Projecting Grammatical Features in Nominals: Cognitive Theory and Computational Model[1]

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Abstract

A localist theory of the representation and projection of grammatical features in nominals is presented in which words and phrases functioning as specifiers and modifiers—in addition to heads—project grammatical features to encompassing nominals. Grammatical features may be redundantly encoded in words and phrases fulfilling different grammatical functions. At the level of the nominal, the projected grammatical features are collected into a set without duplicates. Redundantly encoded grammatical features may occasionally conflict or a grammatical feature may be unspecified—without the expression being ungrammatical—necessitating mechanisms for handling conflicts and accommodating unspecified features. An incremental, pseudo-deterministic system for processing nominals which operates over an interactive, constraint-based substrate is presented and motivated. Within this overall processing capability, non-monotonic mechanisms of blocking and overriding of grammatical features, without backtracking, are presented for handling conflicts. These non-monotonic mechanisms are part of normal processing and are not viewed as exceptional. Construal mechanisms for handling unspecified features are also needed. In the simplest case, the referent of the referring expression provides the (semantic) basis for construal of unspecified features. The processing of nominals within a computational cognitive model of language analysis, implemented in the ACT-R cognitive architecture, is used to demonstrate and support various representational and processing claims.

Representational Considerations

The current linguistic standard as exemplified in X-Bar Theory (Chomsky, 1970; Jackendoff, 1977), Generative Grammar more generally (cf. Radford, 1997, 2004), and HPSG (Sag & Wasow, 1999; Sag, Wasow & Bender, 2003) is that heads project the category of the phrases they head. In the case of a noun phrase, it is assumed that a noun head projects the category of the noun phrase. It is also typically assumed that heads project various grammatical features to the phrases they head (or that grammatical categories are really just collections of grammatical features). For example, the noun head of a noun phrase may project grammatical features like person, number and gender to the noun phrase. More specifically, if the noun phrase is "the man", the noun head "man" may project the grammatical features *third-person*, *singular*, and *male*. The person and number features are assumed to be needed for determining agreement in expressions like "the man runs" and the person, number and gender features are needed for binding pronouns and reflexives appropriately as in "the men$_i$ like themselves$_i$" or "the man$_i$ believes he$_i$ is smart". Projection of features is especially important to localist theories in which there is no non-local access to grammatical features (cf. Sag 2009). For example, on localist principles, in "the man runs", only grammatical features associated with the noun phrase "the man" are accessible to satisfy agreement with the verb "runs" (or its projection). There is no non-local access to the agreement features of "man" which have not been projected to the noun phrase.

It is sometimes also assumed that only heads project grammatical features. For example, the head feature principle (HFP) of HPSG is (largely) based on this assumption (Sag & Wasow, 1999), and in the Minimalist Program as described in Radford (1997) only semantically interpretable head features are retained in LF representations. However, this assumption leads to a system of linguistic representation in which most of the subcomponents of a phrase must be heads in order to project the needed grammatical features to the headed phrase, or to a system in which heads must redundantly encode features marked on non-heads. Consider the simple expression "the man". If the grammatical feature *definite* which is part of the grammatical behavior of "the" needs to be projected to the encompassing phrase and the grammatical features of "man" also need to be projected, then the following options are apparent: 1) "the" is the unique head (cf. Abney, 1987) and we must somehow mark the grammatical features of "man" on "the"; 2) "man" is the unique head and we must somehow mark the definiteness feature of "the" on the head "man", 3) both "the" and "man" are heads and project grammatical features, or 4) we must relax the assumption that only heads project grammatical features (the approach adopted herein).

In the first approach—the functional head approach—since "the" is the unique head, "man" is typically treated as a complement of "the" (complement being the best available place in the X-Bar schema for the non-head noun given a functional head). How then do the grammatical features of "man" get projected to the encompassing phrase (typically called a determiner phrase or DP)? Grimshaw (2000) introduces the notion of extended projections in which a noun complement can project grammatical features without violating basic notions of endocentricity (Bloomfield, 1933) by assuming that the noun complement and functional head are of essentially the same syntactic category with respect to grammatical feature projection. In fact, Grimshaw treats the noun complement as an extended head. However, treating the noun as both a complement and an extended head distorts the basic notional definition of complement (which we take to be largely synonymous with argument). The basic function of complements is to describe distinct objects that are related to the head of an expression. The linguistic description of these distinct objects requires its own grammatical features. In order to accommodate functional heads, Grimshaw is forced to adopt a distinction between complements of lexical heads and complements of functional heads, since complements of lexical heads do not project features, whereas complements of functional heads do. Radford (1997) presents an alternative approach in which the grammatical features normally associated with nouns are redundantly encoded on the determiner. This approach leads Radford (1997, p. 188) to suggest that "the" in "the students take themselves too seriously" has the features *third-person*, *plural* and *nominative*—since "the" is the head of the subject! Worse, in an expression like "the man", "the" would presumably encode the gender feature *male* as well (although Radford does not discuss this possibility). Besides the fact that there is no grammatical evidence that "the" encodes these features, note the tremendous ambiguity that such an approach introduces: "the" will have multiple sets of grammatical features (necessitating multiple entries in the mental lexicon) which can only be resolved by the overall context in which it occurs.

The second approach is simply the reverse of the first approach with "man" functioning as the "head" and the grammatical features of "the" needing to be redundantly encoded on "man" or handled via something like extended projections. The grammatical evidence suggests that singular count nouns are not marked for definiteness (in English), and insisting that they carry a definiteness feature adds ambiguity that cannot be resolved by the noun. For example, to handle "a man" vs. "the man", "man" would need to be coded as either *indefinite* or *definite*, depending on the determiner. At least the determiner "the" or "a" is available when "man" is processed and can influence the selection of the appropriate grammatical features for "man". This is not the case in the first approach where "the" is the head.

In the third approach, both "the" and "man" are treated as heads (on the same level) and can project grammatical features to the encompassing phrase. For example, in Cann (2001), "the"—which functions as a specifier—is treated as a secondary head. The primary problem with this approach is the positing of two heads to capture the fact that both the determiner and noun need to be able to project grammatical features to the encompassing phrase. As will be argued below, modifiers (but not complements) can also project grammatical features. Rather than proposing a three-headed monster to allow modifiers and specifiers to project grammatical features as well as heads, we will relax the assumption that only heads project grammatical features.

In the fourth approach—which is adopted and motivated in this paper—if we allow non-heads to project grammatical features to encompassing phrases, then in the example "the man", the determiner "the" can project the feature *definite* and the noun "man" can project the features *third-person*, *singular* and *male*. We will further assume that "man" is the head of the expression based on semantic evidence that the expression "the man" can be used to refer to an object of type man—assuming a semantic motivation for the functional category head (see Ball 2007a for further details). If "man" is functioning as the head, what is the functional status of "the"? A traditionally suggested candidate is *modifier* (cf. McCawley in Cheng & Sybesma, 1998), but a better candidate is *specifier*—we agree with Cann (2001) and Chomsky (1970), in this respect. To the extent that the functional categories *modifier* and *specifier* are distinct, determiners are better treated as specifiers since they combine with nouns to form complete noun phrases (e.g., "the man") whereas modifiers often combine with nouns to form incomplete noun phrases (e.g., "old man"). (For arguments against the distinction between specifiers and modifiers, see van Eynde, 2006.) This is an original insight behind the idea put forward in Chomsky (1970) that specifiers combine with heads to form maximal projections. Ball (2007a) adapts Chomsky's formalism in positing four phrase internal (or sub-maximal projection) functional categories: *specifier*, *head*, *modifier* (called *adjunct* by Chomsky) and *complement*. HPSG (cf. Sag & Wasow, 1999) adopts the same set of basic phrase internal functional categories. Huddleston & Pullum (2002) adopt the sub-phrasal functional categories *determiner* (where determiner is a functional category and determinative is the part of speech of words like "the"), *head*, *modifier* and *complement*. Biber, Conrad & Leech (2002) adopt the same functional categories as Huddleston & Pullum, but do not make a distinction between *determiner* as a functional category and *determiner* as a part of speech. In this paper, *determiner* will be used as the part of speech of words like "the" and *specifier* as the grammatical function that is typical of determiners.

Allowing for specifiers to project grammatical features (which is also assumed by Grimshaw, 2000, in the case of possessive nominals), one can ask if modifiers and complements can also project grammatical features. If "two" in "the two books" is functioning as a modifier, then the modifier "two" can project the number feature *plural*. Since "books" also projects the feature *plural*, projection of this feature by "two" is redundant. However, in an expression like "the two on the counter are ready", the grammatical evidence suggests that "two" projects the feature *plural* as indicated by the plural agreement with "are". In this example, is "two" functioning as a modifier or head? On the assumption that the head is empty, it is functioning as a modifier. Further support for the existence of empty heads in noun phrases (which are henceforth called nominals since a noun head need not occur) is provided below.

With respect to complements, to the extent that "of books" is functioning as a complement in "a pile of books are on the table", it appears that complements can also project grammatical features—at least the number feature. However, I do not believe that "of books" is functioning as a complement (i.e., to the extent that nouns take complements, it is the combination of the noun—in this case "pile"—with the non-optional preposition "of" that licenses the complement, not the

noun by itself), and if there is a phrase internal functional category that does not project grammatical features it is the complement category. Complements describe objects that are related to heads. The elements of the complement project grammatical features to the complement phrase, which requires its own set of grammatical features, but complements do not contribute to the grammatical description of the head per se. Given the basic function of complements (which has unfortunately been clouded with the introduction of functional heads), it would be surprising if they projected features to the encompassing phrase. If "of books" is not functioning as a complement in "a pile of books", what is its grammatical function? "Of books" may be functioning as a modifier of "pile", with "pile" functioning as the head (in which case "a pile of books is on the table" would be expected), or "books" may be functioning as the head of "a pile of books" with "a pile of" functioning as a phrasal specifier (or "pile of" functioning as a modifier). Note that in the latter case, the *plural* feature of "books" overrides the *singular* feature of both "a" and "pile" and yet "a pile of books are on the table" is grammatical for many speakers of English. It is also the case that the closer proximity of a non-head noun to a main verb, relative to the head noun of the subject which normally determines verb agreement, can influence verb agreement in ways that are not discussed in this paper, but which could explain the plural agreement between "books" and "are" without assuming "books" is the head of "a pile of books" (cf. Quirk et at., 1985). More generally, if a non-head noun (i.e., pre- or post-head modifier) is more cognitively salient than the head noun as in "a pile of books" or "the airspeed and altitude setting **are** unchanged", the non-head noun, or conjunction of nouns, may block or override the number feature of the head noun.

The representations to be presented adapt elements of X-Bar Theory (prior to the introduction of functional heads) and Construction Grammar. From X-Bar Theory, the grammatical functions specifier, head, modifier and complement are adopted and explicitly represented. These grammatical functions constitute the primary elements of various constructions, including nominal constructions which are the focus of this paper. A nominal construction includes the grammatical functions along with a collection of grammatical features. A key representational assumption is that constructions are linguistic elements which are encoded as chunks (i.e. named and typed collections of slots and values) in declarative memory where they represent explicit knowledge of language ("chunk" is a psychological term used to describe a piece of declarative knowledge). The value of a slot in a chunk may be a literal or the name of another chunk. The name of a chunk provides a pointer to the chunk. The chunk itself cannot be the value of a slot. It is the assumption that slot values may be chunk names, not chunks, which enforces localist constraints. A nominal construction may be embedded in a clausal construction, but only the grammatical features of the subject nominal which is a clausal element (i.e. external complement of the clause) are available at the clausal level. Further, only grammatical features of the specifier and head of the subject nominal which are projected to the nominal are available at the level of the clause. A specifier or head feature which is blocked or overridden is simply not available. For example, in "a few books are on the table", the *singular* number feature of "a" is overridden by the *plural* number features of "few" and "books". At the level of the subject nominal, the *plural* number feature is projected, and this determines agreement with "are". On the other hand, the *singlular* number feature of the nominal "the table" which functions as the complement of "on" in "on the table" is not available at the level of the clause.

Definiteness, Person and Number

What the determiner does when functioning as a specifier is provide the primary indication of the definiteness of the nominal in which it is embedded. I use the term "primary" since not all nominals contain a determiner and yet they nonetheless provide an indication of definiteness. For example, the nominal "books" in "books are fun to read" is *indefinite*. Since the nominal only

contains the plural noun "books", "books"—and more generally plural nouns—must be capable of providing an indication of definiteness. An alternative is to assume a zero determiner (cf. Biber, Conrad & Leech, 2002) that projects the definiteness feature. But that leaves unexplained why "books" but not "book" can occur alone as a nominal.

If we allow both specifiers and heads to project grammatical features, there is the possibility of conflict between the grammatical features that each projects. For example, the nominal "the books" contains both a determiner and a plural noun. On the assumption that "the" projects the feature *definite* and "books" projects the feature *indefinite* there is a conflict. This conflict can be resolved if we assume that the definiteness feature of the specifier is primary and blocks the definiteness feature of the head. Thus, "the books" refers to a *definite*, but *plural* quantity of books. Note that "books" may still project the features *third-person* and *plural* which are not blocked by "the". On the other hand, the determiner "a", unlike "the" projects the number feature *singular* and blocks the number feature *plural* making "a books" ungrammatical. Within this formulation, why "a books" is ungrammatical, whereas "the books" is grammatical is an interesting and as yet unanswered question. This question is complicated by the fact that "a few books are on the table" is grammatical, suggesting that at least under some circumstances the *singular* number feature of "a" can be overridden.

An assumption worth exploring is that for a nominal to be grammatical it needs to encode a set of grammatical features which, as a minimum, might include definiteness, person and number— regardless of whether these features come from the specifier, modifier or head. Adopting this assumption, the ungrammaticality of "the" and "a" used by themselves as nominals can be explained if they do not encode for one or more of these grammatical features. In the case of "a", the person feature may not be encoded, and in the case of "the" both person and number are not encoded. Similarly, *singular* count nouns like "dog"—unlike *plural* and *mass* nouns—fail to encode the definiteness feature and do not normally occur alone as nominals. On the other hand, the fact that "that" and "these" can occur alone as full nominals suggests that they do encode these grammatical features. "That" is *definite*, *third-person*, *singular*, and "these" is *definite*, *third-person*, *plural*.

Animacy and Gender

We have so far argued for the existence and projection of the grammatical features definiteness, person and number. But what of the grammatical features animacy and gender? It is clear that nouns like "man" and "woman" encode the gender features *male* and *female*, since these features are needed for resolving co-referring pronouns (e.g. "the man" and not "Mary" is the antecedent of "he" in "Mary likes the man. He is nice."), but it is unclear that nouns like "book" and "rice" encode a gender feature. One could posit a *neuter* gender feature and make it the default for nouns, but an alternative is to simply assume the absence of a gender feature. Allowing the gender feature to be absent or unmarked is consistent with a dependency between gender and animacy in English. It may be that the gender feature is only encoded by nouns which are *animate* (or more specifically *human*). If a noun is *animate* (*human*), it may have a gender feature, otherwise, it does not encode for gender—except for a few well-known exceptions like proper nouns naming ships. The existence of a distinction between *animate* and *inanimate* nouns makes the *neuter* gender feature unnecessary. Gender does not apply to *inanimate* nouns.

In contrast to the blocking of the head feature for definiteness by the specifier, one can ask if any head features can override specifier features. If we assume a grammatical feature for animacy, and if both specifiers and heads can code for this feature, the grammatical evidence suggests that the animacy feature of the head is primary. For example, in "that dog", if "that" encodes the

animacy feature *inanimate* and "dog" encodes the animacy feature *animate*, then the animacy feature of "dog" overrides the animacy feature of "that". In support of "that" having the feature *inanimate*, consider "I like *that*" in which "that" indicates an inanimate object (i.e., it cannot typically be used to refer to something that is animate). In support of treating animacy as a grammatical feature (i.e., a feature that has grammatical consequences) consider

1. The food$_i$ given the dog t$_i$ (was crunchy)
2. The dog$_i$ given t$_i$ the food (was hungry)
3. The man$_i$ that I gave t$_i$ the book
4. The book$_i$ that I gave the man t$_i$

My preference is for "the food" to be the understood object of "given" in 1 (indicated by the position of the trace with matching index) and for "the dog" to be the understood indirect object of "given" in 2. This preference hinges on the animacy feature of "the food" and "the dog", showing that animacy can have grammatical consequences. Likewise in 3, "the man" is the understood indirect object of "gave", and in 4, "the book" is the understood object. Again, animacy is the determining factor in this grammatical preference, suggesting the need to encode animacy as a grammatical feature.

Subjective and Objective Case

A grammatical feature which has not been discussed to this point is the feature case. A small set of pronouns are clearly marked for case in English. The pronoun "I" is marked for subjective case whereas the pronoun "me" is marked for objective case. But what about the pronoun "you"? Are there two separate entries in the mental lexicon—one marked with subjective case and the other marked with objective case—or is the pronoun "you" simply not marked for case? And what about common and proper nouns? Are all common and proper nouns doubly marked for subjective and objective case, or are they simply not marked? Since the pronoun "you" and common and proper nouns can occur as the heads of subjects and objects without grammatical effect—e.g., "you like me" vs. "I like you" and "the tree fell" vs. "he felled the tree", and "John likes me" vs. "I like John"—we will assume that "you" and common and proper nouns are not marked for case. Note the implication that only case marked pronouns participate in case agreement. For "you" and common and proper nouns which are not marked for case, case agreement does not arise.

Selective Coding of Grammatical Features

It was claimed above that *singular* count nouns do not encode for definiteness, whereas *plural* and *mass* nouns encode the *indefinite* feature. The encoding for definiteness allows *plural* and *mass* nouns, but not *singular* count nouns, to function as full nominals. Pronouns and proper nouns, like *plural* and *mass* nouns, differ from *singular* count nouns in encoding for definiteness which also allows them to function as full nominals. It was also claimed that only a small number of pronouns encode for *subjective* and *objective* case. And it was claimed that only nouns which are *animate* (*human*) may also be coded for gender. This selective encoding of grammatical features is founded on the basic principle that **where there is no grammatical distinction, there is no marking for a grammatical feature**. Without grammatical evidence, there is simply no basis for learners of English to learn the distinction. The following discussion explores the consequences of this basic principle for the representation and projection of grammatical features.

Person and Number in Subject-Verb Agreement

Under the assumption that grammatical features are only posited when there is a grammatical effect, we can revisit the grammatical features person and number which are presumed to be involved in subject-verb agreement. Consider the simple paradigm involving the present tense verb "sit":

Person	Number	
	singular	**plural**
first	I sit	we sit
second		you sit
third	he sits	they sit

First note the assumption that there is no *second-person singular* form in English (vice Huddleston & Pullum, 2002, p. 1463) since "you" always shows *plural* agreement, even when referring to a single individual (e.g., "John$_i$, you$_i$ **are** a saint$_i$"). Insisting on the existence of a *second-person singular* form of "you" conflates the concept of notional concord (or more specifically notional number agreement) with grammatical concord (or grammatical number agreement) (Quirk et al., 1985). Notionally (or semantically), "you" may refer to a single individual, but grammatically, it is construed as plural. As Quirk et al. (1985) note, when notional and grammatical **number differ**, notional concord often dominates in determining subject-verb agreement. (As I write this, I see that Microsoft Word does not like my use of "number differ" above suggesting "number differs" or "numbers differ" instead. If you actually see "number differs" in the text, then Microsoft Word has intervened at some point and corrected my use of notional number.) Although there is a difference between notional and grammatical number, we do not claim that grammatical number is purely syntactic. Rather, grammatical number is a conventionalization of notional number which can occasionally evoke alternative construals as in the case of words like "scissors" and "pants". The categorization of objects as singular and plural—like most human categories—is not based on necessary and sufficient criteria, but is subject to basic processes of construal which occasionally conflict (cf. Langacker, 2000). For example, in "notional and grammatical number differ" the modifier "notional and grammatical" is *plural* (with the *plural* feature coming from the conjunction "and"), whereas the head "number" is singular. For me, it feels more natural to treat "notional and grammatical number" as plural, despite the singular head "number". This suggests that the number feature of a modifier may occasionally block the number feature of the head.

Given the above paradigm, *third-person singular* agreement appears to be special in English, with the present tense verb "sit" having a special form which adds an "s". All other present tense verb forms lack this verbal marking. However, if we ignore *first-person singular* agreement for a moment, then it looks like the "s" marking on the present tense verb is associated with *singular* agreement and no marking on the present tense verb is associated with *plural* agreement. This is the converse of number marking on nouns: *plural* nouns are marked with "s" and *singular* nouns are unmarked.

> Noun + "s" → plural
> Present Tense Verb + "s" → singular agreement

If we can somehow model the treatment of *first-person singular* agreement without invoking a general *person* feature, then the grammatical feature person can be eliminated, leaving only number to determine subject-verb agreement. From the perspective of projecting grammatical features, the pronoun "he" projects a *singular* number feature that must agree with the "s"

marking on the present tense verb. On the other hand, regardless of what "I", "we", "you" and "they" project for number, there may be no agreement with the verb. But if there is no subject-verb agreement, how do we preclude combinations like "I runs" or "we runs"? If we re-introduce an explicit *plural* agreement requirement then we can eliminate "we runs" since the *plural* number projected by "we" is incompatible with the *singular* agreement marking on "runs". But that still leaves "I runs" unexplained. In fact, *first-person singular* agreement is the special case, not *third-person singular* agreement. If "run" agrees with *plural* subjects, and "runs" agrees with (*third-person*) *singular* subjects, then why do we say "I run" and not "I runs"? Must we assume two versions of "run", one which agrees with *plural* subjects and one which agrees with *first-person singular* subjects? If not, how do we model *first-person singular* agreement? One common approach makes a distinction between *third-person singular* and *non-third-person singular*. The "s" on the verb agrees with *third-person singular* subjects whereas the lack of an "s" agrees with *non-third-person singular* subjects. In this approach, nominals are marked for person and number and *non-third-person singular* can be further subtyped to include: *first-person singular*, *first-person plural*, *second-person plural*, and *third-person plural* (a rather unusual collection of subtypes).

Person	Number	
	singular	**plural**
non-third (first)	I sit	we sit
non-third (second)		you sit
third	he sits	they sit

A simpler approach only distinguishes *first-person*, leaving *second-person* and *third-person* unmarked. Note that there is a single first-person, subjective, singular pronoun "I", whereas all common and proper nouns would need to be marked as third-person in the alternative approach. Under this approach verbs ending in "s" exhibit (*non-first-person*) *singular* agreement and unmarked verbs exhibit *first-person singular* or *plural* agreement.

Person	Number	
	singular	**plural**
first	I sit	we sit
non-first		you sit
non-first	he sits	they sit

This *first-person singular* approach works for the special case of present tense "be" as well, with one caveat. Consider

Person	Number	
	singular	**plural**
first	I am	we are
non-first		you are
non-first	he is	they are

The *first-person singular* agreement "I am" is special, otherwise present tense "be" agrees with either singular subjects via "is" (s-form) or plural subjects via "are" (plural agreement form). The caveat is the base form of "be" (i.e., "be") is not the same as the plural agreement form (i.e., "are") as it is for other verbs.

Unlike present tense verbs, past tense verbs (with the exception of past tense "be") do not show agreement in English.

Person	Number	
	singular	plural
first	I sat	we sat
non-first		you sat
non-first	he sat	they sat

There is simply no grammatical basis for assuming subject-verb agreement with past tense verbs other than "be". On the other hand, the case of past tense "be" is special and interesting

Person	Number	
	singular	plural
first	I was	we were
non-first		you were
non-first	he was	they were

Under the assumption that subject-verb agreement is only marked for *singular* or *plural* agreement (with the *first-person singular* exception for present tense verbs), the past tense of "be" turns out to be entirely regular!

The best evidence that pronouns are marked for the grammatical feature person is not provided by subject-verb agreement. Rather, it has to do with the matching (or binding) of reflexive pronouns to subjects (cf. Radford, 1997) and co-reference, more generally. It appears that person agreement is required to handle examples like:

5. I like myself; *I like yourself
6. He likes himself; *He likes myself; *The woman likes myself; *John likes myself
7. You like yourself; You like yourselves

The examples with mismatching person features are ungrammatical in English. Example 6 demonstrates that this applies to nominals headed by nouns and proper nouns as well as pronouns. Example 7 is especially interesting in that subject-verb agreement is plural regardless of the actual referent of "you" whereas the use of "yourself" or "yourselves" for the matching reflexive pronoun depends on the referent. Whereas a mismatch in person between the subject and matching reflexive pronoun is ungrammatical, a mismatch in number (at least for second person "you" and "yourself") is not.

The need for a person feature is further demonstrated in the case of co-reference. Consider

8. John likes me. He is nice.
9. I like John. He is nice.
10. John likes me. I am nice.
11. I like John. To me, he is nice.

It seems clear that the decisive grammatical feature for establishing co-reference in these examples is person. *Third-person* "he" is co-referential with *third-person* "John" and *first-person* "me" is co-referential with *first-person* "I". If "John" lacked a *third-person* feature, then the co-reference of "he" would have to be established by allowing *third-person* to match the absence of

person. While this is possible, it would require an additional test which can be eliminated by making the default value for person *third* instead of relying on the absence of a value for this feature. Overall, the evidence appears to favor introduction of a *third-person* grammatical feature for all nouns and proper nouns, even if that feature is not needed in the case of subject-verb agreement.

The Genitive "Case"

In English, there are a small number of pronominal function words which are marked for the genitive (possessive) grammatical feature (often called genitive case) (e.g., "my", "your", "her", "mine", "yours", "hers") combined with a general capability to indicate the genitive grammatical feature of full nominals by attaching the genitive marker "'s" to the head of the nominal (e.g., "the man's book"). The reason "case" is quoted in the heading above is that the genitive marker is a nominal internal marker which establishes a referential relationship between two nominals—the genitive marked nominal which is called a reference point (Taylor, 2000), and an encompassing nominal. On the other hand, subjective and objective case marking marks a non-referential relationship between a nominal and the head of the encompassing clause. These are very different grammatical functions and subsuming them under the label "case" seems inappropriate. The primary grammatical evidence for treating the genitive as being like subject and object case marked pronouns is the existence of distinct subject, object and genitive pronominal forms as in "he, him, his" and "she, her, hers". However, there are really two genitive forms, one that functions as a nominal specifier and is in complementary distribution with determiners (e.g. "my" in "my book", "their" in "their house"), and one that has a more complex function and is in complementary distribution with non-genitive pronouns (e.g. "mine" as in "it is mine" vs. "it is him", "theirs" as in "theirs is nice" vs. "he is nice"). In neither of these functions is the genitive nominal like a subject or object pronoun in that the genitive nominal provides a reference point for determining the referent of the overall nominal, but is not the head of the overall nominal as is the case for subject and object pronouns. A nominal like "mine" in "mine is nice" is a complex referring expression that indicates two objects, the referent of "me"—the reference point—and the referent that is (abstractly) possessed (Taylor, 2000) by "me"—the referent of the overall expression. This referent is identified with respect to the reference point without the possibility of a head occurring in the case of "mine" (e.g. "*mine book" vs. "my book"). Despite the complex referential nature of words like "mine" and "my", we will refer to them as possessive pronouns. We also make a distinction between "my" and "mine" by subcategorizing the former as a possessive determiner (following Biber, Conrad & Leech, 2002).

The primary grammatical function of the genitive grammatical feature is to allow pronouns like "me" from which "my" is derived (e.g., "my" in "my book") and full nominals (e.g., "the man" in "the man's book") to function as specifiers within encompassing nominals. In this function, they provide an internal reference point for identifying the actual referent of the nominal. The genitive nominal functioning as a specifier projects the definiteness feature *definite* to the encompassing nominal, but does not project any other features (the typical behavior of specifiers). English also allows genitives to function as independent nominals. In this pronominal function, some possessive pronouns are marked by the addition of "s" to the possessive determiner as in "hers", "theirs", "yours", providing a grammatical distinction from possessive determiners. There is no grammatical distinction in the case of possessive nominals (e.g., "John's book is red" vs. "John's is red"). Note, that in this pronominal function, the value of the number feature of the encompassing nominal depends on the actual referent (e.g., "hers **is** nice" vs. "hers **are** nice") and not the possessive pronoun or nominal, which only determines the number feature of the internal reference point. There are languages like Spanish which do not have a distinct subcategory of

possessive determiner. In Spanish, personal pronouns perform the function of possessive determiners in English (e.g. "Tu libro" – glossed as "your book", but literally "you book").

As noted above, the genitive marker "'s" establishes a referential relationship between two nominals. Possessive determiners, pronouns and nominals are unique in projecting grammatical features both internally to the reference point they encode and externally to the higher level nominal they project. For example, in the nominal "my book", the possessive determiner "my" projects the grammatical features of "me" (less case) to the internal reference point that functions as the specifier and the grammatical feature *definite* to the higher level nominal that is headed by "book".

For pronouns and nominals which are not marked as genitive, how should they be handled? Positing a grammatical feature like *non-genitive* so all pronouns and nominals could carry a genitive marker would be highly inefficient and counter-intuitive. We will simply assume that non-genitives are unmarked for this grammatical feature. This aligns with the treatment of subjective and objective case which is also unmarked on all but a few pronouns.

Grammatical Function Revisited

It is well known that the words "that" and "these" can function as full nominals (e.g., "give me *that*" or "*these* are nice"), and when they do, they are often called demonstrative pronouns, whereas when they occur with a nominal head as in "*that* man" or "*these* books" they are sometimes called demonstrative determiners (cf. Biber, Conrad & Leech, 2002). Regardless of part of speech categorization, one can ask—when "that" and "these" function alone in a nominal, are they functioning as a specifier, a head, or both (i.e. fused heads as in Huddleston & Pullum, 2002)? If they are functioning as a specifier, then the nominal is headless. In a formulation in which specifiers as well as heads can project nominals, either is possible. Although we prefer to allow either the specifier or the head to be empty (but not both), the alternative of treating the specifier and head as fused when one is otherwise missing has similar representational and processing implications. Whether the demonstrative word is functioning as a specifier or head, or both, the endocentric claim that the head of a phrase projects the category of the phrase is brought into question. Do we really want to insist that words like "that" and "these" are subtypes of noun in order for our endocentric assumption to hold (van Eynde, 2006, suggests that we do)? Further, given examples like "the red is nice" where there appears to be no head in the nominal "the red", and expressions like "what did he eat" where "what" constitutes a nominal, do we really want to insist that nominals must be headed, and headed by nouns? Note also in "the red is nice", that fusing the determiner and head is complicated by the adjective which intervenes between them. Further, if nominals like "the red" are grammatical, must we relax the claim that grammatical nominals encode the features definiteness, number and person, as a minimum? An alternative is to assume a construal process (cf. Langacker, 2000) that adds the needed features in the right context (often based on the referent of the expression). In the absence of a noun head, the expression "the red" can be construed as being *singular* despite the absence of a noun that encodes this feature. Such construals have been posited in what is called the "universal grinder" (Pelletier, 1975) as in

> 12. Her house is 5000 sq. ft. That's a lot of *house*!

wherein a count noun like "house" is construed as a mass noun that projects the definiteness feature *indefinite* as well as the number feature *singular*. Needless to say, construal processes complicate notions of grammaticality and projection of grammatical features from lexical items in interesting ways that are difficult to formalize. However, an approach of assuming that there are multiple lexical entries for words like "house" that distinguish *singular* count noun uses from

singular mass noun uses flies in the face of usage based notions. Since "house" is almost never used in universal grinder expressions, it is unlikely to be encoded in the mental lexicon as such and universal grinder construal processes presumably operate over *singular* count nouns converting them into *singular* mass nouns and adding an *indefinite* feature in the right context.

Such overriding processes are rampant in morphology. The word "house" is *singular*, but the word "houses" is *plural*. The plural morpheme "s" projects the definiteness feature *indefinite* and overrides the *singular* number feature of the base count noun with which it combines. This is particularly obvious in the use of "ones" as in "give me the red ones". Whereas it may be the case that "houses" occurs frequently enough to be stored in the mental lexicon with the indefinite and plural features, this cannot be the case in general for count nouns. The claim of this paper is that overriding processes are also rampant at the level of phrasal processing. Consider

> 13. The ball bearings
> 14. The rice grains

In an incremental language processor, at the processing of the word "ball", "ball" will be integrated as the head of the nominal projected by "the" and the number feature *singular* will be projected to the nominal. But when "bearings" is subsequently processed, "bearings" will be made the head of the nominal—shifting "ball" into a modifier function—and the number feature will be overridden with the value *plural*. Based on such evidence, it is claimed that **a serial, incremental processor is necessarily non-monotonic**. It is only by ignoring the essentially incremental nature of the human language processor that non-monotonic constraint-based theories can handle such examples.

Besides convincing arguments for the existence of headless nominals like "the red" in "the red is nice", arguments that nominals can have non-noun heads are also quite common and quite convincing. Dixon (1991) argues that words like "kick" in "he gave it a kick" are verbs that head noun phrases. Pullum (1991) argues that in expressions like "our going to the movies was fun", "going to the movies" functions as a VP head of the NP "our going to the movies". The syntactic category NP or noun phrase seems inappropriate to describe such expressions and it is for this reason that the more neutral term "nominal" is used in this paper (although this use of "nominal" unfortunately conflicts with the use in Huddleston & Pullum, 2002). But if verbs like "kick" do not designate grammatical features like number, how can nominals with verb heads be grammatical? There must be some capability to construe the head of a nominal as projecting this feature even when the head is not a noun. When the head of a nominal is a verb or verb phrase, the verb or verb phrase is construed objectively and may project the feature *singular*. However, in "he gave it some kicks", the plural marking on "kicks" may override the *singular* feature and project the *plural* feature instead. Note that we are not saying that "kicks" is a noun in this context. Of course, if "kick" or "kicks" occurs frequently enough as the head of a nominal, the words may come to be encoded as nouns in the mental lexicon. In this case, the action of kicking is construed objectively and the words are encoded in the mental lexicon as such, along with the relevant grammatical features. But this cannot be true in general for verbs.

In the version of HSPG described in Sag & Wasow (1999), specifiers combine with phrasal heads to form higher level units like NP and S. However, treating "man" in "the man" as a phrasal head goes against the grammatical evidence since "man" is a word not a phrase. It is not the fact that the specifier combines with a phrasal head that leads to a maximal projection, it is the fact that the specifier combines with a head, phrasal or not, that leads to a maximal projection. (In Sag, Wasow & Bender (2003), the distinction between words and phrases is relaxed such that "man" can be viewed as both a word and a phrase.) Given the functional category head, there is little

need to posit an intermediate level of nominal structure as occurs in most variants of X-Bar Theory (cf. Chomsky, 1970, 1995). As argued above there are few true complements in nominal expressions. In "the days of the week", "of the week" functions as a modifier of either the head "days" or the nominal "the days". The "of" in "of the week" is not optional. "*The days the week" is not grammatical. "The week" is not a complement of "days", it is a complement of "of". Positing a level at which complements combine with nominal heads introduces extra structure that is seldom needed. An example like "the fact that he likes you" where "that he likes you" appears to be functioning as a complement, is the exception, not the norm in nominals. And in "the very fact that he likes you" it seems as likely as not that the modifier "very" combines with the head "fact" before "fact" combines with the complement "that he likes you", as X-Bar Theory requires. X-Bar Theory went off track when researchers started assuming the universal existence of levels of structure that were only occasionally needed (starting with the X-Bar level itself). Based on assumptions that X-Bar Theory is universal, innate and unlearned, researchers argued that if a level of structure exists in some language it must exist in every language—even in languages where there is no evidence for the structure as is the case for verb-object agreement in English. Even in languages which show evidence for some grammatical feature like subject-verb agreement (as in English), it is highly questionable whether such features should be represented structurally as occurs in treatments of X-Bar theory which assume a structural level like AgrSP (i.e. the maximal projection of subject-agreement). The alternative of representing grammatical features without introducing additional levels of structure has considerable merit. The representation of grammatical features is orthogonal to the representation of linguistic structure— at least to the extent that grammatical features are inflectionally represented as is the case for subject-verb agreement in English.

A lexical head (e.g. "book") may combine with a modifier (e.g. "red") to form a phrasal head (e.g. "red book"). The lexical and phrasal head have the same grammatical status. Both can combine with a modifier to form a phrasal head (e.g. "big red book" and "big book") and both can combine with a specifier to form a maximal projection (e.g. "the red book" vs. "the book"). But what is a maximal projection? A maximal projection is simply an expression which has all the grammatical features needed to support its use as a referring expression—at a minimum, definiteness, number and person in the case of nominals. For nominals, that typically means having a specifier that indicates definiteness and a head that indicates number and person. But some nominal heads also indicate definiteness and can occur without a specifier—including personal pronouns and proper nouns, plural count nouns, mass nouns and demonstrative pronouns (if they are heads). Further, via construal processes it is also possible for headless nominals to function as referring expressions (e.g., "*the red* is nice") and for heads to acquire grammatical features needed to support there use as referring expressions (e.g., "I like *goat*").

There are also limits on the stacking of words which project a definiteness feature. The marking feature of van Eynde (2006) and HPSG, more generally, is an attempt to constrain such stacking. For example, van Eynde (ibid.) treats "the" as being marked and determinate (i.e., *definite*), whereas "books" is unmarked and *indefinite*. In van Eynde's terms, additional prenominals can precede an unmarked nominal, whereas this is precluded for marked nominals. For example, "books" can occur alone as a nominal, but "the books" is also possible. On the other hand, "two the books" is precluded. However, "all the books" is allowed. There does appear to be a partial ordering of definiteness along the following lines: *universal > definite > indefinite* (introduction of the *universal* feature comes from van Eynde, 2006). Note that there is no claim that this partial ordering is universal across languages or inviolable even in English—there may be (marked) exceptions to the partial ordering. An *indefinite* nominal (e.g., "books") can be preceded by a word that promotes it to *definite* (e.g., "the books"), and a *definite* nominal can be preceded by a word that promotes it to *universal* (e.g., "all the books"). On the other hand, since "two" is

indefinite and "the" is *definite*, "two the books" is precluded, whereas "the two books" is allowed. Further, since "all" is *universal* and "the" is *definite*, "the all books" is precluded. The extent to which this partial ordering holds, and whether nominals containing multiple instances of words which project *universal* and/or *definite* grammatical features can be grammatical, will not be explored in any depth in this paper. The occurrence of expressions like "the two books" strongly suggests that nominals with multiple words projecting an *indefinite* feature are allowed (e.g., "two" and "books"). And expressions like "She's Betty Davis, but not **the** Betty Davis" suggest the possibility of multiple words that are *definite* (e.g., "the" and "Betty Davis"). Left unexplained by the partial ordering is why an expression containing the indefinite determiner "a" cannot be preceded by a definite or universal determiner as in "the a book" or "all a book". Van Eynde (2006) captures this constraint by treating "a" as marked and indefinite. However, the marking approach leaves unexplained how pre-determiners like "all" can occur with marked expressions like "the books" as in "all the books". Van Eynde (p.c.) suggests that pre-determiners (uniquely) combine with marked expressions. But at the processing of "all" which is ambiguous between a pre-determiner (e.g., "all the books"), a determiner (e.g., "all books") or a pronoun (e.g., "all are here"), one doesn't know if a marked determiner will follow. Treating "all" as a (universal) quantifier which can function as a pre-specifier (or modifier of a specifier), specifier or head, depending on context, is an alternative which is supported by the incremental nature of language processing.

Adjectives

Up to this point, adjectives functioning as modifiers in nominals (i.e., attributive adjectives) have only been used to motivate the existence of headless nominals as in "the *red* is nice". Little has been said about whether or not they project any grammatical features. They appear not to—at least not any of the grammatical features that have been discussed up to this point. For example, in "the big book", the adjective "big" functions as a modifier, but doesn't project any grammatical features. Although not the topic of this paper, the same appears to be true of adjectives used predicatively as in "the book is *big*". In this case, the auxiliary verb "is" projects the grammatical features normally associated with clausal predicates and is typically assumed to be the head, although Ball (2007a) treats the predicate adjective as the clausal head and the auxiliary verb as a clausal specifier. Since adjectives do not project grammatical features like definiteness, number and tense, they do not typically occur alone as well formed grammatical units—with a few exceptions where the bare adjective is licensed by an encompassing construction as in "the book made me *sad*".

Adjectives are, however, associated with a grammatical feature not yet discussed—what we will call *degree*—which is marked for the comparative and superlative forms as in "big", "bigger" and "biggest". A key question is whether or not this grammatical feature is projected to the encompassing nominal. In an expression like "the bigger one is on the table" is the comparative feature projected to the nominal? On localist assumptions, if there is a grammatical effect at the level of the nominal which relies on this feature then it should be projected. We assume that there are such grammatical effects and that the degree feature should be projected to the nominal. Constructions like "the harder I try, the worse I do" in which the comparative form (e.g. "harder" and "worse") is required by both parts of the construction, provide evidence for the projection of this feature.

The superlative form is particularly interesting in that it frequently occurs in nominals without a noun head as in "Give me the *biggest*". There is a clear sense in which "the biggest" identifies a specific object and we might be tempted to associate the grammatical feature *definite* with "biggest". However, in English, the superlative form normally requires the definite determiner

"the". To the extent that superlatives encode a *definite* feature, this feature is redundant with the definite determiner which is the primary indicator of definiteness. More problematic is whether or not the superlative projects the number feature *singular*. Assuming that the definite determiner does not project this feature and that the nominal acquires a *singular* number feature, the superlative is the obvious candidate to provide this feature. But consider the following

15. The biggest books are on the bottom shelf
16. The biggest are on the bottom shelf

If "biggest" projects the *singular* feature, than this feature is overridden by "books" in 15, and in 16 there appears to be notional agreement between the referent of "the biggest" and the auxiliary verb "are"—similar to the treatment of possessive pronouns like "hers" discussed earlier. Notional agreement also appears to apply in expressions like "the red is nice" vs. "the red are nice" (which sound OK to me). Note the implication that the referent of an expression—which is typically assumed to be pragmatic information—may determine subject-verb agreement when the subject nominal does not grammatically encode a number feature! Overall, the grammatical evidence for a *singular* number feature for superlatives is inconclusive and we will assume that they do not project a number feature.

Verb Participles

The topic of verb participles functioning as modifiers and heads in nominals is especially challenging. Consider

17. The (rapidly/rapid) *running* bull
18. The (rapid) *running* of the bull

I think it is a mistake to say that because "running" functions as the head of the nominal in 17, it is a noun. Likewise, it is a mistake to say because "running" functions as a modifier in 18, it is an adjective. It is important to distinguish the function of a word in any particular expression from the part of speech of the word which I take to be based on the overall history of use of the word—along with grammatically conventionalized semantic motivation. Arguments for this position are put forward in Ball (2007a). However, in terms of projecting grammatical features, if "running" is a progressive participle in 17 and 18, then it follows that "running" does not project grammatical features like number which are associated with nouns. In this case, some general mechanism for projecting *singular* number to nomimals which reify events is needed—although this mechanism can be overridden when the event is pluralized as in

19. The *runnings* of the bulls

Again, just because "runnings" is pluralized in 19, does not necessitate treatment of "runnings" as a noun. Part of speech is not determined purely based on distributional evidence, and not even a combination of distributional and morphological evidence. In 19, the morphological evidence conflicts: "-ing" provides a strong indication of the progressive participle, and "-s" provides morphological evidence of a noun. However, we do not want all progressive participles to be triply encoded as nouns and adjectives in the mental lexicon, just because they can function as modifiers and heads in nominals. Doing so would significantly increase the amount of ambiguity in the mental lexicon—causing more problems than it would solve. On the other hand, we do want to allow heads of nominals to be pluralized, even when they are not nouns as in "the *hold outs* are being counted" or "he knows the *ins* and *outs* of baseball", which suggests that pluralization may not be a purely morphological process. If distributional evidence were the only or primary determinant of POS, then all nouns would need to be doubly encoded as adjectives (or

the categories noun and adjective could be collapsed) since nouns, like adjectives, can function as pre-head modifiers as in "the *altitude* restriction"—i.e., nouns have a similar distribution to adjectives in nominals. For additional arguments against the use of purely distributional evidence for determining POS, see Croft (2001, p.29ff).

Wh-words

Wh-words are unique in that they combine the functions of multiple part of speech categories. In addition to having functions that are specific to wh-words, they also have functions that correspond to other part of speech categories. For example, the wh-words "who" and "whom" function like pronouns as suggested by their ability to occur alone as nominals (e.g., "Who is it?" and "To whom did he send a letter?"), along with the explicit objective case marking on "whom"—where case marking is limited to a small class of pronouns. The wh-word "what" also functions like a demonstrative pronoun since it can occur alone as a nominal (e.g., "What did he do?") or with a head noun (e.g., "What book did he read?"). Expressions like "What stays and what goes?" (compare to "?What stay and what go?" which is awkward for me although possible if the referents are plural) suggest that "what" encodes a *singular* number feature even though it can occur with both a singular or plural noun (e.g., "What book did he read?" vs. "What books did he read"). When "what" occurs with a noun head, the number feature of the noun overrides the number feature of "what". Note that other demonstrative pronouns do not allow overriding since they come in distinct singular and plural forms (e.g., "this" vs. "these"). Further, unlike other demonstrative pronouns, "what" does not provide an indication of distance (compare to the demonstrative pronouns "this" and "that"). Since "what" is not marked for distance, it behaves more like a determiner in this respect. But determiners like "the" and "no" cannot occur alone as nominals. The wh-word "whose" is very special. In addition to being a wh-word, it also functions like a possessive determiner. Since the category possessive determiner is itself a complex POS category that combines the functions of the categories possessive and determiner, "whose" combines the functions of three distinct POS categories: wh-word, possessive, and determiner.

The other wh-words—where, when, why and how—are not typical elements of nominals, and are not discussed in this paper. However, it should be noted that "how much" and "how many" behave like nominals in encoding a number feature.

Processing Considerations

There is extensive psycholinguistic evidence that human language processing is essentially incremental and interactive (Gibson & Pearlmutter, 1998; Altmann, 1998; Tanenhaus et al., 1995; Trueswell, Tanenhaus & Garnsey, 1994; Ball, 1992; Altmann & Steedman, 1988). Further, garden-path effects, although infrequent, strongly suggest that processing is essentially serial at the level of phrasal and clausal analysis (Bever, 1970)—although lower level processes of word recognition suggest parallel, activation-based processing mechanisms (McClelland & Rumelhart, 1981; Paap et al., 1982). At the level of phrasal and clausal analysis, humans appear to deterministically pursue a single analysis which is only occasionally disrupted, requiring reanalysis. One of the great challenges of psycholinguistic research is to explain how humans can process language effortlessly and accurately given the complexity and ambiguity that is attested (Crocker, 2005). As Boden (2006, p. 407) notes, deterministic processing "would explain the introspective ease and speed of speech understanding", but a purely deterministic, incremental processing mechanism would more frequently make incorrect local choices requiring reanalysis than is evident in human language processing. Marcus (1980) proposed a lookahead mechanism to improve the performance of a deterministic, yet monotonic, processor, bringing it into closer alignment with human performance. However, there is little evidence that humans make use of

lookahead (cf. Altmann & Mirkovic, 2009; Kim, Srinivas & Trueswell, 2002). Later in this paper, a limited form of lookahead based on the perceptual span for visual input which can exceed the space delimited word in the fovea, providing parafoveal information to the right of the foveated word, will be discussed.

To capture the essentially incremental nature of human language processing, we propose a serial, pseudo-deterministic processor that builds linguistic representations by integrating compatible elements, relying on a non-monotonic mechanism of context accommodation (Ball, 2010b) to handle cases where some incompatibility that complicates integration manifests itself. Context accommodation makes use of the full context to make modest adjustments to the evolving representation or to construe the current input in a way that allows for its integration into the representation. Context accommodation need not be computationally expensive (i.e., a single production may effect the accommodation, just as a single production may effect integration without accommodation). In this respect, context accommodation is not a reanalysis mechanism that disrupts normal processing; rather, it is part of normal processing. Reanalysis mechanisms need only kick in when context accommodation fails and larger adjustment is needed. Further, as will be shown below, context accommodation can give the appearance of parallel processing in a serial processing mechanism, blurring the distinction between serial and parallel processing.

The mechanism of context accommodation is most closely related to the limited repair parsing of Lewis (1998). Lewis describes limited repair parsing as a form of reanalysis and contrasts it with reanalysis by backtracking, reanalysis by selection from parallel alternatives, and reanalysis by refining commitments (i.e., underspecification). Lewis's use of the term reanalysis to describe these different mechanisms is quite liberal. In this paper, we will limit use of the term reanalysis to reanalysis by backtracking. However, we accept Lewis's arguments against the other mechanisms and in favor of repair mechanisms. Context accommodation may be viewed as a very modest form of repair, but since context accommodation need not take any more time than normal processing, the use of the term repair is somewhat inappropriate.

To capture the essentially interactive nature of human language processing, we propose a probabilistic, context-sensitive mechanism for activating alternatives in parallel and selecting the most highly activated alternative. This parallel, probabilistic mechanism selects between competing alternatives, but does not build any structure—building structure is the function of the incremental integration mechanism. At each choice point, the parallel, probabilistic mechanism uses all available information to activate and select the preferred alternative, and the serial, pseudo-deterministic mechanism integrates the preferred alternative into the evolving representation. Use of the full local context supports selection of alternatives that are likely to be correct, allowing the serial integration mechanism to be largely deterministic. However, the local context is not always consistent with the global context and locally preferred choices sometimes turn out to be globally dispreferred. The mechanism of context accommodation allows the processor to adjust the evolving representation to accommodate the subsequent context, without lookahead, backtracking or reanalysis. Only when the context accommodation mechanism breaks down do more disruptive reanalysis processes become necessary. The use of the term *pseudo-deterministic* reflects the integration of parallel, probabilistic activation and selection mechanisms and context accommodation with what is otherwise a serial, deterministic processor.

The primary alternatives to this approach are constraint-based approaches which rely on some kind of settling out mechanism to make choices rather than having an explicit selection mechanism. This settling out mechanism may be based on inhibition between competing

alternatives (cf. Vosse & Kempen, 2000) which may or may not result in a single choice at each choice point; or, by unification of linguistic structures such that the result is a selection of compatible linguistic structures—such structures might be feature structures as in HPSG (cf. Sag, Wasow & Bender, 2003) or trees as in Tree Adjoining Grammar (Joshi, 1988); or, by probabilistic computation of alternatives which allows for the possibility of ranking and bounding alternatives without requiring selection of a single alternative—at least not until the end of the input is determined (Kim, Srinivas & Trueswell, 2002). It may be difficult to provide empirical evidence which can decide between parallel, constraint-based approaches and a serial approach which allows for non-monotonic adjustment of the evolving representation. For example, probabilistic reranking of alternatives—which is essentially non-monotonic—is computationally similar to context accommodation. Both are presumably less disruptive than reanalysis. On the other hand, an inhibition or unification-based approach which leads to a single choice at each choice point, would still require some mechanism capable of making minor adjustments without reanalysis. Proponents of constraint-based approaches often overlook the implications of having to build multiple structures at each choice point—it is not unusual for proponents of such approaches to focus on a particular choice point of interest (e.g., the noun phrase following an NP vs. clause bias verb) and simply ignore the existence of other choice points. If multiple structures must be built and carried forward at each choice point, the computational system will slow down with the length of the input as more and more structures are built and carried forward, but humans do not exhibit this behavior. It follows that the number of structures built at each choice point must be highly constrained, and the building of structures extremely limited. Kim, Srinivas & Trueswell (2002) avoid the building of structure by incorporating pre-compiled trees into their constraint-based system. Instead of building up structures from lexical items, lexical items are associated with a collection of pre-compiled trees and the constraint-based mechanism need only determine which pre-compiled tree is appropriate for each lexical item in a given context. Kim, Srinivas & Trueswell (2002) call the process of determining the pre-compiled tree for each lexical item "supertagging", in comparison to part of speech taggers which label words with part of speech tags, but don't build any structure. The selected trees must still be integrated, but in the simplest case, there is a single point of integration for each pair of trees. From a localist perspective, the pre-compiled trees provide an extended notion of locality (Joshi, 2004).

At the processing of each word in a linguistic input, humans typically succeed in determining the correct grammatical function of the word, and also succeed in integrating the word into the evolving linguistic representation. The likely way this is accomplished is by using all available information—be it lexical, syntactic, semantic or pragmatic—to make the correct grammatical choice. This implies a highly context sensitive, parallel determination of the grammatical function of the current word (consistent with constraint-based theories), followed by the serial and deterministic integration into (or projection of) the evolving representation (an aspect of processing ignored—or at least de-emphasized—by most constraint-based theories). At each choice point (typically at the processing of a word or multi-word unit), all information is considered in parallel in making the best choice, but once a choice is made, processing proceeds serially and deterministically forward until the next choice point.

In the processing of nominals, this means that the processing of each word leads to determination of the appropriate phrase internal grammatical function of the word, projection of a higher level phrasal unit or integration of the grammatical function into an existing higher level phrasal unit, and projection of grammatical features from the grammatical function to the higher level unit. For example, in the processing of "the man", the processing of the word "the" leads to determination of its grammatical function as a specifier, projection of a nominal construction, and projection of the grammatical feature *definite* to the nominal construction. The subsequent processing of "man" leads to determination of its grammatical function as a head, integration of the head into the

nominal construction projected by "the" and projection of the grammatical features *singular* (number), *human* (animacy) *male* (gender) and *third* (person) to the nominal construction. It is important to note that the determiner "the" projects a nominal construction in this example. Not only do determiners project grammatical features, but they project nominal constructions and determine the category of the construction (functioning like a head in this respect). On the other hand, in the absence of a determiner (and projected nominal) a *plural* or *mass* noun can also project a nominal construction. For example, in "*rice* is good for you", the mass noun "rice" projects a nominal construction (in the absence of a nominal construction projected by a determiner), and projects the grammatical features *indefinite* (definiteness), *singular* (number), *inanimate* (animacy) and *third* (person) to the nominal.

When the projection of grammatical features results in a conflict, blocking or overriding mechanisms—specific instances of context accommodation—come into play. The blocking and overriding mechanisms occur within the current context, making full use of the context to determine the appropriate projection of grammatical features.

Determination of the grammatical function of a word has important representational and processing implications. For example, in the processing of "that" in "that man", if "that" functions as a specifier and projects a nominal, then when "man" is processed, "man" can simply be integrated as the head of the nominal. In this case, "that" behaves like a typical determiner. However, if "that" functions as the head—behaving instead like a typical pronoun, then when "man" is processed, "man" must be accommodated by shifting "that" into the specifier function to allow "man" to function as the head. Whether or not "that" is encoded in the mental lexicon as a determiner, a pronoun (including relative pronoun), or both, is likely to depend on the history of use of the word. Regardless of which form is retrieved, the language processor must be capable of accommodating the alternative use. Given that the function of "that" cannot be fully determined until the subsequent input is processed (assuming an incremental processor without lookahead), retrieval mechanisms are likely to retrieve the most frequent form (unless the prior context is somehow able to bias retrieval of the alternative form). This basic fact is often overlooked in grammatical treatments which ignore processing considerations. Thus, it is often suggested that "that" in "that man" is a (demonstrative) determiner, whereas, "that" in "that is nice" is a (demonstrative) pronoun. For this to be the case, determining the part of speech of "that" would need to be delayed until after the subsequent input is processed, or ignoring processing, given the syntactic context surrounding "that". Based on related analyses, at least one researcher (Borer, 2003) has suggested that words are encoded in the mental lexicon without part of speech information. We reject this suggestion which goes against the basic lexicalist/constructionist framework which motivates this research (cf. Ball, 2007a, b). It is not linguistic structure which determines the basic grammatical category and features of words—top-down (except in exceptional cases like nonce expressions and unknown words), it is words which determine basic linguistic structure—bottom-up, based on their grammatical category and features. Lacking lexically specified grammatical (including morphological) information, language processing would soon break down. Even in the case of the well-known poem "The Jabberwocky" (e.g., "'Twas brillig and the slithy toves did gyre and gimble in the wabe…") (Carroll, 1872) the function words and morphological endings on the nonce words, along with associations between the nonce words and real words (e.g. "brillig" → "brilliant"), provide sufficient cues to support some level of comprehension.

Like demonstrative pronouns/determiners, a similar mechanism is needed in the incremental processing of noun-noun combinations. For example, in the processing of "the altitude restriction", when "altitude" is processed it can be integrated as the head of the nominal projected by "the", but when "restriction" is subsequently processed, "altitude" must be shifted into a

modifier function to allow "restriction" to function as the head. Most grammatical treatments refrain from calling nouns like "altitude" adjectives when they function as modifiers in expressions like "the altitude restriction". However, if "altitude" is not encoded as a noun in the mental lexicon, then it might very well be categorized as an adjective based purely on the syntactic context.

The need for non-monotonic mechanisms like overriding and function shifting is not widely accepted. From a psycholinguistic perspective, Lewis (1998) provides a strong defense of non-monotonic processing without backtracking in his exposition of limited repair parsing. According to Lewis (1998, p. 262) "The putative theoretical advantage of repair parsers depends in large part on finding simple candidate repair operations". The mechanisms of context accommodation proposed in this paper provide support for this theoretical advantage. From a linguistic perspective, Sag (2009) argues that a monotonic constraint-based approach to grammatical feature projection is to be preferred over non-monotonic mechanisms like overriding in his description of Sign Based Construction Grammar (SBCG)—a variant of HPSG. Purver, Cann & Kempson (2006) put forward a description of Dynamic Syntax which they claim captures the incremental, serial and context-dependent nature of language processing without abandoning monotonicity.

It is a basic claim of this paper that **an incremental, serial, pseudo-deterministic language processing mechanism**—which we take the human language processor to be—**is necessarily non-monotonic**. Given the incremental nature of the human language processor, it is not possible to always make the globally correct choice at each choice point based on local information. In particular, the non-availability of the right context makes local choices subject to revision. The simple example "the altitude restriction" is intended to make this point. The more complex example "pressure value adjustment screw fastener part number" suggests that carrying forward in parallel the possibility of a noun functioning as either a head or a modifier at each choice point is just not feasible. There are 2^7 possibilities in this nominal. At a minimum, the occurrence of a subsequent noun must disambiguate the function of the preceding noun. But what if the subsequent noun can also be a verb (e.g., "screw", "part" and "number"), or an adjective, or the POS isn't even determined? These mundane examples differ from the disruptive garden-path examples which are typically used in psycholinguistic studies of reanalysis (e.g., the famous "the horse raced past the barn fell" from Bever, 1970). Context accommodation is not capable of handling such disruptive inputs, but it is capable of handling the more mundane examples.

As noted above, non-monotonic processes like overriding are often criticized by proponents of constraint-based theories like HPSG (cf. Sag, 2009) and monotonic approaches are often touted as superior to non-monotonic approaches (cf. Dynamic Syntax as described in Purver, Cann & Kempson, 2006). But such theories are missing a key point—incremental processors do not have the full input that is needed for a constraint-based model to be able to monotonically settle in on the appropriate global representation. Local choices must be made that may later turn out to be globally incorrect. There is simply no viable alternative to non-monotonic adjustment of the evolving representation—although there may be alternative mechanisms which can reduce the amount of non-monotonicity. The alternative of having a non-deterministic processing mechanism with some form of backtracking is inadequate on several grounds: 1) it's computationally explosive, 2) it typically assumes retraction of structure, and 3) it requires knowing when you've reached a dead end and need to backtrack. The alternative of full parallelism is also computationally explosive—there is just too much ambiguity to be able to carry forward all possible alternatives and it is clear that humans are not doing so (Ball, 2011a, provides a more detailed discussion). Some form of ranked and bounded parallelism is often put forward as a viable alternative. But any amount of parallelism will of necessity be isolated and

temporary. In this respect it is important to note that non-monotonic processes give the appearance of parallelism in a serial processing mechanism. In adjusting an evolving representation, it appears that the resulting alternative was carried along in parallel. For example, in "the airspeed restriction" when the processing of "restriction" causes "airspeed" to be shifted into a modifier function, it appears that the treatment of "airspeed" as a modifier was carried along in parallel with the treatment of "airspeed" as the head. Serial, non-monotonic processing gives the appearance of parallelism without the computational expense of carrying forward multiple representations. Finally, mechanisms of lookahead, delay and underspecification can only go some way towards supporting monotonic processing. If used extensively, they create more processing problems then they resolve.

In an early and influential deterministic parser, Marcus (1980) relied on a lookahead mechanism to allow the right context to influence local parsing decisions in order to maintain monotonicity. Unfortunately, there are two basic problems with lookahead mechanisms: 1) the processor can't predict how far it needs to look ahead to make a correct choice (e.g., how much lookahead is needed to find the head of the nominal "pressure value adjustment screw fastener part number", and 2) lookahead mechanisms are inconsistent with psycholinguistic evidence on human language processing (cf. Altmann & Mirkovic, 2009).

Besides the mechanism of lookahead, alternative mechanisms of delay and underspecification have also often been proposed to support incremental, yet monotonic processing. For example, Purver, Cann & Kempson's description of a Dynamic Syntax based parser (2006) relies on underspecification to delay decisions until the needed context is available. However, mechanisms of delay and underspecification suffer from problems similar to lookahead. In the case of delay, it is undetermined how long a delay is sufficient. In the case of both delay and underspecification, the failure to determine the grammatical function of an expression degrades the context for making subsequent decisions. Delaying determination of structure or underspecification, if used extensively, is a non-solution. Without that determination, subsequent ambiguity cannot effectively be resolved and the result is an explosion of different possible structures. Further, as Lewis (1998) notes, delay and underspecification (or minimal commitment) is inconsistent with the incremental and immediate determination of meaning which is characteristic of human language processing (see also Altmann & Mirkovic, 2009). Even in the case of prepositional phrase attachment—the poster child for underspecification—there is good evidence that humans make immediate attachment decisions when sufficient context is available (cf. Novick, Thomson-Schill & Trueswell, 2008), although there is some evidence that attachment decisions are delayed when sufficient context is unavailable (Swets, et al., 2008). Overall, the evidence suggests that only a limited amount of delay and/or underspecification is viable, necessitating some form of non-monotonic processing.

Computational Implementation

The processing of nominals has been implemented as a subcomponent of a computational cognitive model of language analysis (Ball, Heiberg & Silber, 2007; Ball, 2011a) developed using the ACT-R Cognitive Architecture (Anderson et al, 2004; Anderson, 2007). ACT-R combines a production system for modeling proceduralized behavior with a declarative memory (DM) system for modeling declarative knowledge. Declarative knowledge is encoded in the form of DM chunks (or frames) which are named and typed slot/value lists. DM chunks are organized into a single inheritance hierarchy. The production system, which can only execute a single production at a time, is the locus for incremental processing. The selection of a production to execute relies on a context sensitive conflict resolution process. The production with the highest utility which matches the context is selected for execution at each step in processing. The production system

interacts with the DM system via productions which retrieve chunks from DM. These retrieval productions provide a retrieval specification (e.g. retrieve a word chunk) which combines with a parallel, spreading activation mechanism to determine which chunk gets retrieved—the single most active chunk which is consistent with the retrieval specification is retrieved. The parallel, spreading activation mechanism, combined with the context sensitive selection of productions, are the loci of interactive processing.
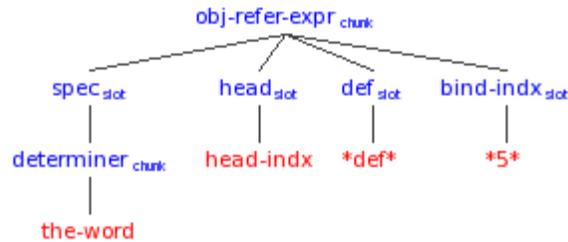
DM chunks which have been retrieved from memory, encoded from the environment and constructed during processing constitute the current context or working memory (Ball, 2012). The slot values of these working memory chunks spread activation to matching chunks in DM, providing the context for further DM retrievals and for production selection. The production system incrementally constructs a single representation given the sequence of DM chunks that are retrieved from DM. Declarative memory encodes chunks at varying levels of representation from letter, to trigram, to word, to multi-word unit, to phrase, to clause. These chunks capture explicit knowledge of language. The procedural system uses the DM chunks that are retrieved to build larger representations which may be stored in DM for subsequent use. The procedural system captures implicit knowledge of language.

The word recognition subcomponent of the model uses ACT-R's spreading activation mechanism in conjunction with word retrieval productions to retrieve the word or multi-word unit which is most consistent with the perceptual input. Retrieval involves an interaction of the perceptual form of input with declarative knowledge (Freiman & Ball, 2008), allowing the model to recognize misspelled words, variations in word form, and multi-word expressions. Perceptual input is not pre-segmented into words, but arrives in the form of a perceptual span of letters, spaces and punctuation. The perceptual span extends beyond the space delimited word in the fovea, providing parafoveal information to the right of the foveated word. The perceptual information in the parafovea provides a limited form of lookahead to support the recognition of multi-word units, but this lookahead does not otherwise participate in processing (i.e. the parafoveal information is used in DM retrievals, but is not used by the serial integration mechanism).

The model contains a capability to display the representations that are generated from the linguistic input in a tree format (Heiberg, Harris & Ball, 2007). In the model, nominals are called object referring expressions (abbreviated obj-refer-expr). The use of the term "object referring **expression**" indicates that the representations are linguistic, but not purely syntactic. According to Lyons (1977, p. 445) "Looked at from a semantic point of view, nominals are referring expressions". This is the perspective adopted in this paper, although object referring expressions (i.e. nominals) are differentiated from situation referring expressions (i.e. clauses), location referring expressions (i.e. locatives), etc. The terminal nodes may contain words, but do not contain anything like abstract concepts or word senses. To more fully represent the meaning of the object referring expression, it must be mapped to a non-linguistic representation of the object to which it refers (within the context of a situation model). This mapping will not be discussed in this paper (see Rodgers et al., 2012 for more details), but it is noted that the mapping is simplified by the nature of the linguistic representations as compared to typical syntactic representations.

The incremental processing of the nominal "the man" is shown below:

"the" →

```
                        obj-refer-expr chunk
            ┌──────────────┬──────────┬──────────────┐
        spec slot      head slot   def slot     bind-indx slot
            │              │          │              │
        determiner chunk  head-indx  *def*          *5*
            │
         the-word
```
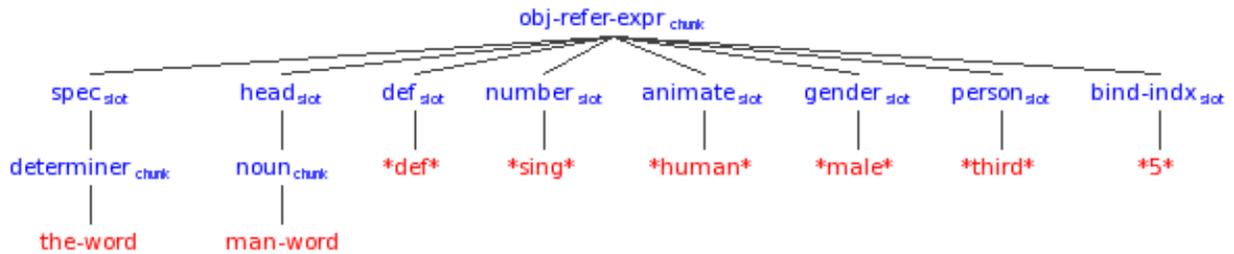
The processing of the word "the" leads to retrieval of an object referring expression chunk in which "the", identified as a determiner, is functioning as a specifier (abbreviated "spec"). Direct retrieval of an object referring expression chunk from "the" circumvents the need to separately determine the part of speech of "the", as well as the need to project an object referring expression in which "the", identified as a determiner, functions as a specifier. This direct retrieval is made possible by the frequent use of "the" as the specifier of an object referring expression. The retrieved object referring expression chunk has a head slot. The value "head-indx" indicates that this slot does not yet have a value. The object referring expression chunk also has a definiteness slot (abbreviated "def") which has the value *definite* (abbreviated "*def*"). Finally, the object referring expression has a "bind-indx" slot which contains the index *5* (which was set as part of the retrieval process). This index supports the binding of traces and anaphors in more complex linguistic expressions. It should be noted that the tree representations are simplified in various respects. In particular, the grammatical feature slots of the individual lexical items are not displayed. Further, only some slots without values are displayed. For example, the head slot is displayed even if it doesn't have a value, but grammatical feature slots and modifier slots (pre and post-head) without values are not displayed.

The object referring expression chunk corresponds to a construction in Construction Grammar terms. In this example, the obj-refer-expr construction contains the grammatical function slots specifier and head, the grammatical feature slot definiteness, and the index slot bind-indx (object referring expressions have additional slots like pre and post-head modifier functions, and number and animacy features which are not shown in this example). The specifier slot is pre-filled with the determiner "the" and the definiteness slot is pre-filled with the value *definite*. The head and bind-indx slots are empty, but indicate the constructional prediction that a head will occur and that every referring expression has a bind-indx. Not all constructional predictions must be satisfied for the result to be grammatical. Even the *head* slot may remain empty in some expressions, in which case the head is implicit and may be recoverable from the context. Missing from the representation is any indication of the object that the expression refers to. In a fuller representation of meaning, the bind-indx slot of the object referring expression will be bound to a representation of the referent of the expression.

Henceforth processing descriptions will abstract away from references to production execution, chunks and slots.

"the man" →

obj-refer-expr chunk

spec slot — head slot — def slot — number slot — animate slot — gender slot — person slot — bind-indx slot

determiner chunk — noun chunk — *def* — *sing* — *human* — *male* — *third* — *5*

the-word — man-word

The processing of the word "man" in the context of "the" leads to identification of "man" as a noun which is integrated as the head of the object referring expression retrieved during the processing of "the". The noun "man" projects the grammatical features number, animate (i.e., animacy), gender and person with the values *singular*, *human*, *male* and *third* to the object referring expression. The animate feature has the possible values *human* (a subtype of *animate*), *animate* and *inanimate*.

The processing of "that man" proceeds as follows:

"that" →

pron-obj-refer-expr chunk

head slot — def slot — number slot — animate slot — person slot — distance slot — bind-indx slot

demon-pron chunk — *def* — *sing* — *inanimate* — *third* — *not-near* — *5*

that-word
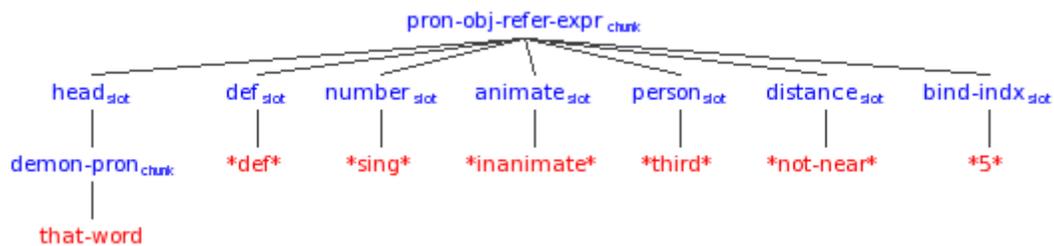
The word "that" is determined to be a demonstrative pronoun (abbrev. "demo-pron") which projects a pronoun object referring expression (pron-obj-refer-expr) with "that" functioning as the head rather than the specifier as was the case for "the". (Note that "that", unlike "the", can occur alone as an object referring expression—e.g. "I like that".) Pron-obj-refer-expr is a subtype of obj-refer-expr. "That" also projects the features def, number, animate, person and distance with the values *definite*, *singular*, *inanimate*, *third* and *not-near*. It is assumed that "that" projects the animacy feature *inanimate* since "that" alone cannot generally be used to refer to an animate or human referent (e.g. "I like that").

"that man" →

pron-obj-refer-expr chunk

spec slot — head slot — def slot — number slot — animate slot — gender slot — person slot — distance slot — bind-indx slot

demon-pron chunk — noun chunk — *def* — *sing* — *human* — *male* — *third* — *not-near* — *5*

that-word — man-word
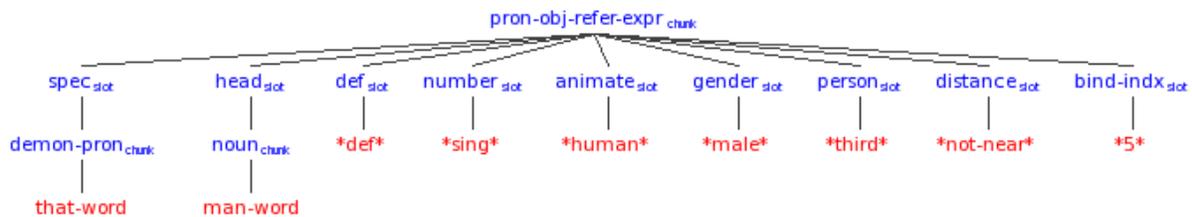
The processing of "man" following "that" leads to its identification as a noun. The noun is integrated as the head of the pron-obj-refer-expr with "that" shifted to the specifier function. This is a form of context accommodation called *function shifting* (Ball, 2010a). Note that "that" is still categorized as a demonstrative pronoun when it functions as a specifier. There is no separate entry in the mental lexicon in which "that" is a demonstrative determiner (cf. Biber, Conrad & Leech, 2002). Having such an entry would only add ambiguity. At the incremental processing of "that", it is not possible to know which entry is needed. Some form of accommodation will be needed regardless of which entry is chosen. The integration of "man" overrides the animacy feature of "that" changing it to *human* and projects the gender feature *male*. *Feature overriding* is another form of context accommodation.

The processing of "a man" proceeds as follows:

"a" →
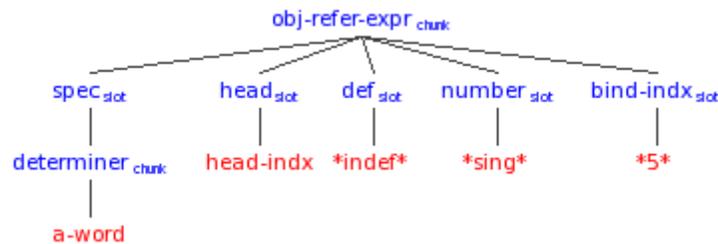
The word "a" is similar to "the" except that it projects the def feature *indefinite* (abbreviated *indef*) rather than *definite*, and it also projects the number feature *singular*.

"a man" →
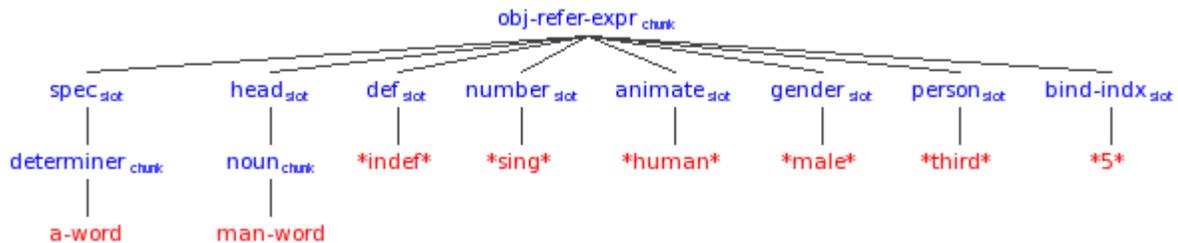
The processing of "man" following "a" is very similar to its processing following "the".

The processing of "the two books" proceeds as follows:

"the two" →

obj-refer-expr chunk

spec slot   head slot   def slot   number slot   person slot   bind-indx slot

determiner chunk   obj-head chunk   *def*   *plur*   *third*   *5*

the-word   mod slot   head slot

quantifier chunk   head-indx

two-word

The processing of "two" following "the" leads to its identification as a quantifier which projects an object head in which it functions as a modifier (abbrev. "mod"). The object head is integrated as the head of the object referring expression, even though the object head does not actually contain a head at this point. The modifier "two" projects the number feature *plural* and the person feature *third* to the object referring expression.

Why is it necessary to project an object head in this example? Why not have the head slot of the object referring expression expand into a modifier and a head (when the head occurs)? Because the head slot of the object referring expression can only be filled with a single value, whereas the object head construction has multiple slots (including a modifier and head slot) each of which can be filled wit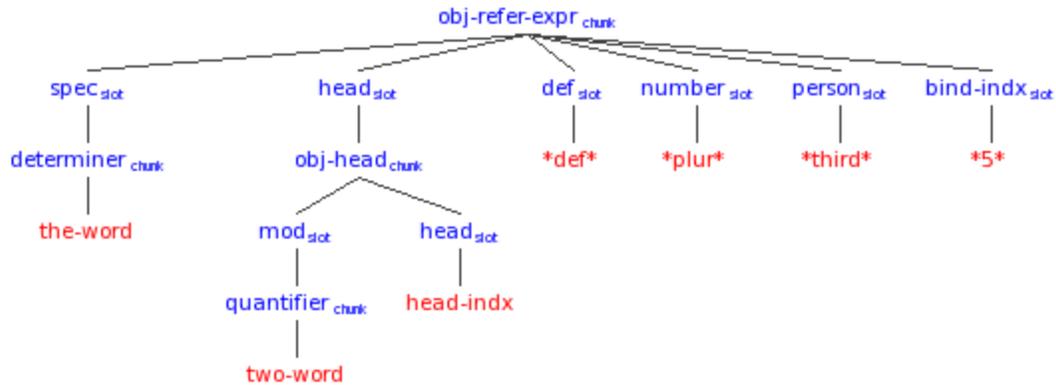h a single value. Although the value of a slot is limited to a single value, that value can be a construction with arbitrary complexity of its own. In this case, what gets put in the slot is the name of the construction not the contents of the construction (i.e. in the diagram the value obj-head in the head slot should really be Obj-head-1 which names the obj-head chunk that fills the slot). The diagram above disguises this level of indirection via the single links from slots to the values of slots that are chunks (e.g., from the head slot of the object referring expression chunk to the obj-head construction). This representational commitment, which stems from the ACT-R cognitive architecture (Anderson, 2007) in which the model is implemented and also aligns with construction grammar, differs from approaches like HPSG in which the value of an attribute can be a complex structure and not just the name of a complex structure. However, as Sag (2010, p.23) notes, Minimal Recursion Semantics which he adopts as the semantic component of his Sign Based Construction Grammar (SBCG) differs from HPSG and the syntactic component of SBCG in not nesting structures within structures: "This 'flat' conception of semantics simulates embedding by identifying the value of a feature in one frame with the label that identifies another frame". The ACT-R cognitive architecture works similarly, substituting the term "chunk" for the term "frame", the term "slot" for the term "feature", and the term "chunk name" for the term "label". The tree diagrams disguise this lack of direct embedding, but they are more convenient to examine than the raw chunks.

"the two books" →
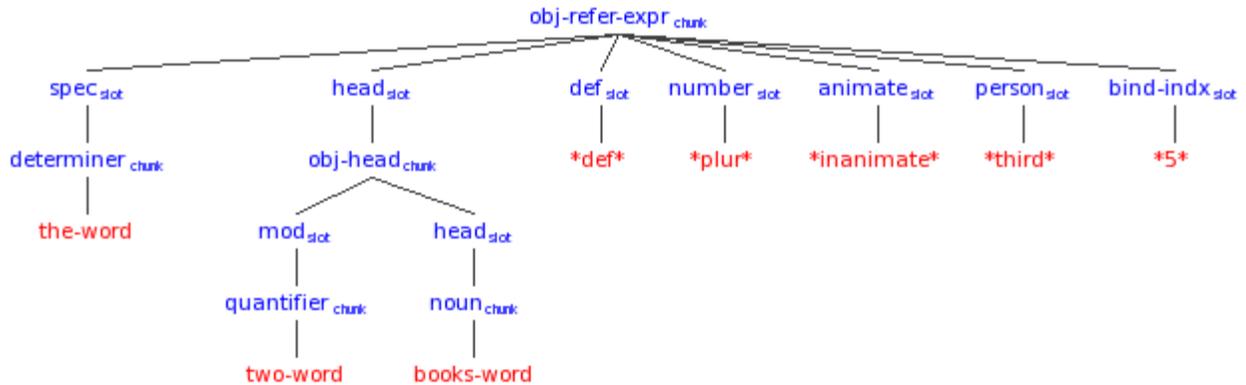
"the two books" tree

```
                              obj-refer-expr chunk
         ┌──────────┬────────────┬──────┬──────────┬──────────┬──────────┐
      spec slot   head slot    def slot number slot animate slot person slot bind-indx slot
         │          │            │        │          │          │          │
    determiner chunk obj-head chunk *def*  *plur*   *inanimate* *third*    *5*
         │          │
     the-word    ┌──┴──┐
              mod slot  head slot
                 │         │
           quantifier chunk noun chunk
                 │         │
             two-word  books-word
```

The processing of "books" leads to its identification as a noun and integration as the head of the object head which is functioning as the head of the object referring expression. The head "books" projects the features *plural, inanimate* and *third* to the object referring expression, overriding the *plural* and *third* features projected by "two" with the same value. "Books" does not project a gender feature since it is *inanimate*. The projection of the *indefinite* feature of "books" is blocked by "the". *Feature blocking* is another form of context accommodation.

The processing of "two books" differs in important respects from "the two books". In particular, in the absence of a determiner, the quantifier "two" projects an object referring expression in which it functions as a specifier as shown below:

"two" →

```
                          obj-refer-expr chunk
         ┌────────────┬───────┬──────────┬──────────┬──────────┐
      spec slot    head slot def slot number slot person slot bind-indx slot
         │            │        │         │          │          │
   quantifier chunk head-indx *indef*  *plur*    *third*     *5*
         │
     two-word
```
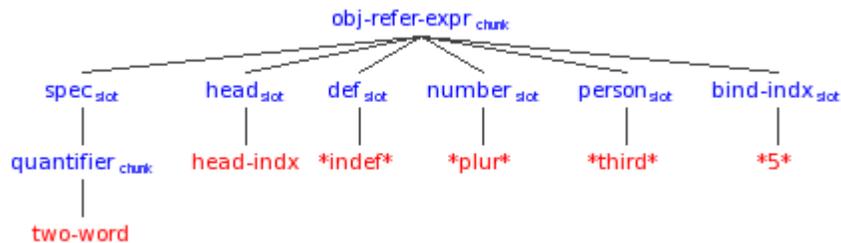
Determining the function of a lexical item is context dependent. Quantifiers can function as specifiers or modifiers, and perhaps even heads under some conditions. "Two" also projects the grammatical features *indefinite*, *plural* and *third* to the object referring expression. Note that projection of the definiteness feature *indefinite* was blocked in "the two books" since the specifier is the primary determiner of definiteness.

"two books" →

obj-refer-expr ₍chunk₎

spec ₍slot₎   head ₍slot₎   def ₍slot₎   number ₍slot₎   animate ₍slot₎   person ₍slot₎   bind-indx ₍slot₎

quantifier ₍chunk₎   noun ₍chunk₎   *indef*   *plur*   *inanimate*   *third*   *5*

two-word   books-word
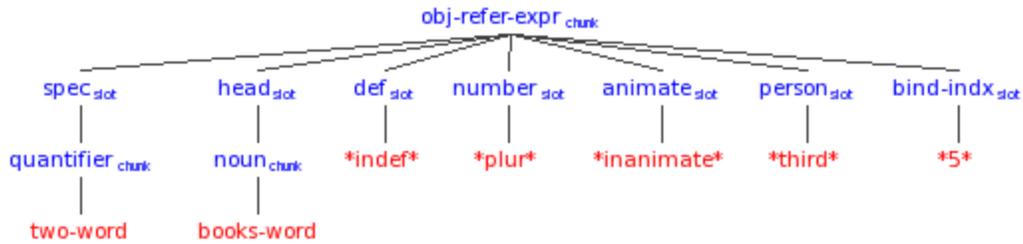
The processing of "books" leads to its identification as a noun which functions as the head of the object referring expression. "Books" also projects the grammatical features *inanimate*, *plural* and *third*, overriding the *plural* and *third* features projected by "two". The *indefinite* feature of "books" is blocked by the corresponding feature for "two".

The processing of "his book" proceeds as follows:

"his" →

pron-obj-refer-expr ₍chunk₎

spec ₍slot₎   head ₍slot₎   def ₍slot₎   number ₍slot₎   animate ₍slot₎   person ₍slot₎   bind-indx ₍slot₎

poss-obj-spec ₍chunk₎   head-indx   *def*   *sing*   *inanimate*   *third*   *6*

head ₍slot₎   def ₍slot₎   number ₍slot₎   animate ₍slot₎   gender ₍slot₎   person ₍slot₎   case ₍slot₎   bind-indx ₍slot₎

poss-pron ₍chunk₎   *def*   *sing*   *human*   *male*   *third*   *gen*   *5*

his-word

The possessive pronoun "his" (abbreviated "poss-pron") projects a possessive object specifier (abbreviated "poss-obj-spec") which is a special type of object referring expression that can function as a specifier. Although "his" is categorized as a possessive pronoun, it contains a subtype slot (not shown) that indicates its normal use as a specifier. That is, "his" functions more like a possessive determiner than a possessive p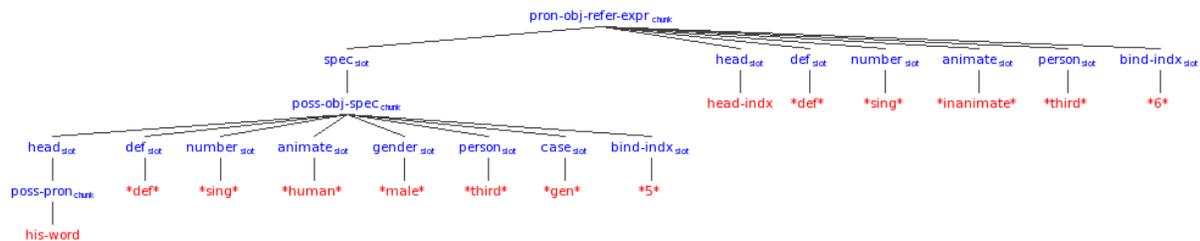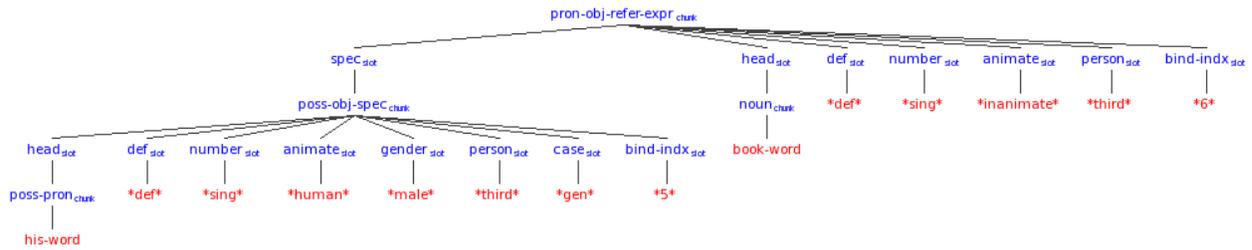ronoun. The possessive object specifier in turn projects a higher level pronoun object referring expression and functions as the specifier. The *definite* feature of the possessive object specifier is projected to the higher level object referring expression. None of the other features of "his" project to the higher level object referring expression, however, by default, the features *singular*, *inanimate* and *third* are projected to the pronoun object referring expression. Note that although "his" has the feature *human*, the projected pronoun object referring expression has the feature *inanimate*. In an expression like "I like his", the implicit head of the pronoun object referring expression projected by "his" is presumed to be *inanimate* (although this preference can be overridden by the actual referent as in "We all have wives. I like *his*. She is nice.). Note also that there are two distinct bind indexes to support co-reference to either object referring expression (e.g. "John likes his wife. He met her at school."). A recent modification to the model allows "his" to project directly to a pronoun object referring expression without first projecting a possessive object specifier (via retrieval of a pronoun object referring expression from DM). The projected pronoun object referring expression has the possessive object specifier headed by "his" functioning as the specifier. This modification simplifies processing and speeds up the model.

"his book" →

The tree diagram (first):
- pron-obj-refer-expr_chunk
  - spec_slot
    - poss-obj-spec_chunk
      - head_slot
        - poss-pron_chunk
          - his-word
      - def_slot → *def*
      - number_slot → *sing*
      - animate_slot → *human*
      - gender_slot → *male*
      - person_slot → *third*
      - case_slot → *gen*
      - bind-indx_slot → *5*
  - head_slot
    - noun_chunk
      - book-word
  - def_slot → *def*
  - number_slot → *sing*
  - animate_slot → *inanimate*
  - person_slot → *third*
  - bind-indx_slot → *6*

The word "book" is identified as a noun and integrated as the head of the higher level object referring expression projected by "his". The features *singular*, *inanimate* and *third* are projected to the higher level object referring expression.

The pronoun "her" differs from "his" in that it can function as both a personal pronoun and a possessive pronoun (e.g., "I like her" vs. "I like her book"). Whereas "her" alone functions as a personal pronoun, "his" alone does not. In "I like his", "his" is functioning as a possessive pronoun, not a personal pronoun. At the processing of the word "her", it is treated as a personal pronoun (abbreviated "pers-pron") and functions as the head of an object referring expression. (Note that like "the", "her" leads directly to retrieval of a pronoun object referring expression without the need to separately determine the part of speech of "her".)

"her" →

The tree diagram (second):
- pron-obj-refer-expr_chunk
  - head_slot
    - pers-pron_chunk
      - her-word
  - def_slot → *def*
  - number_slot → *sing*
  - animate_slot → *human*
  - gender_slot → *female*
  - person_slot → *third*
  - case_slot → *obj*
  - bind-indx_slot → *5*
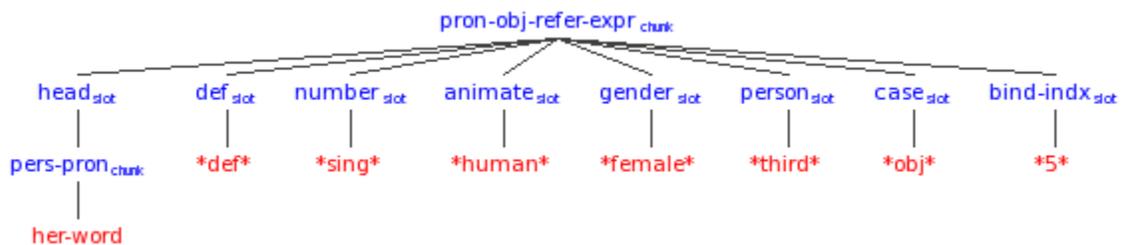
"Her" also projects an objective case feature (abbreviated *obj*) and is subcategorized as a pronoun-with-case (not shown in the diagram).

If "her" is followed by "book", a higher level object referring expression is projected and "her" is shifted into a specifier function, so "book" can function as the higher level head:

"her book" →

pron-obj-refer-expr chunk

spec slot — head slot — def slot — number slot — animate slot — person slot — bind-indx slot

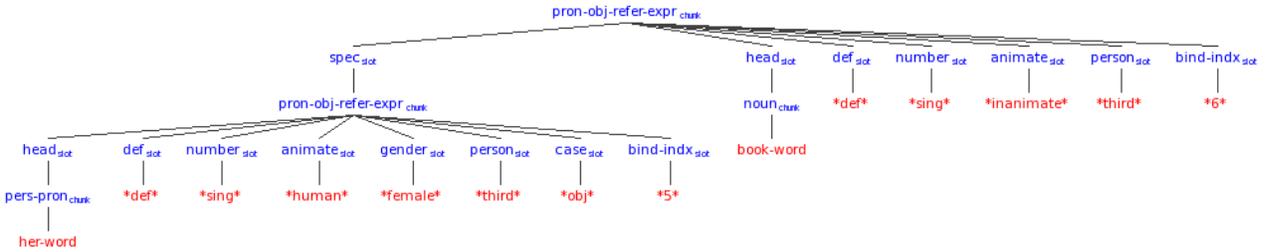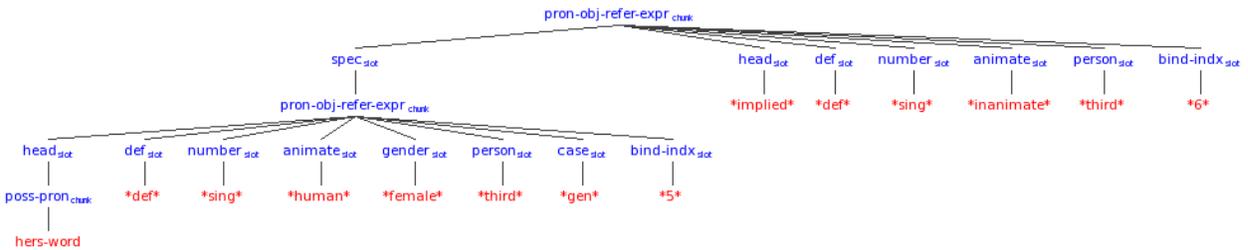pron-obj-refer-expr chunk — noun chunk — *def* — *sing* — *inanimate* — *third* — *6*

head slot — def slot — number slot — animate slot — gender slot — person slot — case slot — bind-indx slot — book-word

pers-pron chunk — *def* — *sing* — *human* — *female* — *third* — *obj* — *5*

her-word

From a processing perspective, the primary difference between "his" and "her" is that "his" immediately projects a higher level object referring expression and functions as a specifier within the higher level expression—setting up the expectation for a head—whereas "her" does not.
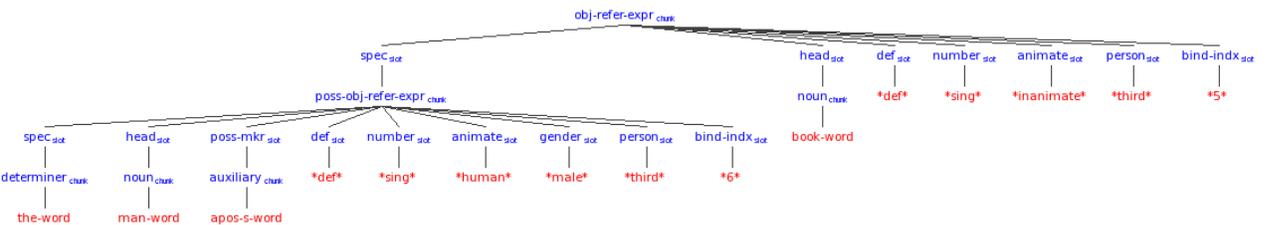
The possessive pronoun "hers" differs from "his" in that there is no expectation for the occurrence of a head in the higher level object referring expression (e.g. "*hers book" vs. "his book"). This grammatical difference is reflected in the subtype slot for these two possessive pronouns (not shown in the diagram). The lack of a head in the higher level object referring expression is indicated by marking the head as "*implied*" (a similar approach is adopted in the treatment of the implied subject of imperative statements):

"hers" →

pron-obj-refer-expr chunk

spec slot — head slot — def slot — number slot — animate slot — person slot — bind-indx slot

pron-obj-refer-expr chunk — *implied* — *def* — *sing* — *inanimate* — *third* — *6*

head slot — def slot — number slot — animate slot — gender slot — person slot — case slot — bind-indx slot

poss-pron chunk — *def* — *sing* — *human* — *female* — *third* — *gen* — *5*

hers-word

The processing of the possessive object referring expression "the man's book" leads to the following representation:

"the man's book" →

obj-refer-expr chunk

spec slot — head slot — def slot — number slot — animate slot — person slot — bind-indx slot

poss-obj-refer-expr chunk — noun chunk — *def* — *sing* — *inanimate* — *third* — *5*

spec slot — head slot — poss-mkr slot — def slot — number slot — animate slot — gender slot — person slot — bind-indx slot — book-word

determiner chunk — noun chunk — auxiliary chunk — *def* — *sing* — *human* — *male* — *third* — *6*

the-word — man-word — apos-s-word

It should be noted that the possessive object referring expression (abbreviated poss-obj-refer-expr) is not projected until the noun "book" is processed due to the ambiguity of "'s" (e.g., "the man's book" vs. "the man's going"). At the time it is processed, "'s" is identified as an auxiliary, but its processing is delayed. This is one of the few places in which the model delays determination of the function of a word until the subsequent context is available—due to the

major difference between projecting an object referring expression (i.e., nominal) and projecting a situation referring expression (i.e., clause). However, note the possibility of having to switch back from a clausal to a nominal analysis in "the man's going was a surprise" (this example is not currently handled by the model). In the processing of "book", after it is identified as a noun, and in the context of "'s" and the object referring expression "the man", an object referring expression is projected in which "book" functions as the head and "the man's", a possessive object referring expression, functions as the specifier. In this possessive object referring expression, "'s" functions as a possessive marker (abbreviated "poss-mkr"). To avoid the need for a separate retrieval, "'s" currently retains its classification as an auxiliary. The *definite* feature of the possessive object referring expression is projected to the higher level object referring expression. The processing of the noun "book" also projects the features *singular*, *inanimate* and *third*. Note that this treatment of possessive object referring expressions aligns with the treatment of possessive pronouns and is grammatically consistent with the cliticization of the possessive marker on the preceding nominal. An earlier analysis treated "the man" as a reference point and the possessive marker as a specifier within the higher level object referring expression. That analysis was less consistent with the treatment of possessive pronouns than the current analysis. However, the current treatments still differ in that possessive pronouns like "hers" do not allow a higher level head "*hers book". In this respect, nominals marked with the possessive marker (e.g. "the man's") behave more like possessive determiners (e.g. "my") than possessive pronouns (e.g. "hers"), despite the morphological similarity between "'s" and the "s" of some possessive pronouns.

The processing of the mass noun "rice" proceeds as follows:

"rice" →
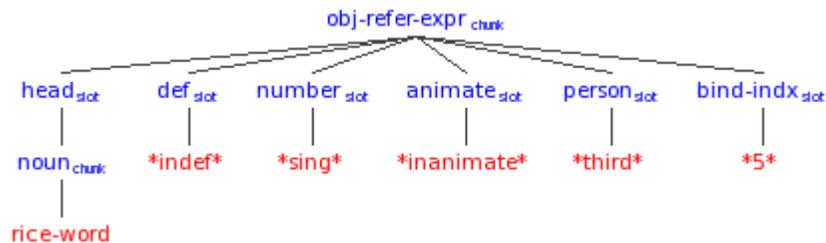
The word "rice" is identified as a noun. In the absence of an object referring expression, the noun "rice" projects an object referring expression and is integrated as the head. Because "rice" is a mass noun, the definite feature is set to the value *indefinite* and number feature is set to the value *singular* (mass nouns are grammatically *singular* in English). The categorization of "rice" as a mass noun is indicated via a subtype slot (not shown in the diagram).

The processing of "the rice" differs in that the *definite* feature of "the" is projected to the nominal, blocking the *indefinite* feature of "rice".
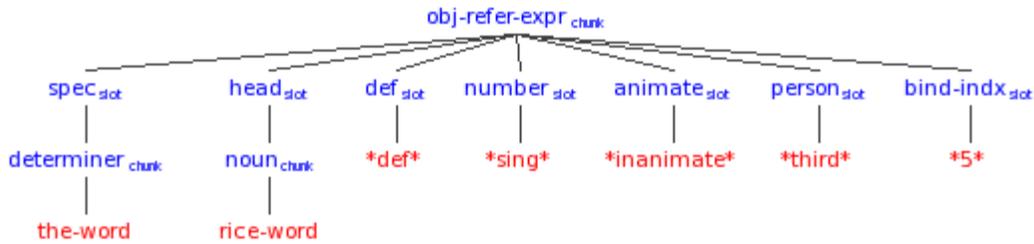
The processing of the isolated singular count noun "man" leads to the following:
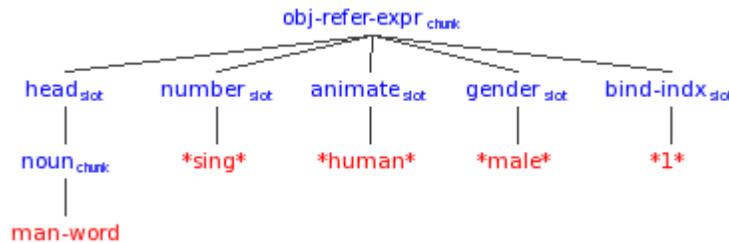
The word "man" is identified as a noun and in the absence of an object referring expression in which it can be integrated, it also projects an object referring expression. However, note that the object referring expression lacks a definite feature which is normally required. Construal processes operating over this object referring expression might add additional grammatical features like *indefinite* and might identify the noun as a *mass* noun as occurs in universal grinder constructions like "there is man all over the rug" (Pelletier, 1975).

If adjectives functioning as modifiers do not project grammatical features, then the expression "old man" also lacks a marking for definiteness. Consider

"old man" →
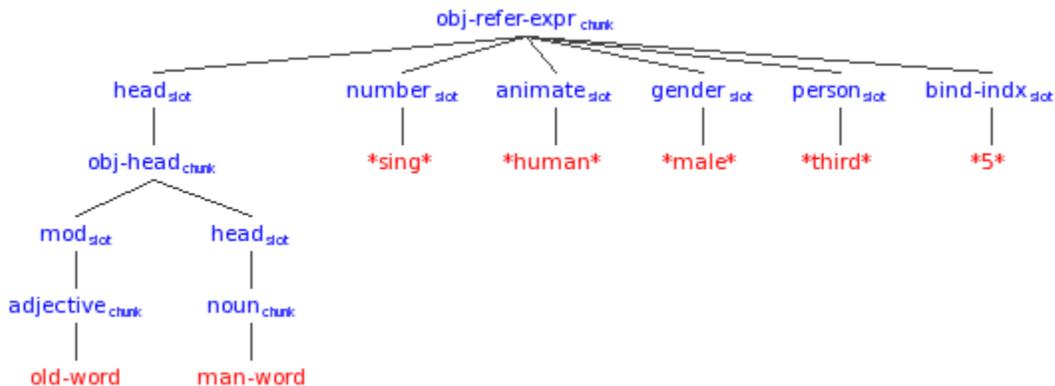
In this example, "old" is identified as an adjective that projects an object head in which it is integrated as a modifier. The object head in turn projects an object referring expression in which the object head is integrated as the head. However, the object referring expression lacks a definiteness feature.

On the other hand, if the input is "the old", the object referring expression is marked as *definite*, but it lacks a number and person feature as well as a head.

"the old" →
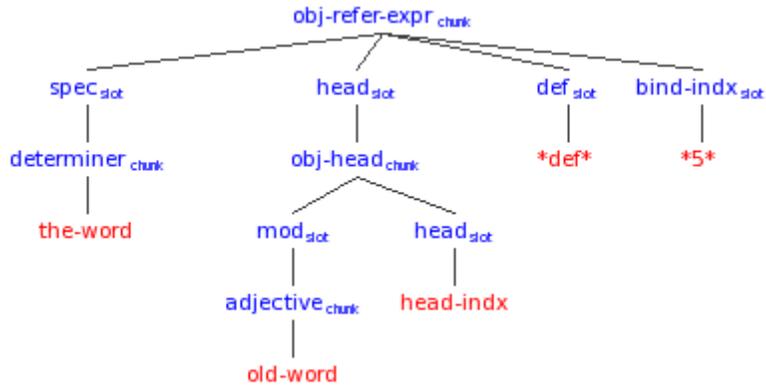
If we add a head as in "the old man" we finally get a fully specified object referring expression.

"the old man" →
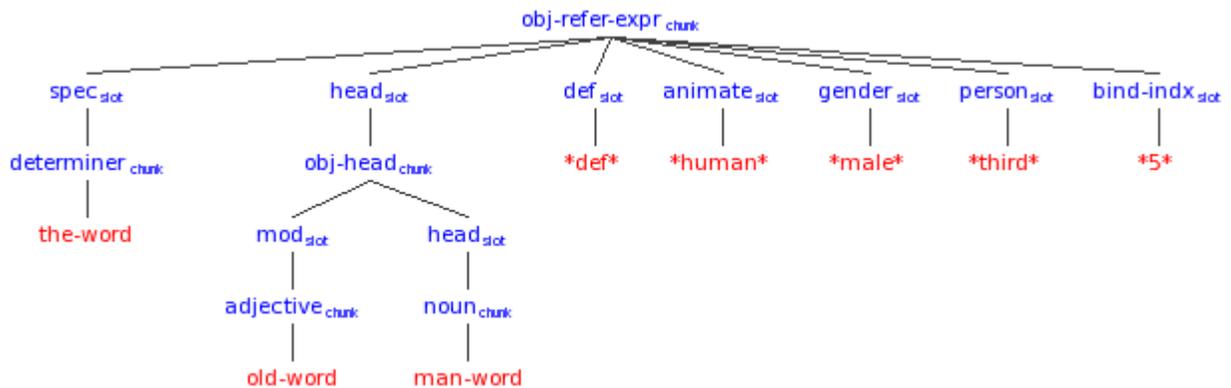
As a more complex example, consider the processing of the nominal "no target airspeed or altitude restrictions"

"no" →
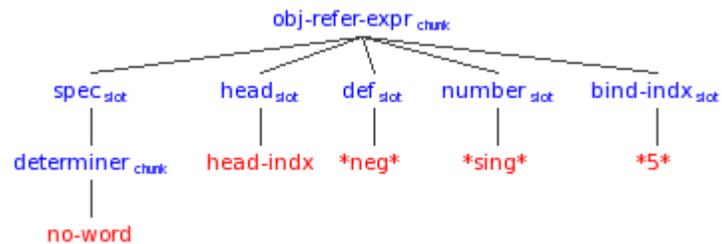
The processing of the word "no" leads to retrieval of an object referring expression in which "no" is identified as a (negative) determiner that functions as a specifier. "No" is a special determiner that projects the definiteness feature *negative* (abbreviated "*neg*"). The categorization of "no" as a determiner is based on its grammatical behavior. Like the determiner "the", "no" provides an indication of definiteness. Also like "the", "no" combines with heads which may be either singular or plural as in "no **one is** here" and "no **books are** on the table". Based on this, we assume that "no" does not project a number feature. Finally, like "the", "no" does not occur alone as a nominal—which is related to the fact that "no" does not project a number or person feature. Overall, the grammatical behavior of "no" is closer to that of the determiner "the" than it is to quantifiers like "all" and "some" (previously "no" was treated as a quantifier). On the other han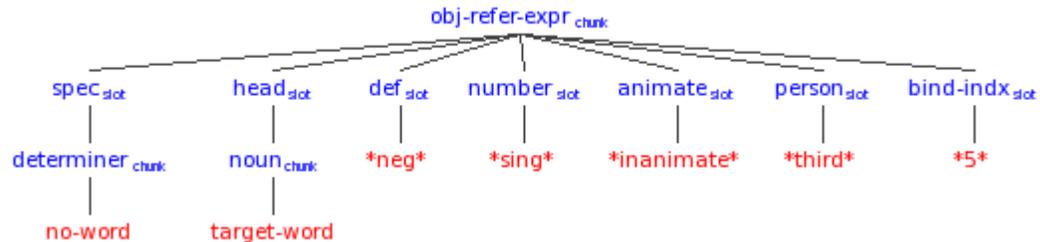d, "none" (i.e., "no" + "one") behaves more like a quantifier in encoding a *plural* number feature and occurring alone as a nominal (e.g., "None are here"). Grammatical motivation for why "none" is *plural* and not *singular*, whereas "no one" is *singular* (e.g., "No one is here"), is an open research question.

"no target" →

The processing of "target" leads to its identification as a noun and integration as the head of the object referring expression retrieved for "no". "Target" also projects the number feature *singular*, the animacy feature *inanimate* and the person feature *third*. In parallel, "target" also projects an object head in which it is integrated as the head to support the processing of more complex object referring expressions. The primary reason for projecting an object head in parallel is for efficiency of processing when a more complex input occurs. Although not discussed previously, this is the default behavior for all noun heads of object referring expressions—even when an object head has already been projected by a pre-head modifier (e.g. "the previous target"). The primary, but less efficient, alternative is to wait until the additional structure is needed to project it.

"no target airspeed" →

obj-refer-expr chunk

spec slot   head slot   def slot   number slot   animate slot   person slot   bind-indx slot

determiner chunk   obj-head chunk   *neg*   *sing*   *inanimate*   *third*   *5*

no-word   mod slot   head slot
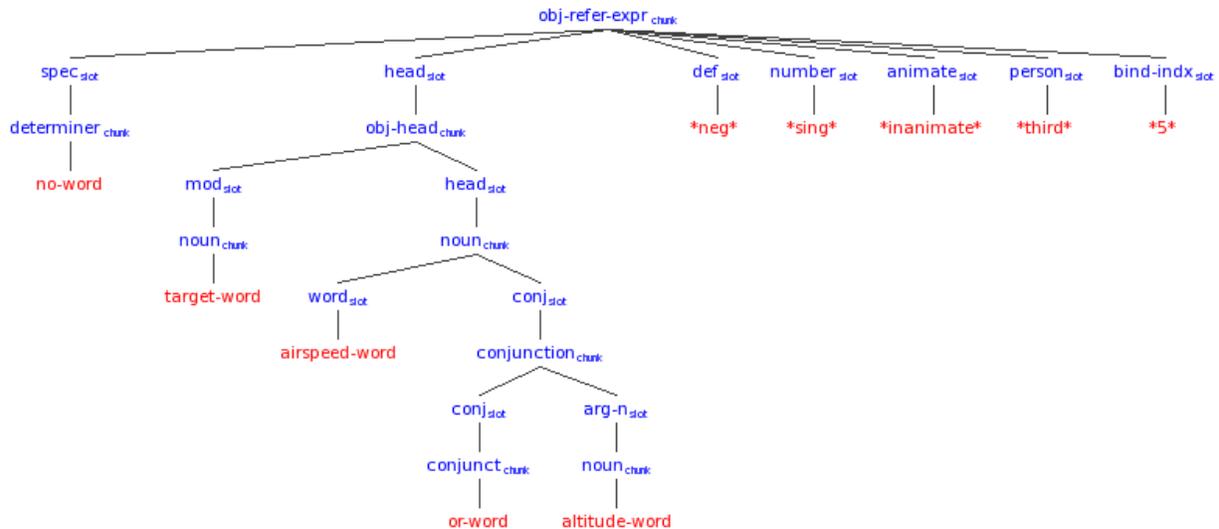
noun chunk   noun chunk

target-word   airspeed-word
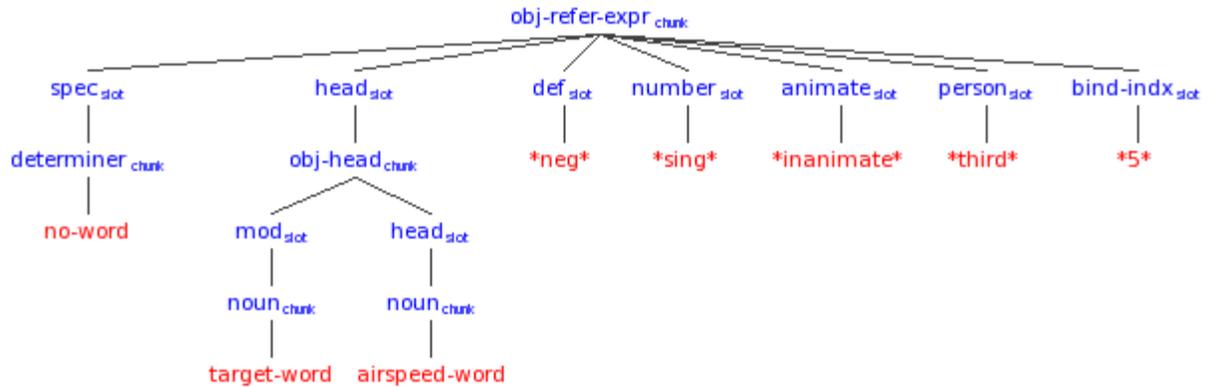
The processing of the noun "airspeed" following "target" leads to substitution of the object head projected in parallel by "target" as the head of the object referring expression retrieved for "no". In addition, "target" is shifted from the head of the object head to a modifier function so that "airspeed" can be integrated as the head of the object head which is the head of the overall object referring expression. "Airspeed" projects the number feature *singular*, the animacy feature *inanimate*, and the person feature *third*, which override the features projected by "target". All of this accommodation occurs within the context of a single production. If "target" had not projected an object head in parallel with its integration as the head of the object referring expression retrieved for "no", then it would be necessary to project an object head at the time "airspeed" is processed and then substitute the object head for "target". ACT-R does not provide a capability to project or retrieve a new structure and simultaneously integrate the new structure within the context of a single production. Given the rapidity of human language processing, we assume some limited parallelism is supported within the incremental, serial processor; however, the amount of parallelism must be highly constrained. In particular, the ability to build multiple structures in parallel within the serial processing mechanism is assumed to be highly limited.

In parallel with the integration of "airspeed" into the object head projected by "target", "airspeed" projects an object head in which it functions as the head to support the processing of even more complex input.

"no target airspeed or" →

The processing of the disjunction "or" leads to retrieval of a conjunction chunk and its addition to working memory via storage in a specialized conjunct buffer, since the category of the first conjunct of a conjunction cannot be effectively determined until the linguistic element after the conjunction is processed—due to rampant ambiguity associated with conjunctions (compare "the man and woman" vs. "the man and the woman" vs. "the red and blue ball" vs. "the red and the blue ball" vs. "the high and the mighty", etc.). This is another example of delay in processing and it can cause processing problems (e.g., overloading of working memory which has a limited capacity) if the status of the conjuncts is not quickly resolved.

"no target airspeed or altitude" →

```
                                    obj-refer-expr chunk
        ┌──────────────┬──────────────────────┬─────────┬──────────┬────────────┬──────────┬──────────────┐
     spec slot       head slot              def slot  number slot  animate slot  person slot  bind-indx slot
        │               │                     │         │            │            │             │
  determiner chunk   obj-head chunk          *neg*    *sing*    *inanimate*    *third*          *5*
        │          ┌───────────┐
    no-word      mod slot   head slot
                   │           │
               noun chunk   noun chunk
                   │      ┌──────────┐
             target-word  word slot  conj slot
                             │          │
                      airspeed-word  conjunction chunk
                                   ┌──────────┐
                                conj slot   arg-n slot
                                   │           │
                              conjunct chunk  noun chunk
                                   │           │
                               or-word     altitude-word
```

The processing of the noun "altitude" in the context of the disjunction "or" and the nominal "no target airspeed" with head noun "airspeed" results in the integration of "altitude" via the conjunct (abbrev. "conj") slot of the "airspeed" noun chunk, resulting in the complex noun "airspeed or altitude". Note that all linguistic chunk types, including parts of speech, have a conjunct slot to support the processing of conjunctions (although this slot has not been displayed before now). In this case, the noun "altitude" is integrated into the final argument slot (abbrev. "arg-n") of the conjunction chunk in working memory, and the conjunction chunk is integrated into the conj slot of the noun "airspeed" chunk. Although "airspeed or altitude" is labeled a conjunction, it projects the number feature *singular* not *plural* because it contains the disjunction "or" (e.g., "no target airspeed **or** altitude **is** specified"). If the input had been "airspeed and altitude" the *plural* number feature would have been projected by the conjunction "and" (e.g., "no target airspeed **and** altitude **are** specified"). Conjunctions provide additional evidence for the projection of grammatical features from non-heads. Further, if either of the disjuncts is *plural* (e.g., "apples **or** pears **are** available"), then the overall nominal is *plural* despite the disjunct. Overall, the *singular* feature of the disjunction "or" is (or, at least, may be) blocked by the *plural* feature of any preceding disjuncts and overridden by the *plural* feature of the last disjunct (compare "rice, barley **or** wheat **is** available" vs. "beans, rice **or** barley **are** available" vs. "rice, barley **or** beans **are** available"), whereas the *plural* feature of the conjunction "and" overrides the *singular* feature of any preceding conjuncts and blocks the *singular* feature of the last conjunct (e.g., "rice, barley **and** wheat **are** available").

"no target airspeed or altitude restrictions" →

obj-refer-expr chunk

spec slot   head slot   def slot   number slot   animate slot   person slot   bind-indx slot

determiner chunk   obj-head chunk   *neg*   *plur*   *inanimate*   *third*   *5*

no-word   mod slot   head slot

noun chunk   obj-head chunk

target-word   mod slot   head slot

noun chunk   noun chunk

word slot   conj slot   restrictions-word

airspeed-word   conjunction chunk

conj slot   arg-n slot

conjunct chunk   noun chunk

or-word   altitude-word

The processing of the noun "restrictions" in the context of the object referring expression "no target airspeed or altitude" results in substitution of the object head projected in parallel by "airspeed" as the head of the object head projected by "target". In addition, the complex noun "airspeed or altitude" is shifted into a modifier function to allow "restrictions" to function as the head. In the current implementation, an object head is a construction which contains four important slots: 1) a pre-head modifier (labeled "mod" above), 2) a head, 3) a post-head modifier (labeled "post-mod", but not shown in the diagram since it is empty), and 4) a conjunction slot (also not shown). The existence of the pre-head modifier slot supports function shifting at no additional cost relative to normal integration. There is no need to adjoin a modifier tree as in Tree Adjoining Grammar (Joshi, 1987), or modify the existing structure above the modifier slot. A production which both shifts the existing head into the modifier slot and integrates the new head competes with a production which merely integrates the new head into the empty head slot. The *plural* number feature of "restrictions" is also projected to the object referring expression, overriding the previous *singular* number feature.

Summary and Conclusion

A localist theory of the representation and projection of grammatical features in nominals has been presented in which words and phrases functioning as specifiers, heads, and modifiers (and conjuncts) project grammatical features to encompassing nominals. Grammatical features may be redundantly encoded in words and phrases fulfilling different grammatical functions within the nominal, and these redundantly encoded grammatical features may occasionally conflict. Non-monotonic mechanisms of blocking and overriding of features were presented for handling conflicts. Blocking occurs when a grammatical feature projected by a preceding functional unit is primary, whereas overriding occurs when a grammatical feature projected by a subsequent functional unit is primary. Blocking and overriding are basic non-monotonic processes which are deemed necessary in a serial, incremental language processing system, which we take the human language processor to be. These mechanisms are inconsistent with unification based approaches to grammatical analysis (e.g. HPSG) since they involve conflicts which would lead to unification failure. These non-monotonic mechanisms are exemplars of a more general context accommodation capability for dealing with expectations in processing which are not realized, resulting in accommodation via adjustment of the evolving representation or construal of the **to be integrated** linguistic element as being of the appropriate functional type—as in construal of

the infinitive phrase "to be integrated" as a modifier of the nominal head "linguistic element" in this sentence. The mechanisms described in this paper are part of normal processing and are not viewed as exceptional.

The grammatical features described in this paper and implemented in the computational cognitive model are largely motivated by functional considerations—i.e., by the need to be able to generate a representation of the linguistic input which facilitates the mapping into a representation of the situation described by the linguistic input—what is called a **situation model** (Kintsch, 1998) or **mental model** (Johnson-Laird, 1983). For example, the definiteness feature is crucial to determining the referent of a nomimal. If the nominal is *definite*, then either a referent has already been introduced into the situation model, or the referent is somehow salient in the context. If the nominal is *indefinite*, then a new referent may need to be introduced into the situation model. The number, animacy, gender and person features are crucial to determining co-reference (Ball, in preparation), especially with respect to the use of pronouns and trace or implied elements. Subjective and objective case features may be useful for identifying the subject and object of a clause.

Number agreement is also helpful in identifying the subject. For example, in "There are some books on the table", the number agreement between "are" and "some books" provides grammatical evidence that "some books" is the subject—despite its non-canonical position in this sentence (although this position is not widely adopted). In the model "there" is treated as a focus element, but is not the subject of the sentence. There are several non-subject focus elements which occur in English. In "Where could there have been a boy kicking a ball", the model treats "a boy" as the subject despite its being preceded by numerous linguistic elements and lacking an indication of subject-verb agreement. In this example, "where" functions as a wh-focus element, "could" functions as an operator, "there" functions as an existential-there element, "have been" functions as the specifier (which combines with the operator to provide the overall specification), "a boy" functions as the subject" and "kicking a ball" functions as the clausal head.

Although it is argued above that the person feature is not needed for subject-verb agreement—with the exception of first-person singular agreement, the person feature is needed to establish co-reference. The genitive feature of possessive pronouns (e.g. "my", "mine") and the possessive marker "'s" establish a reference point with respect to which a secondary referent can be identified. Although grammatical features do not always map neatly to the corresponding conceptual features of referents, they provide useful information for establishing reference and determining meaning.

The larger context for this research is a focus on the development of a language analysis system that is at once cognitively plausible and functional (Ball, 2011a; Ball, et al., 2010; Ball, Heiberg & Silber, 2007). Despite the fact that the only existing exemplar of a functional language comprehension capability is the human language processor, there is too little research on the relevance and value of cognitive constraints and human language processing within computational linguistics. We are in a phase of computational linguistic research in which the use of statistical and machine learning techniques, which have limited cognitive and linguistic validity, predominate. Such approaches have achieved impressive gains and may ultimately succeed in developing human level language comprehension capabilities, but there is room for more research that is less focused on powerful computational techniques and more focused on traditional analysis of linguistic and cognitive phenomena and their utility for language comprehension.

Appendix I contains tables listing basic nominal elements and the grammatical features which they project.

References

Abney, S. P. (1987). *The English noun phrase in its sentential aspect* (Doctoral dissertation). Massachusetts Institute of Technology, Cambridge, MA.

Altmann, G. (1998). Ambiguity in sentence processing. *Trends in Cognitive Sciences*, *2*(4), 146-152.

Altmann, G. & Mirkovic, J. (2009). Incrementality and Prediction in Human Sentence Processing. *Cognitive Science*, 222, 583-609.

Altmann, G., & Steedman, M. (1988). Interaction with context during human sentence processing. *Cognition*, *30*, 191-238.

Anderson, J. R. (2007). *How Can the Human Mind Occur in the Physical Universe?* NY: Oxford University Press.

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S, Lebiere, C, & Qin, Y. (2004). An Integrated Theory of the Mind. *Psychological Review, 111*(4), 1036-1060.

Ball, J. (in preparation). The Representation and Processing of Referring Expressions in Double-R – Binding and Co-Reference.

Ball, J. (2012). Explorations in ACT-R Based Language Analysis – Memory Chunk Activation, Retrieval and Verification without Inhibition. In N. Russwinkel, U. Drewitz & H. van Rijn (eds), *Proceedings of the 11th International Conference on Cognitive Modeling*, 131-136. Berlin: Universitaets der TU Berlin.

Ball, J. (2011a). A Pseudo-Deterministic Model of Human Language Processing. In L. Carlson, C. Hölscher, & T. Shipley (Eds.), *Proceedings of the 33rd Annual Conference of the Cognitive Science Society*, 495-500. Austin, TX: Cognitive Science Society.

Ball, J. (2011b). Explorations in ACT-R Based Cognitive Modeling – Chunks, Inheritance, Production Matching and Memory in Language Analysis. *Proceedings of the AAAI Fall Symposium: Advances in Cognitive Systems*, 10-17. Arlington, VA: AAAI.

Ball, J. (2010a). Simplifying the Mapping from Referring Expression to Referent in a Conceptual Semantics of Reference. *Proceedings of the 32nd Annual Meeting of the Cognitive Science Society.*

Ball, J. (2010b). Context Accommodation in Human Language Processing. *Proceedings of the 7th International Workshop on Natural Language Processing and Cognitive Science*. Portugal: SciTePress.

Ball, J. (2007a). A Bi-Polar Theory of Nominal and Clause Structure and Function. *Annual Review of Cognitive Linguistics*, *5*(1), 27-54. Amsterdam: John Benjamins.

Ball, J. (2007b). Construction-Driven Language Processing. In S. Vosniadou, D. Kayser, & A. Protopapas (Eds.), *Proceedings of the 2nd European Cognitive Science Conference* (pp. 722-727). NY: LEA.

Ball, J. (1992). *PM, Propositional Model, a Computational Psycholinguistic Model of Language Comprehension Based on a Relational Analysis of Written Englis*h. Ann Arbor, MI: UMI Dissertation Information Service.

Ball, J., Freiman, M., Rodgers, S. & Myers, C. (2010). Toward a Functional Model of Human Language Processing. *Proceedings of the 32nd Annual Meeting of the Cognitive Science Society*

Ball, J., Heiberg, A., & Silber, R. (2007). Toward a Large-Scale Model of Language Comprehension in ACT-R 6. In R. Lewis, T. Polk & J. Laird (Eds.) *Proceedings of the 8th International Conference on Cognitive Modeling* (pp. 173-179). NY: Psychology Press.

Bever, T. (1970). The cognitive basis for linguistic structures. In J. Hayes (Ed.), *Cognition and the development of language* (pp. 279-362). New York: Wiley.

Biber, D., Conrad, S., & Leech, G. N. (2002). *Longman Student Grammar of Spoken and Written English*. Harlow, Essec: Longman.

Bloomfield, L. (1933). *Language*. New York: Holt, Rinehart & Winston.

Boden, M. (2006). *Mind as machine: A history of cognitive science*. New York: Oxford University Press.

Borer, H. (2003). *Zionism: Myths and the Reality.* Presentation at the 2003 Western Conference on Linguistics (WECOL), September 26, 2003, University of Arizona.

Cann, R. (1999). Specifiers as secondary heads. In D. Adger, S. Pintzuk, B. Plunkett & G. Tsoulas (Eds.) *Specifiers: Minimalist approaches* (pp. 21-45).New York: Oxford University Press.

Carroll, L., & Tenniel, J. (1872). *Through the looking-glass: And what Alice found there*. London: Macmillan and Co.

Cheng, L., & Sybesma, R. (1998). Interview with James McCawley: "What's right about X-bar syntax is the X and the bar. What's wrong is everything else!" University of Chicago. *Glot International, 3*(5).

Chomsky, N. (1970). Remarks on Nominalization. In Jacobs & Rosembaum, (Eds.), *Readings in English Transformational Grammar*. Waltham, MA: Ginn.

Chomsky, N. (1995). *The Minimalist Program*. Cambridge, MA: The MIT Press.

Crocker, M. (1999). Mechanisms for Sentence Processing. In S. Garrod, & M. Pickering (Eds.), *Language Processing*. London: Psychology Press.

Crocker, M. (2005). Rational models of comprehension: addressing the performance paradox. In A. Culter (Ed), *Twenty-First Century Psycholinguistics: Four Cornerstones.* Hillsdale: LEA.

Croft, W. (2001). *Radical construction grammar: Syntactic theory in typological perspective*. Oxford, NY: Oxford University Press.

Dixon, R. (1991). *A New Approach to English Grammar, On Semantic Principles*. Oxford: Clarendon Press.

Ericsson, K., & Kintsch, W. 1995. Long-term working memory. *Psychological Review*, *102*, 211-245.

Gibson, E., & Pearlmutter, N. (1998). Constraints on sentence comprehension. *Trends in Cognitive Sciences*, *2(*7), 262-268.

Grimshaw, J. (2000). Locality and Extended Projection. In Coopmans, P., Everaert, M., & Grimshaw, J. (Eds.), *Lexical Specification and Insertion* (pp. 115-133). Philadelphia: John Benjamins,

Heiberg, A., Harris, J., & Ball, J. (2007). Dynamic Visualization of ACT-R Declarative Memory Structure. In *Proceedings of the 8th International Conference on Cognitive Modeling, July 27-29, 2007, Ann Arbor, Michigan* (pp. 233-234). Oxford, UK: Taylor & Francis/Psychology Press.

Huddleston, R. D., & Pullum, G. K. (2002). *The Cambridge Grammar of the English Language*. New York: Cambridge University Press.

Jackendoff, R. (1977). *X-Bar Syntax: A Study of Phrase Structure*. Cambridge, MA: The MIT Press.

Johnson-Laird, P. (1983). *Mental Models: Towards a cognitive science of language, interence and consciousness*. New York: Cambridge University Press.

Joshi, A. (1987). An introduction to tree adjoining grammars. In A. Manaster-Ramer (Ed.), *Mathematics of Language* (pp. 87-114). Amsterdam: John Benjamins.

Joshi, A. (2004). Starting with complex primitives pays off: complicate locally, simplify globally. *Cognitive Science*, 28, 637-668.

Kim, A., Srinivas, B., & Trueswell, J. (2002). A computational model of the grammatical aspects of word recognition as supertagging. In P. Merlo & S. Stevenson (Eds.),*The Lexical Basis of Sentence Processing: Formal, Computational and Experimental Issues* (pp. 109-135). Amsterdam: John Benjamins.

Kintsch, W. (1998). *Comprehension: a Paradigm for cognition*. New York: Cambridge University Press.

Langacker, R. (2000). Why a mind is necessary: Conceptualization, grammar and linguistic semantics. In L. Albertazzi (Ed.), *Meaning and Cognition* (pp. 25–38.). Amsterdam: John Benjamins.

Lewis, R. L. (1998). Leaping off the garden path: Reanalysis and limited repair parsing. In J. D. Fodor, & F. Ferreira (Eds.), *Reanalysis in Sentence Processing*. Boston: Kluwer Academic.

Lyons, J. (1977). *Semantics, Vols 1 & 2*. NY: Cambridge University Press.

Marcus, M. (1980). *A Theory of Syntactic Recognition for Natural Language*. Cambridge, MA: The MIT Press.

McClelland, J., & Rumelhart, D. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychologcial Review*, *88*(5), 375-407.

Novick, J., Thompson-Schill, S., & Trueswell, J. (2008). Putting lexical constraints in context into the visual-world paradigm. *Cognition*, *107*(3), 850-903.

Paap, K., Newsome, S., McDonald, J., & Schvaneveldt, R. (1982). An Activation-Verification Model of Letter and Word Recognition: The Word-Superiority Effect. *Psychological Review*, *89*, 573-594.

Pelletier, F. (1975). Non-singular reference: some preliminaries. *Philosophia*, *5,* 451-465.

Pinker, S. (2000). *Words and Rules, the Ingredients of Language*. London: Phoenix.

Pullum, G. (1991). English nominal gerunds as noun phrases with verb phrase heads. *Linguistics, 29*, 763-799.

Purver, M., Cann, R., & Kempson, R. (2006). Grammars as parsers: meeting the dialogue challenge. *Research on Language and Computation, 4*(2-3), 289-326.

Quirk, R., Greenbaum, S., Leech, G., & Svartvik, J. (1985). *A Comprehensive Grammar of the English Language*. New York: Longman.

Radford, A. (1997). *Syntactic Theory and the Structure of English*. New York: Cambridge.

Radford, A. (2004). *Minimalist Syntax, Exploring the structure of English*. New York: Cambridge.

Rodgers, S., Myers, C., Ball, J. & Freiman, M. (2012). Toward a Situation Model in a Cognitive Architecture. *Computational and Mathematical Organization Theory*.

Sag, I. (2010). Sign-Based Construction Grammar: An informal synopsis. In H. Boas & I. Sag (Eds.), *Sign-Based Construction Grammar*. Stanford: CSLI.

Sag, I. (2009). Feature Geometry and Predictions of Locality. In A. Kibort & G. Corbett (Eds.), *Features: Perspectives on a Key Notion in Linguistics*. Oxford: Clarendon Press.

Sag, I., & Wasow, T. (1999). *Syntactic Theory, a Formal Introduction*. Stanford: CSLI Publications.

Sag, I., Wasow, T., & Bender, E. (2003). *Syntactic Theory, a Formal Introduction, Second Edition*. Stanford: CSLI Publications.

Swets, B., Desmet, T., Clifton, C., & Ferreira, F. (2008). Underspecification of syntactic ambiguities: Evidence from self-paced reading. *Memory & Cognition*, *36*(1), 201-216.

Tanenhaus, M., Spivey-Knowlton, M., Eberhard, K., & Sedivy, J. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science, 268*(5217),1632-1634.

Taylor, J. (2000). *Possessives in English: An exploration in cognitive grammar*. Oxford: Oxford University Press.

Trueswell, J., & Tanenhaus, M. (1994). Towards a Lexicalist Framework of Constraint-Based Syntactic Ambiguity Resolution. In C. C. Jr., L. Frazier, & K. Rayner (Eds.), *Perspectives on Sentence Processing* (pp. 155-180.) Hillsdale, NJ: LEA.

Trueswell, J., Tanenhaus, M., & Garnsey, S. (1994). Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language*, *33*(3)*,* 285-318.

Van Eynde, F. (2006). NP-internal agreement and the structure of the noun phrase. *Journal of Linguistics*, *42,* 139-186.

Vosse, T., & Kempen, G. (2000). Syntactic structure assembly in human parsing: a computational model based on competitive inhibition and a lexicalist grammar. *Cognition, 75*(2*)*, 105–143.

Appendix I: Projection of Grammatical Features to Nominals

Determiner

The defining features of determiners are that they cannot occur alone as a nominal, they function as the specifier of the nominal they project (not the head), and they project the definiteness feature to the nominal. Given these defining features, there are very few true determiners. The classic determiners are the words "the" and "a" which are also called "articles". "No" is also treated as a determiner, rather than a quantifier, since it cannot occur alone as a nominal. Further, like "the", "no" is compatible with both singular and plural head nouns (e.g., "no book" vs. "no books") indicating that it does not project a number feature. The determiner "a/an" is unique among determiners in projecting a *singular* number feature. Despite projecting both a definiteness and a number feature, "a" cannot occur alone as a nominal.

Word	Def
The	Def
No	Neg

Word	Def	Number
A	Indef	Sing
An	Indef	Sing

Possessive (Pronoun) Determiner

Possessive determiners are a complex part of speech which projects an internal possessive nominal (possessive object referring expression) that functions as a specifier within a higher level nominal which is also projected. The possessive determiner projects the grammatical features of the pronoun from which it is derived (i.e., me → my), less the case feature, to the internal possessive nominal. These features are needed to bind the possessive nominal to its antecedent. Possessive nominals only project the feature *definite* to the encompassing nominal. We have not identified any grammatical evidence that the possessive (or genitive) feature is projected to the encompassing nominal. Possessive determiners are a subtype of possessive pronoun—they are pronouns whose typical function is that of a specifier. "Her" is unique among possessive pronouns in also being a personal pronoun and its use as a possessive pronoun is secondary to its use as a personal pronoun (i.e. "her" alone functions as a personal pronoun, but in "her book" it functions like a possessive determiner).

Word	Def
My	Def
Our	Def
Your	Def
His	Def
Her*	Def
Their	Def
Its	Def

The wh-word "whose" is special in being both a possessive determiner (which is itself a complex POS category) and a wh-word. It projects both a wh-feature and a definiteness feature, but does not project a number feature (e.g., "whose book" vs. "whose books"). We make a distinction between the definiteness feature of wh-words *wh-definite*/*wh-indefinite* and other pronouns (discussed further below).

Word	Wh	Def
Whose	Wh	Wh-Def

Personal Pronoun

Personal pronouns constitute a small, well-defined set of words that encode a broad range of grammatical features. Since they function as full nominals, they encode both a definiteness and a number feature. They also encode a person feature (from whence "personal" comes) and a case feature, although these features need not be universally encoded by all personal pronouns. The personal pronouns "you" and "it" occur in both subject and object position (e.g. "you are nice", "I like you", "it is nice", "I like it"). Rather than positing separate entries in the mental lexicon for the subject and object case, we will assume that these pronouns are unmarked for case. Similarly, only the personal pronouns "he", "him", "she" and "her" encode a gender feature. We assume that the other personal pronouns are unmarked for this feature.

Word	Def	Person	Number	Animacy	Case
I	Def	1st	Sing	Human	Subj
Me	Def	1st	Sing	Human	Obj
We	Def	1st	Plur	Human	Subj
Us	Def	1st	Plur	Human	Obj

Word	Def	Person	Number	Animacy
You	Def	2nd	Plur	Human

Word	Def	Person	Number	Animacy
It	Def	3rd	Sing	Animate

Word	Def	Person	Number	Animacy	Case
They	Def	3rd	Plur	Human	Subj
Them	Def	3rd	Plur	Human	Obj

Word	Def	Person	Number	Animacy	Gender	Case
He	Def	3rd	Sing	Human	Male	Subj
Him	Def	3rd	Sing	Human	Male	Obj
She	Def	3rd	Sing	Human	Female	Subj
Her	Def	3rd	Sing	Human	Female	Obj

The wh-words "who" and "whom" are special in that they encode some of the features of both a personal pronoun and a wh-word. However, they do not appear to be marked for number since they are compatible with singular and plural subjects (e.g., "who is he", "who are they", and "whom did he meet" where "whom" can refer to one or many people). Note that there is strong grammatical evidence (both number and case agreement) that "they" and "I" are the subjects in

"who are they" and "who am I" despite the fact that "who" occurs in the canonical subject position. By way of contrast in "who is going", there is grammatical evidence that "who" is functioning as the subject (nothing else is available) and projects a *singular* number feature. However, "?who are going" may also be acceptable and "two men who are going" is certainly acceptable. Overall, the grammatical evidence for a *singular* number feature is weak and yet "who" can certainly function like a nominal.

The wh-words "whoever" and "whomever" differ from "who" and "whom" in that they are *indefinite* rather than *definite*. Although there is a clear contrast between "who" and "whoever" which appears to be captured in terms of definiteness (e.g. "I know who you want" vs. "whoever you want"), it is less than clear what it means for a wh-word to be *definite* or *indefinite*. To distinguish the definiteness of wh-words from other words, we will refer to "who" as *wh-definite* rather than *definite*. We leave the explication of the terms *wh-definite*/*wh-indefinite* for later analysis.

Word	Wh	Def	Number	Person	Animate	Case
Who	Wh	Wh-Def	Sing?	3rd	Human	Subj
Whom	Wh	Wh-Def	Sing?	3rd	Human	Obj
Whoever	Wh	Wh-Indef	Sing?	3rd	Human	Subj
Whomever	Wh	Wh-Indef	Sing?	3rd	Human	Obj

Possessive (Pronoun) Pronoun

There is a subtype of possessive pronoun which we call possessive (pronoun) pronoun (for lack of a better term to indicate a possessive pronoun that functions like a pronoun) that is unique in referring to a referent which is not linguistically expressed and cannot be expressed (e.g., "mine is nice" vs. "*mine book is nice"). Possessive (pronoun) pronouns differ from the possessive (pronoun) determiners from which they are derived (my → mine) in this respect (e.g. "my book" vs. "*my"). The number feature of the unexpressed or implied referent depends on the actual referent (e.g., "mine is nice" vs. "mine are nice"). The head of the encompassing nominal is an implied element that binds to the referent, thereby acquiring the number feature of the referent. This implicit element is projected from the possessive (pronoun) pronoun. The possessive pronoun "his" has a single form for both the pronominal and determinative uses.

Word	Def	Number	Person	Animate
Mine	Def	Depends on referent	3rd	Depends on referent
Ours	Def	Depends on referent	3rd	Depends on referent
Yours	Def	Depends on referent	3rd	Depends on referent
His*	Def	Depends on referent	3rd	Depends on referent
Hers	Def	Depends on referent	3rd	Depends on referent
Theirs	Def	Depends on referent	3rd	Depends on referent

Possessive Nominal

Possessive nominals (e.g., "John's" in "John's book") collapse across the subtypes of possessive pronouns, preferring to occur with a noun head, but allowing for its absence (e.g., "John's book is red" vs. "John's is red"). The preference for a noun head suggests that the possessive nominal functions as the specifier of the projected nominal, not the head. In functioning as a specifier, the possessive nominal behaves like a determiner, but in not requiring a noun head it behaves like a pronoun.

Word	Def	Number	Person	Animate
John's *book*	Def	Depends on *book*	3rd	Depends on *book*
John's	Def	Depends on referent	3rd	Depends on referent

Reflexive Pronoun

Reflexive pronouns are a subtype of personal pronoun that may be derived from either a personal pronoun (e.g. "himself", "themselves") or more usually a possessive pronoun (e.g. "myself", "yourself"). Like personal pronouns they encode a person feature and they are uniformly objective case (although non-standard uses like "myself loves me" do occasionally occur). There is some flexibility in whether the personal or possessive pronoun forms the base for the reflexive (e.g. "themselves" vs. "theirselves"). There is also considerable flexibility in the number feature. The two forms "yourself" and "yourselves" apply to singular and plural referents—although "you" itself is always plural (e.g. "John, you are a saint"). More generally, the actual referent can influence the choice of reflexive pronoun and corresponding number feature in some contexts which may be considered grammatically non-standard. The number feature adjusts to accommodate royal uses of the reflexive (e.g. "we must choose which aspects of ourself to express to the world") and non-gender, singular uses of "their" (e.g. "It allows a person to register theirself without interference"). One can even imagine a split personality context in which one might say "We did it myselves" (or from http://theselves.blogspot.com/ "conversations with myselves"). This flexibility is made possible by separate number encoding in the pronominal element (e.g. "my" vs. "them") and the suffix (e.g. "self/selves") and by the mapping from referring expression to actual referent.

Word	Def	Number	Person	Animacy	Case
Myself	Def	Sing	1st	Human	Obj
Ourselves	Def	Plur	1st	Human	Obj
Ourself	Def	Sing/Plur	1st	Human	Obj
Yourself	Def	Sing	2nd	Human	Obj
Yourselves	Def	Plur	2nd	Human	Obj
Itself	Def	Sing	3rd	Animate	Obj
Themselves	Def	Plur	3rd	Human	Obj
Theirselves	Def	Plur	3rd	Human	Obj
Theirself	Def	Sing/Plur	3rd	Human	Obj

Word	Def	Number	Person	Animacy	Gender	Case
Himself	Def	Sing	3rd	Human	Male	Obj
Hisself	Def	Sing	3rd	Human	Male	Obj
Herself	Def	Sing	3rd	Human	Female	Obj

Demonstrative Pronoun

The defining feature of demonstrative pronouns is that they are marked for distance. Since this feature helps in determining the referent of the pronoun, it is projected to the nominal. Although demonstrative pronouns can function alone as nominals, they can also be combined with a noun head as in "this book". In combining with noun heads they behave like determiners rather than pronouns. For this reason, they are sometimes cross classified as demonstrative determiners (cf. Biber, Conrad & Leech, 2002). However, from a processing perspective, when the demonstrative pronoun is processed, it projects a nominal and functions as the head, just like other pronouns.

However, unlike other pronouns, if a noun head occurs subsequently, the demonstrative pronoun is shifted into a specifier function.

Word	Def	Number	Person	Distance
This	Def	Sing	3rd	Near
That	Def	Sing	3rd	Far
These	Def	Plur	3rd	Near
Those	Def	Plur	3rd	Far

The wh-word "what" is special in that it behaves like a demonstrative pronoun in both occurring alone as a nominal and combining with a noun head (e.g., "what did he read?" vs. "what book did he read?"). However, unlike demonstrative pronouns it does not encode for distance. If the distance feature is considered definitional for demonstrative pronouns, then "what" is not technically speaking a demonstrative pronoun, but neither is it technically an ordinary pronoun since it can combine with a noun head. Expressions like "What stays and what goes?" suggest that "what" encodes a singular number feature even though it can occur with both a singular or plural noun (e.g., "What book did he read?" vs. "What books did he read"). When "what" occurs with a noun head, the number feature of the noun overrides the number feature of "what". To capture the ability of demonstrative pronouns and "what" to occur with and without a noun head, we could introduce a superordinate part of speech called something like "determiner-pronoun" or using multiple inheritance, we could have demonstrative pronouns and "what" inherit from both determiners and pronouns.

Word	Wh	Def	Number	Person
What	Wh	Def	Sing	3rd
Which	Wh	Def	Sing	3rd
Whatever	Wh	Indef	Sing	3rd
Whichever	Wh	Indef	Sing	3rd

Quantifier

The quantifier "some" is interesting in that is appears to encode the number feature plural (e.g., "some are missing"), yet it can occur with a singular noun head (e.g., "some book is on the table"). We will assume that the later is a case of number overriding by "book" which is suggested by the stress placed on "some" in spoken language in such expressions (compare "some books are on the table" vs. "**some** book is on the table").

Word	Def	Number	Person
Some	Indef	Plur	3rd
Many	Indef	Plur	3rd
Much	Indef	Mass/Sing	3rd
More	Indef	Plur	3rd
Most	Indef	Plur	3rd
All	Univ	Plur	3rd
Both	Def?	Plur	3rd
Each	Def?	Sing	3rd
Each Other	Def?	Sing	3rd
Either	Def?	Sing	3rd
Neither	Neg	Sing	3rd
Every	Indef	Sing	3rd

Few	Indef	Plur	3rd
None	Neg	Plur	3rd
No one	Neg	Sing	3rd
One	Indef	Sing	3rd
Two	Indef	Plur	3rd

Word	Def	Number	Person	Polarity
Any	Indef	Plur	3rd	Neg

Quantified Pronoun

Word	Def	Number	Person	Animacy
Somebody	Indef	Sing	3rd	Human
Everybody	Indef	Sing	3rd	Human
Nobody	Neg	Sing	3rd	Human
Someone	Indef	Sing	3rd	Human
Everyone	Indef	Sing	3rd	Human
No one	Neg	Sing	3rd	Human
Something	Indef	Sing	3rd	Inanimate
Everything	Indef	Sing	3rd	Inanimate
Nothing	Neg	Sing	3rd	Inanimate

Word	Def	Number	Person	Animacy	Polarity
Anybody	Indef	Sing	3rd	Human	Neg
Anyone	Indef	Sing	3rd	Human	Neg
Anything	Indef	Sing	3rd	Inanimate	Neg

Wh-words

Besides the wh-words "who" and "what" which are categorizable as pronouns, and "whose" which is categorizable as a possessive (pronoun) determiner, the expressions "how much" and "how many" behave like nominals in their inclusion of a definiteness and number feature. Of course, the definiteness and number features are projected by the quantifier and not the wh-word, but the inclusion of these features allows the expression to function as a nominal. For example, in "how many went?", even if "how many" isn't the subject of this clause, it is presumably bound to the implicit subject similar to the treatment of "who" in "Who went?"

who$_i$ t$_i$ went?
how many$_i$ t$_i$ went?

Word	Wh	Def	Number	Person
How much	Wh	Indef	Sing (Mass)	3rd
How many	Wh	Indef	Plur	3rd

Noun

Word	Number	Person	Animacy
Dog	Sing	3rd	Animate
Rock	Sing	3rd	Inanimate

Word	Number	Person	Animacy	Gender
Man	Sing	3rd	Human	Male
Woman	Sing	3rd	Human	Female
Baby	Sing	3rd	Human	

Word	Def	Number	Person	Animacy
Dogs	Indef	Plur	3rd	Animate
Rocks	Indef	Plur	3rd	Inanimate
Cattle	Indef	Plur	3rd	Animate

Word	Def	Number	Person	Animacy	Gender
Men	Indef	Plur	3rd	Human	Male
Women	Indef	Plur	3rd	Human	Female
People	Indef	Plur	3rd	Human	

Word	Def	Number	Person	Animacy
Rice	Indef	Sing (Mass)	3rd	Inanimate

Proper Noun

Word	Def	Number	Person	Animacy
IBM	Def	Sing	3rd	Inanimate

Word	Def	Number	Person	Animacy	Gender
Tom	Def	Sing	3rd	Human	Male
Mary	Def	Sing	3rd	Human	Female
The Fillmores	Def	Plur	3rd	Human	