterances in centering, which is restated below. The example contains nested infinitive clauses with grammatically controlled unexpressed subjects. This is a case of grammaticized monadic tendency, and leaves little ambiguity.

(10) **Tenseless Conjunct Hypothesis (TlessConj):** Tenseless subordinate clausal conjuncts do not update the center, and belong to the same utterance unit as the immediately superordinate clause.

1. CHAIN: I wanted [to grab her by the arm and beg her [to wait, to consider, to know for certain]]

Syntactic conjunction demonstrates, on the other hand, grammaticized parallelism tendency, where parallel constituents can be elided from positions that must be overt in a standalone sentence.

(11) **Conjunct Parallelism Hypothesis (CPara):** Two adjacent conjuncts (tensed or tenseless) induce parallelism.

1. CHAIN: She had held to the letter of her contract
2. CHAIN: and 0 didn’t come onto the stage. (zero-subject)

(See also the second example for TConj above for an elided verb showed in conjuncts.)

**Adjuncts**

The central hypothesis about tensed adjunct clauses is this.

(12) **Tensed Adjunct Hypothesis (TAdj):** Tensed clausal adjuncts are utterance units separate from and at the same level of embedding as their immediately superordinate clauses.

TAdj Example 1:

1. CHAIN: Although she’s still a teenager who looks like a baby,
2. CHAIN: she is getting married.

TAdj Example 2:
1. CHAIN: *Her* entrance in Scene 2 Act 1 brought some disconcerting applause
2. CHAIN: *even before she* had sung a note.

Tenseless adjunct clauses and phrases are analogous to tenseless conjuncts:

(13) **Tenseless Adjunct Hypothesis (TlessAdj):** Tenseless clausal and phrasal adjuncts belong to the same utterance unit as the immediately superordinate clause.

1. CHAIN: [In the fullness of *her* vocal splendor], *however, she* could sing the famous scene magnificently.

Hypothesis TAdj in (12) gives a natural account of an example such as the following where the matrix clause either establishes or chains the Cb introduced in the preceding adjunct clause:

(14) **Example: Pearson**

1. NULL: *Although* Pearson disbelieved almost everything Lizzie said
2. ESTABLISH(Cb=Pearson): *and 0* read a sinister purpose into almost everything *she* did
3. CHAIN: *he* happily accepted *her* statement about Bridget as the whole truth.
4. CHAIN: *He* felt nothing further need be said about the servant girl.

This pattern of anaphoric dependency has led syntactic theories to “raise” preposed adjuncts to a position dominating main clauses. The left-to-right center updating dynamics inside a sentence captures this dominance with precedence.

TAdj also predicts that in the case of apparent backward anaphora such as in *When he woke up*, *Bill was very tired*, the pronoun in the adjunct clause actually realizes an entity already in the context, rather than anaphorically dependent on *Bill*. The examples of backward anaphora I found are exactly such cases. In the following, the pronoun in question is in 4:

(15) **Example: Kern**

1. CHAIN(Cb=Jim Kern): *He* was particularly struck by a course on Communist brainwashing.
2. NULL: Kern began reading a lot about the history and philosophy of Communism
3. ESTABLISH(Cb=Jim Kern): *but 0* never felt there was anything *he* as an individual could do about *it*.
4. CHAIN(Cb=Jim Kern): *When he* attended the Christian Anti Communist Crusade school here about six months ago
5. NULL: Jim became convinced that an individual can do something constructive in the ideological battle
6. ESTABLISH(Cb=Jim Kern): *and 0* set out to do *it*.  

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4.2 Hierarchical Intrasentential Centering

When an “embedded discourse segment” is created, an embedded centering sequence $CEN_{k+1}, ..., CEN_{k+m}$ continues from the current center $CEN_k$, and when it closes, the next utterance has multiple alternative input centers. The question of a considerable theoretical import here is the (relative) accessibility of the multiple levels of centering for subsequent discourse. Are they all open? Does one of them close at any point? (See Figure 3.) I found two significantly different types of embedded centering in this connection. One is the reported direct speech, and the other is the nonreport complement.

Reported Speech

The following hypothesis seems reasonable for a number of examples:

(16) **Reported Speech Complement Hypothesis (Speech):** Reported speech is an embedded centering segment that is inaccessible to the superordinate centering level.

A canonical example follows. It is a sequence of reported speeches, where each reported complement (in a syntactic sense) can be a multisentence discourse:

(17) **Example: Hughes**

1. Hughes said Monday, “It is the apparent intention of the Republican Party to campaign on the carcass of what they call Eisenhower Republicanism but the heart stopped beating and the lifeblood congealed after Eisenhower retired. Now he’s gone the Republican Party is not going to be able to sell the tattered remains to the people of the state.”

2. Sunday he had added, “We can love Eisenhower the man even if we considered him a mediocre president but there is nothing left of the Republican Party without his leadership.”

3. Mitchell said the statement should become a major issue in the primary and the fall campaign.

A clause-based centering analysis of (17) follows:

(17) 1. NULL: Hughes said Monday,
   (a) ESTABLISH(Cb=RepParty): “It is the apparent intention of the Republican Party to campaign on the carcass of what they call Eisenhower Republicanism
   (b) CHAIN(Cb=RepParty): *but the heart* stopped beating
   (c) CHAIN(Cb=RepParty): *and the lifeblood* congealed

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26The unexpressed possessor of this relational noun is the Republican Party. The same goes for the *lifeblood* in (c).
(d) NULL: after Eisenhower retired.
(e) ESTABLISH(Cb=Eisenhower): Now he’s gone
(f) NULL: the Republican Party is not going to be able to sell the tattered remains to the people of the state.”

2. ESTABLISH(Cb=Hughes): Sunday he had added,
   (a) NULL: “We can love Eisenhower the man
   (b) ESTABLISH(Cb=Eisenhower): even if we considered him a mediocre president
   (c) CHAIN(Cb=Eisenhower): but there is nothing left of the Republican Party without his leadership.”
3. NULL: Mitchell said
   (a) NULL: the statement should become a major issue in the primary and the fall campaign.

If (17) is analyzed as a left-right flat sequence of clauses, the unambiguity of he in the first utterance of 2 would not be predicted. With the clear marking of the reported segment given with quotations, discourse popping is unambiguous at both utterance 2 and utterance 3, and the salient he-entity within the reported segment does not remain salient at the higher level. The salience is ‘inaccessible’ at the higher level, blocking the left-to-right flow of salience dynamics.

Nonreport Complements

The next embedded centering type is nonreport complements. My hypotheses here are split into tensed and tenseless nonreport complements. I hypothesize that the tensed complement gives rise to an embedded segment whose salience ordering is accessible to the higher-level centering.

(18) Clausal Complement Hypothesis (Comp): Tensed clausal nonreport complements create embedded discourse segments.

1. CHAIN: Her choice of one color means
   (a) CHAIN: she is simply enjoying the motor act of coloring without having reached the point of selecting suitable colors for different objects.

There are not enough examples to determine the finer-grained preference ordering between entities realized in the embedded centering unit and those realized in the higher centering unit, however. The same situation holds for relative clauses. Relative clauses create embedded centering units that carry on nested centering transitions, but when they close, their salient entities may be accessible but may not be salient at the higher level. These are areas for future investigations.

On the other hand, I hypothesize that the tenseless complement does not give rise to an embedded centering level. It is processed with the higher clause. For instance,
Tenseless Complement Hypothesis (TlessComp): Tenseless clausal complements belong to the same utterance units as their superordinate clauses.

1. ESTABLISH: We watched **them** [set out up the hill hand in hand on a rainy day in their yellow raincoats [0 to finger paint at the grammar school]].

5 Conclusion

I have posited a set of plausible mechanisms to treat complex sentences as pieces of discourse where intersentential centering applies on subsentential ‘utterance’ units. These initial hypotheses have been motivated with naturally occurring discourse examples. Both monadic and parallel tendencies observed in intersentential centering have been found in clause-based intrasentential centering, which is a promising sign that sentence-based and clause-based centering analyses would converge on a uniform set of attentional notions and predictions.

With the approach developed here, the example of ambiguous pronouns in (5)-3 is analyzed as follows:

(5) input: [Cb=Sarah1]

1. CHAIN(Cb=Cp=Sarah): She1 went downstairs and received another curious shock,
2. ESTABLISH(Cb=Cp=Glendora): for when Glendora2 flapped into the dining room in her2 homemade moccasins,
3. CHAIN(Cb=Glendora, Cp=Sarah): Sarah1 asked her2
   (a) CHAIN(Cb=Cp=Glendora): when she2 had brought coffee to her1 room,
4. NULL(Cb=NULL, Cp=Glendora): and Glendora2 said
   (a) ESTABLISH(Cb=Cp=Glendora): she2 hadn’t.

The main contribution of the present intrasentential centering approach is to reduce the amount of inferences required for utterance interpretation by making utterances smaller. The tight locality preference of possessive pronouns proposed at the beginning of Section 4 correctly predicts the reference of *her* in utterance 2, but fails for *her* in utterance 3(a). The latter is a case where the commonsense preference overrides the attentional preference, presumably based on an earlier mention of coffee having been brought to Sarah’s room. In fact, utterance 3 outputs an indeterminate centering state, where Sarah and Glendora are both maximally salient (see Section 2.3), so the salience-based interpretation of 3(a) is largely open for a commonsense influence. Note, for instance, that if 3(a) were ”when she should bring coffee to her room,” the local commonsense preference would shift to opposite readings of the pronouns. These commonsense applications are more controlled in smaller utterance units proposed in this paper.

I hope these intrasentential centering proposals make the centering theory more complete, and serve to be the basis for further extensions and integrations.
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