Psychological Review
2005, Vol. 112, No. 3, 000–000

Copyright 2005 by the American Psychological Association
0033-295X/05/$12.00 DOI: 10.1037/0033-295X.112.3.000

Making Syntax of Sense: Number Agreement in Sentence Production

Kathleen M. Eberhard
University of Notre Dame

J. Cooper Cutting
Illinois State University

Kathryn Bock
University of Illinois at Urbana–Champaign

Grammatical agreement flags the parts of sentences that belong together regardless of whether the parts appear together. In English, the major agreement controller is the sentence subject, the major agreement targets are verbs and pronouns, and the major agreement category is number. The authors expand an account of number agreement whose tenets are that pronouns acquire number lexically whereas verbs acquire it syntactically but with similar contributions from number meaning and from the number morphology of agreement controllers. These tenets were instantiated in a model using existing verb agreement data. The model was then fit to a new, more extensive set of verb data and tested with a parallel set of pronoun data. The theory was supported by the model's outcomes. The results have implications for the integration of words and structures, for the workings of agreement categories, and for the nature of the transition from thought to language.

Keywords: verbs, pronouns, number agreement, language production, syntax

Syntax conveys linguistically what belongs together mentally. Different languages use different means to accomplish this end, but fundamentally the role that syntax plays in all languages is the same. The syntactic knowledge shared by the listeners and speakers of a language serves to link the separate elements in a temporal series to one another and to the manifold thoughts behind them. Without the resources of syntax, the newspaper headline "Woman Bites Dog" (2001; cf. Pinker, 1994) would be no more newsworthy than "Dog Bites Woman" and could be as similar in meaning as *woman and dog* is to *dog and woman*. Among the major syntactic resources of language is grammatical agreement. Because agreement is rooted in sense but ramifies into words and structures, its workings reveal how a general, linguistically significant kind of meaning comes to be expressed. Our aim here is to expand and model an account of the psycholinguistic underpinnings of agreement, linking number meaning to syntax and number morphology in normal language production.

Agreement is disarmingly simple in appearance. That is particularly true in English, where the extent of grammatical agreement is limited and agreement morphology is correspondingly sparse. Yet even in English, the normal course of agreement demands the close cooperation of semantic, syntactic, lexical, morphological, and phonological information, to marshal and coordinate elements from all of the systems involved in the linguistic mapping from meaning to sound. The mechanisms behind agreement must be set into motion in the majority of utterances that speakers produce. Most utterances contain verbs, and the forms of verbs in English can change depending on the number properties of other elements with which verbs co-occur, typically subjects. This makes agreement a fundamental psycholinguistic challenge that in everyday speaking must be met on the order of once every few seconds.

Agreement is a morass for linguistic and psycholinguistic theories (den Dikken, 2000; Vigliocco & Hartsuiker, 2002). The dominant theories in contemporary linguistics have until recently ignored it (Pullum, 1984). The dominant theories of language production in psycholinguistics sidestep it. Scattered attempts to explain it in straightforward terms (e.g., as purely syntactically controlled, purely semantically controlled, or purely pragmatically controlled) founder on the data and the realities of usage. Agreement is not only syntactic, not only semantic, and not only pragmatic, but all of these things at once (Corbett, 1998, 2000; P. C. Gordon & Hendrick, 1998; Morgan, 1984; Vigliocco & Hartsuiker, 2002).

In an upsurge of psycholinguistic interest in the dynamics of agreement in language production, research has focused on number agreement between subjects and verbs, grammatical gender agreement between subjects and predicates (see Bock, 2004b, and Vigliocco & Hartsuiker, 2002, for reviews), and agreement be-

Kathleen M. Eberhard, Department of Psychology, University of Notre Dame; J. Cooper Cutting, Department of Psychology, Illinois State University; Kathryn Bock, Beckman Institute, University of Illinois at Urbana–Champaign.

Portions of this article were presented at the 44th Annual Meeting of the Psychonomic Society, Vancouver, British Columbia, Canada, November 2003. This research was supported in part by National Science Foundation Grants BNS 90-09611, SBR 94-11627, SBR 98-73450, and BCS 02-14270 as well as National Institutes of Health Grants R01 HD21011 and R01 MH66089. We thank Gary Dell, Victor Ferreira, Cynthia Fisher, Julie Franck, Robert Hartsuiker, Todd Haskell, Karin Humphreys, Heidi Lorimor, Antje Meyer, Erica Middleton, Gregory Murphy, Janet Nicol, Neal Pearlmutter, Martin Pickering, Jos van Berkum, and Gabriella Vigliocco for many helpful discussions about the research.

Correspondence concerning this article should be addressed to Kathryn Bock, Beckman Institute, University of Illinois at Urbana–Champaign, 405 North Mathews Avenue, Urbana, IL 61801. E-mail: kbock@s.psych.uiuc.edu

tween determiners and nouns (cf. Alario & Caramazza, 2002; Schriefers, 1993). With few exceptions, little psycholinguistic attention has been paid to the links between these kinds of agreement (which tend to be treated as grammatical phenomena) and pronoun agreement (which, apart from bound pronouns such as reflexives, tends to be treated as a pragmatic phenomenon). The links are theoretically important. There are systematic convergences and divergences in how number surfaces on these different grammatical elements, verbs on the one hand and close relatives of nouns on the other (Bock, Eberhard, & Cutting, 2004), and their correlations help to triangulate a course for the transformation from a fundamental kind of meaning, number meaning, into syntactic and lexical forms.

In this work, we consider how an account of verb agreement in normal language performance fares in predicting the workings of pronouns and other agreement targets. We evaluate a theory of verb number agreement called *marking and morphing* (Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001) in terms of a model of the retrieval and production of number-bearing elements by speakers, and we examine the model's performance in predicting pronoun number. On the marking and morphing account, agreement-relevant number meanings are the same for pronouns and verbs, which is the source of basic similarities between them. The major differences in their agreement properties arise during the transition from meaning to syntax, when the linguistic raw materials for verb and pronoun number are separately assembled. The computational model makes explicit some of the proposals from this account. These proposals were shaped in turn by processing assumptions about language production, involving how words and grammatical structures are assembled and integrated under the control of messages (Bock, 1999). We examine how the marking and morphing view helps to unify the psycholinguistic evidence on agreement in English and other languages, discuss how it fits into broader theories of sentence production, and consider its implications for related research in language comprehension. To begin, we introduce some of the devices of English verb and pronoun agreement and some of the puzzles in their behavior. We then sketch an explanation of these puzzles in terms of an elaborated marking and morphing account of agreement implementation.

The Linguistic Devices of Agreement

As the contrast between *Woman bites dog* and *Dog bites woman* shows, English uses word order to establish some of the linkages between language and meaning. However, the syntax of English (like that of other languages) extends to devices that link words to one another across interruptions by other words. *Woman bites dog* contains a verb (*bites*) that reflects the singular number of the subject (*woman*), and this relationship is normally maintained even when the subject and verb are separated (*Woman on brink of divorce proceedings bites dog*). These linkages may seem subtle, but the impact of violations suggests their importance. Native English speakers readily detect the agreement problem in *The newly elected officials hopes to balance the budget*, and there are event-related changes in the electrical activity of the brain (Osterhout & Mobley, 1995, Experiment 3) and in movements of the eyes during reading (Pearlmutter, Garnsey, & Bock, 1999) to prove it.

As a class, the devices of agreement support the communicative power of human language, allowing the selective elaboration of one part of a string by establishing mutual dependence as well as joint independence from other elements. In the example above, it is obvious that a woman and not the divorce proceedings bit the dog. Although that might seem clear regardless of variations in agreement, agreement can make a difference. A sentence that begins with *An event prior to the divorce proceedings that threaten* . . . benefits from the help that agreement morphology provides. *Threaten* links what is about to be said to the divorce proceedings; *threatens* links what is about to be said to the event. Viewed abstractly, such linkages make it easier to selectively enrich the description of a notion without losing track of the relationships among the words in the string or the link to the underlying idea.

Languages call on a wide array of devices to convey these linkages. Some of the devices rest on meaning distinctions (in number or biological gender, for example). These devices support reference in the first instance, tapping differences among things to distinguish them. Number plays this role in many languages (Dryer, 1989). Its simplest referential workings rest on morphologically represented distinctions between one thing and more than one thing (e.g., *dog*, *dogs*), with some languages making further differentiations (Corbett, 1998). Number agreement builds on these distinctions, adding covariations in number morphology that signal mutual linguistic dependencies.

In English, these covariations in number morphology convey two dependencies that interact with the structure of the language and are exceptionally frequent in language use. The first is agreement between verbs and their subjects. Subject–verb number agreement involves covariations between the form of the head of a subject noun phrase (the subject noun, for short) and the form of the number-carrying part of the verb phrase (the verb inflection, for short). The covariation in English is regular and reliable for almost all verbs in most dialects in certain combinations of person and tense (notably the third-person present; *the representative offends–the representatives offend*), and it surfaces in other combinations involving the forms of *be* (e.g., *is*, *are*, *was*, *were*).

The second dependency is number agreement between personal pronouns and their antecedents. By *antecedent* we mean both same-sentence and discourse antecedents of pronouns. Roughly speaking, if the antecedent of a pronoun is plural, the pronoun will be plural; if the antecedent is singular, the pronoun will be singular (with important complications that we examine later). For instance, in *The Yankees lost again, didn't they?* the antecedent *the Yankees* is plural and so is the coreferential pronoun *they*. Personal pronouns in English mark a sparse set of semantically relevant distinctions, including number (e.g., singular *he*, plural *they*) and natural gender (e.g., masculine *he*, feminine *she*, neuter *it*). Additional distinctions involve person (e.g., third person *he* and first person *I*) and case (e.g., nominative *he*, accusative *him*, possessive *his*).

The objective frequencies with which speakers must choose between singular and plural forms can be approximated from word-frequency counts. Among verbs, the forms of *be* and *have* occur more often than any other verbs in English and are among the most frequent words in the language. By themselves, excluding all other verbs, the frequencies of the singular and plural forms of *be* and *have alone* imply that English speakers, on average, implement subject–verb number agreement at least once in every 30

words produced. Adding in the frequencies of only the nominative forms of pronouns, the rate at which English speakers must arbitrate between singular and plural forms is more than once in every 16 words, which is roughly once every 5 s in running speech. Our questions are whether speakers do this in the same way for pronouns and verbs and what that similarity reveals about how language production works.

We assume (as have others before us; Barlow, 1991) that pronoun number and verb number are rooted in the same kinds of meaning-based, referential number distinctions. The number that verbs and pronouns actually display seems to differ, however, with pronouns in many languages being more likely than verbs to maintain their linkage to underlying referential distinctions. One statement of this cross-linguistic generalization in linguistics is found in the agreement hierarchy (Corbett, 1979), which ranks agreement targets in terms of their grammatical involvement. In the agreement hierarchy, verbs are more likely than pronouns to reflect the grammatical number of their controllers. A proposed explanation of this difference is in terms of how pronoun and verb number are formulated linguistically, with pronoun number being formulated lexically and verb number syntactically (Bock, Nicol, & Cutting, 1999). The present extension of marking and morphing to pronouns retains this explanation of basic verb–pronoun differences.

Where the marking and morphing account of pronoun production departs from previous claims is in its explanation for a striking uniformity observed by Bock, Eberhard, and Cutting (2004) in the behavior of verbs and pronouns across a range of different agreement contexts. The uniformity appeared within an aberration of grammatical agreement called *attraction* (Bock & Miller, 1991). Attraction refers to cases in which verbs or pronouns agree not with the apparently intended subject or antecedent but with another noun phrase, as in *One of the other groups* ***were*** verbs of motion. In controlled agreement contexts, attraction affected verbs and pronouns alike and equivalently. There is no satisfactory explanation for this convergence in any existing proposals about number agreement in psycholinguistics or linguistics, and it challenges the generalizations in the agreement hierarchy. Our aim in this work is to explain it in terms of the mechanisms of marking and morphing in language production.

There are four distinctions that aid in understanding how number and number agreement work in language, for both pronouns and verbs. These distinctions involve *notional* number, *grammatical* number, *morphological* number, and *noun subcategorization* (e.g., mass vs. count in English). We discuss these in turn.

Notional number has to do with a speaker's momentary perspective on the numerosity of specific entities in a preverbal message; that is, in a mental model of what is to be communicated on a particular occasion. It is the perceived or inferred number of an intended referent. Notional number thus pertains to what is sometimes called *discourse reference*. If a speaker says *The largest of them is red*, the number of the intended referent is apparently singular; if the speaker instead says *The largest of them are red*, the number of the intended referent is apparently plural. Notional number is often called *conceptual* or *semantic* number in the psycholinguistic literature. We use the term *notional* to emphasize the involvement of intended referents in the control of number, one consequence of which is that number attaches to phrases rather than single words. Because it is phrase number that controls agreement, and because we are dealing with phrases rather than the concepts behind words, we will generally talk about notional number, with the understanding that this usage encompasses what others have termed *conceptual number*.

Grammatical number refers to the linguistic agreement properties of a lexical item. The word *suds* is grammatically plural for most English speakers, because words that agree with it are normally plural: In standard English, it is *suds are* and not *suds is*, and *some suds* rather than *a suds*. Conversely, *news* is grammatically singular for most English speakers, because words that agree with it are normally singular: People say *news is* and not *news are*. Although grammatical number is often a good reflection of notional number, it is not completely reliable. For example, speakers judge grammatical plurals like *scissors* and *pliers* as having notionally singular referents (Bock et al., 2001).

Morphological number refers to the morphological signals of singular and plural grammatical number, such as the presence or absence of plural inflection on nouns and the presence or absence of singular inflection on verbs. Morphologically, the noun *drum* is singular and *drums* is plural; the verb *drums* is singular and *drum* serves as the plural. These morphological signals are highly (but not perfectly) correlated with grammatical number: As just noted, the noun *news* is singular, despite its ending, and the noun *personnel* is plural, despite its lack of morphological triggers. When a noun is grammatically plural, either invariantly or as a result of plural inflection, we will say that it is *specified* as a plural. Note that we use the term *specified* in the way that the term *marked* is sometimes used and that the construct of marking in marking and morphing involves something related but distinct, an abstract precursor of noun phrase number.

Finally, there is a *subcategorization* distinction between mass nouns (like *corn*) and count nouns (like *bean*). Subcategorization in general can be seen as differentiating the syntactic contexts where subtypes of words from the same grammatical form classes typically appear. Verbs come as intransitives, transitives, ditransitives, and so on, and nouns come as mass or count, among other things. Count nouns can freely alternate between singular and plural forms (*bean, beans*) and are correspondingly singular or plural grammatically. In their singular forms, they require determiners (*bean* is odd on its own), and they allow the determiner *a* when singular (*a bean*) and the quantifier *few* (*few beans*) when plural. Mass nouns alternate less freely between singular and plural (*corns* does not mean multiple grains of corn or even multiple ears of corn), and they appear in different syntactic contexts than count nouns (*a corn* and *few corn* are both odd, but *corn* is not). Whether such properties are due to meaning or grammar is controversial (Grimshaw, 1992; Middleton, Wisniewski, Trindel, & Imai, 2004), but whatever the reason, the agreement environments of mass and count nouns differ systematically.

In the next section, we review some of the common underpinnings of verb and pronoun number and some of the contrasts that motivate the features of the model. The review summarizes the arguments and evidence that verbs and pronouns exhibit both notional and grammatical agreement, that their susceptibility to notional and grammatical agreement control typically differs, that their vulnerability to attraction is the same, and that all of these things are relevant to the explanation of agreement.

tapraid1/z2q-psycho/z2q-psycho/z2q00305/z2q0641d05g | stambauj | S=11 | 5/20/05 | 19:38 | Art: 2003-0071-RRR

Verb and Pronoun Agreement: A Comparison

The Commonalities of Verb and Pronoun Number

There are deep-seated commonalities between antecedent–pronoun number agreement (pronoun number, for short) and subject–verb number agreement (verb number, for short). These commonalities may be traced to the roots of verb number. In the history of languages, there is evidence that verb number variations repeatedly arise as a species of the pronoun number variations found in subject–pronoun or topic–pronoun agreement (Givón, 1976). The hypothesis is that verb number variations emerge over time from topicalizing constructions. Topicalization moves the topic of an utterance into initial position (e.g., *My mother, she lives in Pennsylvania, and me, I live in Illinois*). In the Germanic languages from which English descends, topicalization creates forms along the lines of *My mother live-she in Pennsylvania*. Such usages, well attested in languages where verb agreement systems are currently developing, stem from the normal overuse of topicalizing devices by speakers working to capture and maintain listeners' attention (Harris & Campbell, 1995). The resulting co-occurrence of pronouns with verb stems (e.g., *live–she* in the example above), in company with phonological reduction and assimilation processes, supports the *grammaticization* of number, putting it into the realm of syntactic processes. After grammaticization, a pronominal derivative becomes an obligatory companion to the verb regardless of whether the discourse context requires it. In time, the product is a verb agreement system that is the residue of a pronoun system.

This linguistic phylogeny sheds light on some of the functional similarities between pronouns and verbs in English. The main one is obvious: Semantically, verb number and pronoun number both turn on a distinction between one thing and more than one thing. Setting aside the problem of how people distinguish between one and more than one thing, this commonality suggests that both types of agreement call on a basic number sense (Dehaene, 1997).

For English pronouns and verbs alike, what carries and superficially controls the number distinction is a nominal, a fact that is sometimes attributed to a referential function for agreement itself (e.g., Lehmann, 1988). The nominals that are most important to verb and pronoun number are subject noun phrases. For verbs, this relationship follows from the grammatical dependency between subject number and verb number: Finite (i.e., tense-carrying) verbs are always agreement targets for subject noun phrases. For pronouns, the relationship to subjects is the product of a general discourse tendency for the antecedent of a pronoun to be found in subject position when the pronoun is first introduced (Brennan, 1995; Garnham, 2001; P. C. Gordon & Hendrick, 1998). Although pronouns and verbs can and do reflect the values of other number sources, sometimes spuriously (i.e., they may reflect the number of a constituent that is neither the intended referent nor the subject), the subject noun phrase is a carrier of number with which pronoun and verb number are both highly correlated. For verbs, it is always the subject of the verb's clause that matters to agreement. For pronouns, sentence subjects are simply the most common antecedents, whether in current or preceding clauses; though other constituents can serve as pronominal antecedents, their behavior as antecedents may differ (this is an empirical question that has yet to receive much attention).

In linguistics, verb and pronoun number agreement are sometimes treated together (Corbett, 1998; Moravcsik, 1978). In some formal grammatical theories, the basic mechanisms proposed for verb and pronoun agreement are the same (Pollard & Sag, 1994, chap. 2). Barlow (1991; see also Lehmann, 1988) went farther in arguing that there are no good reasons for distinguishing verb and pronoun agreement. In short, it is tempting to regard pronouns and verbs as reflections of the same kinds of notional or grammatical number information. Given that both seem to reflect a one versus more-than-one semantic distinction that is introduced on or carried by a subject noun phrase, both might be expected to carry the same types of one and more-than-one information (whether notional or grammatical) under the same circumstances, with the same values (singular or plural). However, they do not consistently work in the same ways. The next section examines how they diverge.

The Parting of Pronominal and Verbal Ways

With the number properties that they share, it would be unsurprising if pronouns and verbs behaved in similar ways with respect to number agreement. Among the expected resemblances would be at least the following: (a) When the notional source of number is the same, the number expressed on pronoun and verb targets should be the same; (b) when the linguistic controllers of agreement are the same, the grammatical number expressed on pronoun and verb targets should be the same; and (c) under similar conditions, the processing demands of verb and pronoun agreement should be the same. None of these expectations withstands scrutiny.

The first kind of disparity occurs in a phenomenon that is sometimes called *singular they*. Because English lacks a gender-neutral third-person singular pronoun, speakers sometimes resort to the pronoun *they* rather than the stylistically awkward *he or she*. To test the acceptability of this usage, Foertsch and Gernsbacher (1997) examined reading times for clauses containing the pronouns *he*, *she*, or *they* after singular antecedents, as in *A truck driver should never drive when sleepy, even if he or she/they may be struggling to make a delivery on time*. The pronoun reflected the antecedent's stereotypic gender (*he* for the antecedent *truck driver*), or ran counter to stereotype (*she*), or was gender neutral (*they*). The reading times for clauses containing *they* were nearly equivalent to the times for clauses containing stereotype-appropriate singular pronouns, and both were faster than the times for stereotype-inappropriate pronouns. Because the plural pronoun *they* was no hindrance to inferring its connection to a singular antecedent, Foertsch and Gernsbacher concluded that the number of *they* can, in fact, be singular.

Supposing that the pronouns *he* and *they* can have equivalent number, and that their number also determines verb number, the verbs that follow *he* and *they* should also be the same. Yet a verb that follows *they* must be plural. This can be seen in the consequences of replacing the unspecified *may* from the example above with a verb having overtly specified singular number: *A truck driver should never drive when sleepy, even if they* ***is*** struggling to make a delivery on time. The stark unacceptability of the singular verb makes it clear that even if *he* and *they* or their antecedents can have the same notionally singular number, the verbs that accompany *he* and *they* must have different grammatical numbers.

Second, when a verb's subject and a pronoun's linguistic antecedent are the same, or at least arguably the same, the number of the pronoun can differ from the number of the verb. Some instances from speech and in writing are listed in Table 1. In prescriptive grammar, such number clashes are regarded as errors; we see them simply as evidence that pronouns and verbs can have different number properties even when they occur in the same contexts. This difference between pronouns and verbs is the general one that is summarized in the agreement hierarchy (see Corbett, 2000, for discussion).

Finally, if verb and pronoun number were computed in similar ways, by similar mechanisms, one might expect their demands on cognitive processes to be similar. There are reasons to doubt this, too. In the absence of complexities in notional number, the ability to implement verb number agreement reliably in language production (Bock & Cutting, 1992) and language comprehension (Almor, MacDonald, Kempler, Andersen, & Tyler, 2001) is uncorrelated with performance on standard tests of working memory capacity (though see Hartsuiker & Barkhuysen, in press, for a possible counterexample). Pronoun number agreement, however, does show such a correlation in comprehension (Almor et al., 2001) as well as production (Bock, 2004a).

A first guess about the reasons for number agreement disparities between verbs and pronouns is that verbs and pronouns naturally occur in different places with respect to their controllers. These distributional variations are associated with different temporal and structural distances between the controllers and verb or pronoun agreement targets. Verbs tend to be closer to their controllers than pronouns are. Verb number controllers are in the same clauses as the verbs they control; pronoun number controllers can be in different clauses or in the extralinguistic context.

However, the disparities in the agreement behavior of verbs and pronouns persist even when distributional differences are controlled. Bock et al. (1999) elicited verbs and two types of pronouns (reflexive and tag pronouns) in completions for sentences that started with the same collective head nouns (e.g., *the fleet*). The subject noun phrases, for instance *The fleet with the distinctive flag*, functioned as the agreement controllers for verbs in one condition and for reflexive and tag pronouns in two other conditions, eliciting spoken sentences like the following:

1. *The fleet with the distinctive flag was in port.* (verb completion)
2. *The fleet with the distinctive flag betrayed themselves.* (reflexive pronoun completion)
3. *The fleet with the distinctive flag surrendered, didn't they*? (tag pronoun completion)

Like verbs, reflexive pronouns (as in Sentence 2) occurred in the same clauses as their antecedents, whereas tag pronouns occurred in different clauses (as in Sentence 3). Distributionally based linguistic binding principles (Chomsky, 1981) predict that reflexive pronouns should be more likely than tag pronouns to behave like verbs with respect to number agreement (Anderson, 1992; den Dikken, 2000).

The results showed that pronouns of both kinds were much more likely to exhibit plural agreement than verbs (70% plural pronouns to 34% plural verbs), relative to controls. Most problematic for a distributional account was the finding that levels of plural agreement for reflexive pronouns (69%) were almost identical to those for tags (70%). Bock, Butterfield, et al. (2004) replicated these results in both British and American English. This constitutes evidence for a genuine difference between pronouns and verbs in number agreement, one that cannot easily be explained in terms of distributional properties or whether a pronoun is bound or unbound.

Table 1
Examples of Pronouns and Verbs With Clashing Number

Verb and pronoun number	Example
Plural verb, singular pronoun	"We can live with the errors that classification software *make* when *its* output is subsequently reviewed by hand" (Nunberg, 2003, p. 5).
Singular verb, plural pronoun	"Young and fresh, this wine truly *preserves* the quality of the grapes that gave *them* birth" (wine label).
Singular verb, plural pronoun	"One day your child *turns* 16 and you let *them* borrow the keys to the wagon" (advertisement for the Honda Motor Company; as cited in Safire, 1994, p. 12).

Why Do Verb and Pronoun Number Agreement Differ?

An alternative account of differences between verb and pronoun number is in terms of the character of the notional number information that verbs and pronouns express. Bock et al. (1999) used grammatically singular collective nouns (e.g., *fleet*) in the critical conditions of their experiments. *Collectives* refer to groups, and a *group* is a bunch of individuals. This creates ambiguity in notional number: On one reading, a collective denotes the bunch, the singular set (e.g., a fleet as a whole; this is the *collective* reading), and on the other, it denotes the multiple individuals constituting the set (e.g., a fleet has many separate vessels; this is called the *distributive* reading). Despite this notional ambiguity, the grammatical number of most collectives, most of the time, for most American English speakers, is singular; in British English, the grammatical number of many more collective nouns for many speakers is plural (see Bock, Butterfield, et al., 2004, for evidence that British plural usage is based on grammatical and not notional number). This disjunction of notional and grammatical number properties suggests a parallel explanation for the disjunction in agreement properties for pronouns and verbs. Pronouns and verbs may be variably affected by the different kinds of number associated with their controllers, with notional number being more likely to control pronoun agreement and grammatical number being more likely to control verb agreement.

The upshot of this proposal would be that pronouns are controlled by notional number (pragmatic control), whereas verbs are controlled by grammatical number. A pronoun's number would come from the notional valuation of its referent, not from the linguistic representation of an antecedent. This makes the number of a pronoun part of its meaning, with the process of selecting an appropriate pronoun being the same as the process of selecting an appropriate word to denote a particular referent. Bock et al. (1999) suggested this as a likely explanation of their verb–pronoun dif-

ferences. It is a sort of words-and-rules account (Pinker, 1999) applied to pronoun and verb number: Some number meanings are stored in the lexicon with different whole-word forms (e.g., different pronouns); others are syntactically encoded by grammatical inflection (e.g., verb inflections) and implemented by rule. If this is on the right track, differences between pronouns and verbs should arise when notional and grammatical number part company. Unfortunately, this does not always happen.

Why a Words-and-Rules Account Does Not Work

Despite the points in its favor, a words-and-rules explanation fails to capture some further, fairly striking similarities between verb and pronoun number. Broadly stated, the problem is that verbs are sometimes sensitive to notional number and pronouns are sometimes sensitive to grammatical number.

Regarding the notional control of verb number, Morgan (1972, 1984; see also Berg, 1998; Reid, 1991) provided examples of several sorts. The examples included the use of plural verbs with superficially singular collective and corporate subjects (e.g., *The faculty are threatening to protest*), the use of singular verbs with superficially plural subjects (e.g., *Forty acres is a lot to plow in one day*), and changes in verb number that accompany changes in the denotation of a conjunction (e.g., in *His companion and best friend was/were with him when he died*, the verb is singular if *his companion and best friend* are one and the same person but plural if two different people are intended). In all of these cases, the number of the verb is predictable if it is seen as agreeing with the speaker's notion of the number of entities denoted by the subject noun phrase. Another pair of examples (from Pollard & Sag, 1994) illustrates the contrast even more strikingly. In *The hash browns at table nine is getting angry*, a metonymic interpretation of *hash browns* (the patron at table nine who ordered the hash browns) allows the verb to be singular, because the subject refers to a single person. Normally, of course, *hash browns* would be plural, as in *The hash browns at table nine are getting cold.*

Experimental comparisons yield similar conclusions. When a subject noun phrase has a distributive interpretation, bringing the members of a group rather than the group as a whole into focus, plural verb number is more likely. So, a collective subject noun phrase such as *The gang* ***on*** the motorcycles more often elicits a plural verb than a superficially similar phrase such as *The gang* ***by*** the motorcycles (Humphreys & Bock, in press). When a gang is *on* motorcycles, the one-to-one pairing of gang members with motorcycles presumably underscores the members' individuality; when a gang is *by* motorcycles, there is no need to construe the gang as anything more than a single bunch. In the same way, subject noun phrases with plural adjuncts are more likely to elicit plural verbs when the head is collective (e.g., *fleet* in *The fleet with the distinctive flags*) than when the head refers to an individual (e.g., *ship* in *The ship with the distinctive flags*), because of the distributive potential in collectives (Bock et al., 1999). The magnitude of such effects has been found to vary with the concreteness of noun phrases (Eberhard, 1999) and with language (Vigliocco, Butterworth, & Garrett, 1996; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996). These effects add more weight to the evidence that verb number can be notionally controlled, which is inconsistent with a strict words-and-rules division.

For pronouns, treated as independent words, the words-and-rules prediction would be that their number is controlled notionally. This prediction also fails. Pronouns agree with the grammatical number of their controllers in references to objects commonly called *scissors*, *pliers*, *tweezers*, *pants*, and the like. In English, objects in these categories tend to have joined symmetrical parts, and their names capture this bipartite nature in being plural. They are also grammatically plural. Yet single objects of these kinds are regarded as singletons by native speakers. Bock et al. (2001) collected notional number assessments for bipartite objects and for conceptually related objects with singular and plural forms, such as *razor* and *razors*. These ratings revealed no difference between bipartites (e.g., *scissors*) and singleton objects (e.g., *razor*) in rated notional number, and both the bipartites and singletons differed significantly from the notional ratings for multiple objects (e.g., *razors*). Despite this apparent notional singularity, a different deictic pronoun can be used when referring to bipartite objects than when referring to other singletons. For example, if one points to an object and says *Would you hand me [pronoun]?* the normal pronoun when the object is a razor would be *that*, but when it is a pair of scissors, the pronoun can be *those* (Tasmowski-DeRyck & Verluyten, 1981). This suggests that the pronominal form is controlled not by notional number but by the grammatical number of the term used to refer to the object (much as pronoun gender can be controlled in grammatical gender languages; Meyer & Bock, 1999).

A second argument for grammatical number agreement on pronouns comes from the grammatically conditioned ungrammaticality of number attraction. Attraction in verbs occurs most often when the neighbor is plural, as in *The time for fun and games are over*. In this example, the head noun (*time*) is singular, whereas the verb (*are*) is plural. The neighbors responsible for attraction are called *local nouns*, and their effects occur over and above the effects of notional number on agreement (Bock et al., 1999). For verbs, attraction appears to be triggered by local noun interlopers that are grammatically plural: It does not happen with local nouns that are merely conceptual plurals (such as collective nouns; Bock & Eberhard, 1993). In a controlled comparison, Bock et al. (1999) found that pronouns produced the same patterns of attraction as verbs. There was an increased tendency for pronouns to be produced as plurals after plural local nouns, and the magnitude of this increase was equivalent to that for verbs. This occurred even when the subject noun phrase was unambiguously (i.e., both notionally and grammatically) singular and raises the possibility of spurious control of pronoun number by a grammatically plural local noun.

But grammatical plurals are also notional plurals, and it could be that pronouns simply capture the notionally plural properties of plural local nouns. This is what Bock et al. (1999) proposed. For the argument to go through, the magnitude of notional attraction must be identical to the magnitude of grammatical attraction. However, Bock, Eberhard, and Cutting (2004) showed that notional attraction is nonexistent for pronouns as well as for verbs and that the magnitude of grammatical attraction was the same for verbs and pronouns over a range of subject and local noun types, semantic and notional variations, and grammatical number variations. This casts doubt on the hypothesis that pronouns are uniformly more sensitive to notional number than verbs are.

Such results are also problematic for accounts of agreement and attraction that ascribe variations in number to the semantic or

lexical properties of heads and local nouns. In a constraint satisfaction approach proposed by Haskell and MacDonald (2003) and Thornton and MacDonald (2003), heads and local nouns compete along the same dimensions for control of number, so that the properties of heads that influence agreement should be the same as the properties of local nouns that influence attraction. However, Bock, Eberhard, and Cutting (2004) showed that collective nouns behaved differently as heads than as local nouns.

Along similar lines, the maximal input hypothesis (Vigliocco & Hartsuiker, 2002) says that conceptual or notional information is directly used in implementing agreement, buttressing the linguistic operations behind agreement and making semantically supported agreement less variable than semantically unsupported agreement (Vigliocco & Franck, 1999, 2001). Regarding notional and grammatical gender, Vigliocco and Franck (2001, p. 370) wrote that "conceptual information permeates the agreement process, creating a potential advantage when there is a congruent mapping between ... [notional gender] and ... [grammatical gender]." They likened the approach to constraint satisfaction and the competition model (Bates & MacWhinney, 1989). Vigliocco and Hartsuiker (2002) asserted that "the assumption of maximal input is supported by the finding of conceptual influences on the construction of number and gender agreement" (p. 462) and at "the interface between message-level and phrasal integration, maximal input implies that conceptual information that is not necessary can still be used" (p. 464). The implication is that notional information is accessible to later production processes, regardless of whether it is needed. Vigliocco and Hartsuiker emphasized the salutary effects this may have on agreement when conceptual and grammatical information are congruent. Logically, however, the effects may be less salutary when information is incongruent.

In the next section, we present an alternative proposal about how number works in language performance, an extension of marking and morphing that encompasses pronoun as well as verb agreement. The proposal builds on existing ideas about the general architecture of language production (Bock, 1982, 1987, 1995; Bock, Loebell, & Morey, 1992; Dell, 1986; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Garrett, 1988; J. K. Gordon & Dell, 2003; Lapointe & Dell, 1989; Levelt, 1989; Levelt, Roelofs, & Meyer, 1999) and on hypotheses about the specifics of implementing verb number agreement (Bock et al., 2001; Vigliocco, Butterworth, & Semenza, 1995; Vigliocco & Hartsuiker, 2002; Vigliocco & Nicol, 1998). The underlying theme is that the initial pragmatic, message-based sources of number information for pronouns and verbs are exactly the same, as are the properties of the structural representations in which pronoun and verb agreement are implemented. What differs are the marking and morphing events during formulation that cause the morphological number properties of pronouns and verbs, number as it is morphologically instantiated, to diverge.

Meaning, Marking, and Morphing in Number Agreement

The general framework behind the marking and morphing account is sketched in Figure 1. The framework is a composite of contemporary views of word and sentence production, with three additions that are important for present purposes. These are the valuation of notional number, number marking, and number morphing. Roles for these constructs in verb agreement were proposed by Bock et al. (2001); below we explain and elaborate on them where needed to establish their relevance to the realization of pronoun number.

Valuation of Notional Number

The valuation of notional number takes place in the message, which is the preverbal encoding of speaker meaning. The purpose of valuation is to distinguish notional singulars from notional plurals in the speaker's referent model, creating what Figure 1 calls units (notional singulars) and multitudes (notional plurals). It is clear from the formal semantics of number (e.g., Gillon, 1992; Landman, 1989; Lasersohn, 1990; Link, 1991; Schwarzschild, 1992), from the cognitive psychology of number (e.g., Butterworth, 1999; Dehaene, 1997; Gelman & Gallistel, 1978), and from a moment's contemplation that this distinction is enormously complex. Because our aim is a simpler one, to explicate the consequences for agreement of a particular number valuation, here we simply assume that message processes yield number-relevant information that is interpretable by the lexicon and syntax.

Valuation is a matter of judgment or construal. It is weighted toward unity as a stable or default state, with construal of something as a multitude resting on the presence of perceptual and conceptual features that deviate from the default in ways analogous to violations of Gestalt grouping principles (Jackendoff, 1983; Wertheimer, 1923). Conceptual features, by analogy to perceptual grouping, follow a familiar hierarchy in which concrete individuals (humans, nonhuman animals, artifacts, other inanimate objects, in decreasing order of probability) are more likely to be construed and are more easily construed as multitudes than are abstract things (substances, events, abstractions); Corbett (2000, chap. 3) reviewed the relevant evidence regarding linguistic number. Because less imageable referents have less discernible internal boundaries, they may tend to be construed as units even when they are potentially ambiguous in notional number (Eberhard, 1999). Ambiguities in notional number result from conflicts in valuation that can come about when a change in perspective changes the number inferred (Humphreys & Bock, in press). A related source of notional variability is likely to be found in the conceptual operations that integrate over the notional numbers of complex referents (Jackendoff, 1991; Solomon & Pearlmutter, 2004).

We hypothesize that the features involved in number construal, the products of construal, and the construal processes themselves do not differ with respect to verb and pronoun number or, more accurately, with respect to the controllers of verb and pronoun number. A unitary notion should have the same representation regardless of whether it is the source of verb number, pronoun number, or both. So, the notional number of a referent should be the same regardless of whether the referent is expressed as a subject noun phrase that controls verb number, as a bound pronoun with a coreferential same-clause antecedent, or as a free (unbound) pronoun. This commits us to a single notional value, or to the same notional number ambiguities, behind different manifestations of verb and pronoun number.

Marking

Marking is part of functional assembly. Functional assembly proceeds on the basis of constraints imposed from the message to

tapraid1/z2q-psycho/z2q-psycho/z2q00305/z2q0641d05g | stambauj | S=11 | 5/20/05 | 19:38 | Art: 2003-0071-RRR

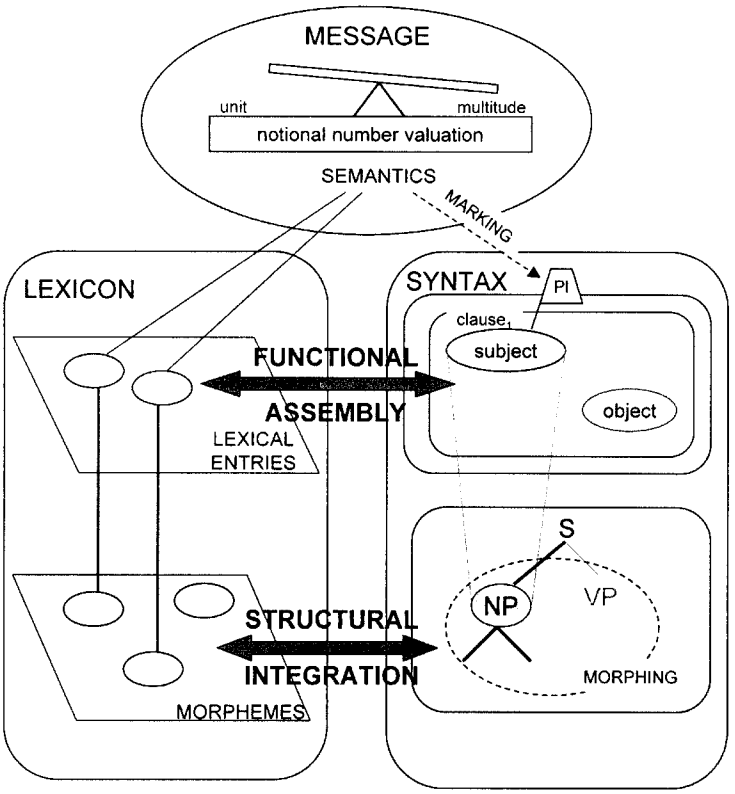

Figure 1. Overview of the components of number formulation in language production (illustrating verb agreement). Pl = plural; S = sentence; NP = noun phrase; VP = verb phrase. From "Producing Number Agreement: How Pronouns Equal Verbs," by J. K. Bock, K. M. Eberhard, and J. C. Cutting, 2004, *Journal of Memory and Language, 51*, p. 254. Copyright 2004 by Elsevier. Reprinted with permission.

marshal the lexical and syntactic raw materials for an utterance. Number constraints from the message, specifically the notional number valuation, are carried by the syntax in the form of features of an utterance's structure. Marking is the mechanism that transmits message number to the syntax. The site of number marking is the seed or root of the subject noun phrase, shown on the right in Figure 1 as the grammatical function of subject.

Marking serves to ensure that, in the absence of other information, a subject noun phrase carries a number consistent with the notional number of the phrase's referent. It can be singular or plural or, presumably, null. It is not notional number per se but a value consistent with notional number that can be linguistically interpreted. Its targets are noun phrases, from which number can be transmitted to verbs during the process of morphing. In contrast to a view put forward by Vigliocco and colleagues (Vigliocco, Butterworth, & Garrett, 1996; Vigliocco et al., 1995; Vigliocco & Franck, 1999, 2001; Vigliocco & Hartsuiker, 2002; Vigliocco, Hartsuiker, et al., 1996), we assume that verb phrases are not routinely marked directly from the message, at least in English. Some support for this assumption is found in widely and long-acknowledged differences between nouns and verbs in how they carry number. Noun number seems to mean something; verb number seems to mean very little (Jespersen, 1933). One consequence is that English speakers, when asked to select a situation represented by the verb *sing* (for example), have considerable difficulty choosing between pictures of one bird and two birds singing (Keeney & Wolfe, 1972). This suggests that singular and plural verb forms on their own may be comparatively numb to number meaning, whereas the singular and plural values of nouns are meaningful. For present purposes, we make this assumption for English only, because our data come from English speakers, but it is an important (and open) question whether verbs in languages with different or richer verb morphology are directly marked with information about numbers of participants. We return to this question in the General Discussion.

Marking constrains the syntax. In the lexicon, other things happen that are relevant to the realization of number, but the lexical coding of number meaning and the grammatical number properties of words are not enough on their own to account for number agreement. Marking is needed to deal with abstract phrase number (e.g., the number of phrases like *what*, *who*, and *which*, which can be either plural or singular), conjunctions (e.g., *ham and eggs*, *Karin and Scott*, which can be either singular or plural without any of the component elements having the relevant value), vague quantification (e.g., phrases like *a number of boys* are normally plural), elided or lexically unrealized phrases (more common in other languages but possible in English; e.g., normal imperatives along with casual expressions such as *doesn't matter*, *does too*, *are not*, *is too*, etc.) as well as differences in the number behavior of pronouns and verbs. All of these are instances in which

number meaning controls agreement in the absence of or in opposition to the expected grammatical number provided by words, and we attribute this to the normal (but not always visible) process of number marking in the syntax.

In the lexicon, events center on the recruiting or *nomination* of lexical entries whose meanings are consistent with the notional number of message elements. The goal is to locate entries whose semantics are compatible with the message. For our purposes, the main question is how number constraints from the message are satisfied by the head nouns of subject noun phrases and by personal pronouns (which constitute phrases on their own).

Pronouns come in distinct singular and plural versions that we assume are semantically as well as grammatically singular and plural; that is, singulars and plurals constitute different lexical entries. Setting aside the discourse and felicity conditions on pronoun use that must be satisfied in the message, the nomination of different pronouns is fairly straightforward. The entries must satisfy the notional number valuations in the message, along with animacy, gender, and person constraints. The entry for a pronoun that is compatible with a unit valuation (e.g., *it*) may differ from an entry that is compatible with a multitude valuation (e.g., *they*), just as the conditions for using an entry for *soldier* might differ from those for using an entry for *army*. This assumption about pronouns is driven by evidence that pronouns, both personal and reflexive pronouns, respond strongly to changes in the number meaning being expressed (as one might expect words to do; Bock et al., 1999), whereas verbs respond much more weakly.

Nouns are harder. One way to recruit plurality, lexically, is to nominate the entry for a count noun (e.g., *dog*, *woman*) together with the entry for the plural morpheme. Entries at this point are abstract, allowing the plural to be realized regularly, in any of its morphophonological variants, or irregularly. This property of the plural morpheme, as a bearer of number meaning, distinguishes it from verb inflections, whose number-related properties are controlled differently.

More complicated are nouns that do not pluralize normally but carry plural meanings nevertheless. Multitude features (e.g., those associated with things that people wear) may in principle be satisfied by mass nouns (*clothing*, *attire*, *lingerie*), invariant plural nouns without singular counterparts (*clothes*, *duds*, *panties*), collective nouns (*wardrobe*, *trousseau*, *combination*), in addition to simple count nouns coupled with the entry for a plural inflection (*outfits*, *uniforms*, *slips*).

Because multitude features in the message may be satisfied by singular collective or mass nouns, and unit features in the message may be satisfied by invariant plural nouns (e.g., *scissors*), it is possible for lexical entries with different grammatical-number properties to be selected for the purpose of referring to exactly the same message element. *Clothing*, *clothes*, *wardrobe*, and *outfits* can fill very similar semantic bills, but their grammatical number properties differ. These grammatical properties come into play during morphing, as morpheme specifications.

Morphing

Morphing helps to create representations that can support phonological encoding. As shown at the bottom of Figure 1, it is part of structural integration, which binds lexical and structural forms together. Whereas functional assembly proceeds on the basis of constraints imposed from the message to be expressed, structural integration proceeds on the basis of constraints imposed from the lexicon and syntax. It sets the stage for phonological encoding (Dell & Sullivan, 2004; Levelt et al., 1999), which we omit from Figure 1 and from further discussion for the sake of clarity. Though phonology may influence the processes with which we are concerned (Vigliocco & Hartsuiker, 2002), particularly morphophonology (Hartsuiker, Schriefers, Bock, & Kikstra, 2003; Haskell & MacDonald, 2003), our interest here is in the semantic, lexical, structural, and morphological factors that play the major parts in agreement.

Some of the relevant properties of morphing can be seen in the kinds of speech errors that Garrett (1975) called *stranding*. In stranding errors, the stems of words exchange while their affixes remain in place. Examples include "She's already trunked two packs" (when *She's already packed two trunks* was intended; Garrett, 1975, p. 158) and "Make it so the apple has more trees" (when *Make it so the tree has more apples* was intended; Garrett, 1988, p. 76).

There are four important features of these errors. One is that they involve parts of words rather than whole words, suggesting a point in production when the structural components of words (stems and affixes) are linked to positions in a phrasal frame. Another is that stranding is reliably present when inflected words are involved in errors: Stemberger (1985) reported that in his error corpus, stranding occurred in 91% of the errors in which it was possible for it to occur. A third key property is that stranded morphemes occupy their syntactically expected positions, unlike their host stems (whose positioning is nonetheless syntactically constrained; Ferreira & Humphreys, 2001). In *I roasted a cook*, the past tense *-ed* is where it should be, as is the plural in *The window doesn't have any domes.* A fourth property has been confirmed in controlled experimental comparisons. Humphreys (1998) showed that with word forms equated, stranded morphemes were much more likely to be inflectional than derivational.

In the marking and morphing framework, morphing is a set of interrelated operations that (a) bind morphological information to structural positions, (b) reconcile number-relevant features from the syntax (number marking) and the lexicon (number specifications), and (c) transmit number features to structurally controlled morphemes (e.g., to verbs). In short, morphing operates during structural integration to select and position the number morphology that surfaces with pronouns and verbs.

The marking and morphing account of verb morphing is straightforward: Verbs inherit the number of the subject noun phrase. This constitutes agreement control of verb number by the subject number. Subject noun phrase number is a joint product or reconciliation of the initial marking of notional number and the number specifications of morphemes that compose the phrase. Number specifications capture the grammatical number properties of morphemes (so that *scissors* is plural and *news* is singular, for example). The reconciliation of inconsistencies between marked and specified number favors lexical specifications.

There are two important properties related to number specification. One is that simple count nouns (e.g., *dog*) appear to be unspecified or only weakly specified for number. Consistent with this is the weakness of singular attraction to singular local nouns, which contrasts with the prevalence of plural attraction to plural local nouns (Eberhard, 1997). A second, correlated property of

tapraid1/z2q-psycho/z2q-psycho/z2q00305/z2q0641d05g | stambauj | S=11 | 5/20/05 | 19:38 | Art: 2003-0071-RRR

specification involves contrastiveness. When plural nouns (e.g., *scissors*, *suds*) lack corresponding singular forms, their selection from the lexicon is unopposed by formally or semantically similar entries. Conversely, when a plural form is strongly opposed by a formally and semantically similar entry (i.e., a much higher frequency singular), its activation or selection requires it to overcome competition from its number counterpart (Baayen, Dijkstra, & Schreuder, 1997). Contrastiveness modulates attraction, with less attraction occurring for invariant than for variable plurals (Bock et al., 2001) and more attraction occurring for low-relative-frequency plurals than for high-relative-frequency plurals (Bock, Eberhard, & Cutting, 2004; see also Spalek & Schriefers, 2005). Related effects on attraction that can be naturally linked to lexical processes include morphological homophony (Hartsuiker et al., 2003; Vigliocco et al., 1995) and morphological irregularity (Haskell & MacDonald, 2003). These variations in attraction can be attributed to gradations in the impact of local noun specifications on the reconciliation of number in subject noun phrases.

Marking and morphing thus distinguishes between two sources of plural verb number that deviate from the normal tendency for verbs to agree in number with the lexical head of the subject noun phrase. One is due to marking and is rooted in the meaning behind the subject noun phrase; the product is notional agreement. The second is due to the dynamics of morphing run amok. When a noun that is not the head succeeds in making its own number specification the reconciled number of the entire subject noun phrase (for reasons considered below), it yields attraction. In the next section, we examine how these same two sources of number influence pronouns.

The marking and morphing of pronouns. A strong claim of marking and morphing is that verb number directly reflects the reconciled number of the subject noun phrase. In other words, verbs do not get number on their own but inherit the subject's number in a process of agreement control. In this respect, the account of pronoun number contrasts with the account of verb number. Pronouns, we argue, do get number on their own in a process of agreement concord. Putting it (too) simply, pronouns get their number in the semantics, whereas verbs get their number in the syntax. Figure 2 illustrates pronoun number agreement in a format parallel to the one used in Figure 1. To explain verb and pronoun number (and number agreement) within a coherent framework, we assume that the operations of marking and morphing work along with the satisfaction of number semantics that takes place during the nomination of lexical entries for pronouns. The satisfaction of number semantics by a nominated lexical entry is the lexical–semantic parallel of number marking in the syntax. F2

One motivation for explaining pronoun number in this way comes from speech errors. Unlike the stranded inflections of nouns and verbs, personal pronouns do not seem to leave their grammatical properties behind when they are involved in exchanges or

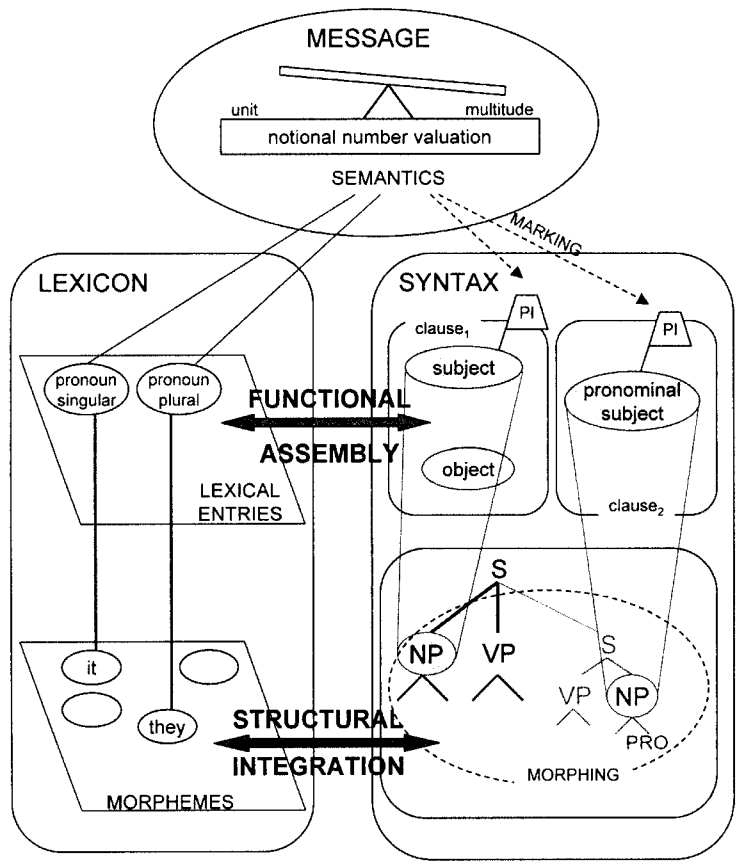

Figure 2. Illustration of pronoun agreement in language production. Pl = plural; S = sentence; NP = noun phrase; VP = verb phrase; PRO = pronoun.

other errors. Instead, they take their agreement properties with them. This yields phrase exchanges such as "Most cities are true of that" (when *That is true of most cities* was intended) and "You are too good for that" (when *That is too good for you* was intended; Stemberger, 1985, p. 154).

Broadly, here is how we suppose that pronoun number comes about. Within an episode of sentence formulation, the lexical entries for pronouns start with a number, either singular or plural, which can be determined by the notional valuation of the pronoun's referent. If the pronoun's referent also happens to be the referent of a subject noun phrase, the referent's number will determine marking on the subject noun phrase, and the marked number should be the same as the pronoun's number. Accordingly, if a pronoun is coreferential with the subject of a particular verb—that is, if the subject is also the antecedent of a pronoun—in simple circumstances the pronoun will have the same number as the verb. This is not because a pronoun inherits its antecedent's number in the way that the verb inherits the subject's number (i.e., via control) but because a pronoun has the same notional number as any noun phrase with which it is coreferential (because of concord).

The circumstances that yield equivalence in verb and pronoun number can become complicated in two distinct ways. One of them leads to a divergence in verb and pronoun grammatical number. The second leads to a convergence of verb and pronoun grammatical number on a value that differs both from notional number and from the expected number of the subject noun phrase.

Divergences in verb and pronoun number arise from differences inherent in their respective lexical and syntactic number realizations. When the marked number of the subject is cancelled or changed by a lexical specification, the grammatical number of the verb is automatically affected, but the grammatical number of a coreferential pronoun (i.e., a pronoun coreferential with the subject) need not be. This is because pronouns can bear a number of their own and do not have to inherit a number from anything else. Verbs cannot do this. In general, then, the grammatical number of pronouns should be more likely to reflect notional number than is the grammatical number of verbs.

Convergence between pronouns and verbs on a deviant grammatical number, a number that is consistent with neither notional number nor the number specifications of the head noun, comes about in attraction. Attraction occurs for pronouns as well as for verbs, as in *The witness to the murders perjured themselves* (cf. Bock et al., 1999). Here the local noun *murders* appears to attract the reflexive pronoun to elicit a spurious plural. Clearly the pronoun does not reflect the (presumably singular) notional number of its referent. How does it become plural? One possibility is that the pronoun erroneously takes the local noun as its antecedent. If so, the kinds of nouns that affect pronoun plurality (e.g., collective nouns) should be associated with increased pronoun attraction when they occur as local nouns. However, the results from Bock, Eberhard, and Cutting (2004) suggest that this is not the case.

Alternatively, if pronoun attraction happens in the same way as verb attraction, the grammatical number of a pronoun's antecedent may enter into the determination of pronoun number in a transmission process analogous to what happens in verb agreement. Assuming that the linguistic form of its antecedent is accessible, a pronoun's eventual number may be influenced by the same reconciliation that leads to the number of a subject noun phrase controlling a verb. Morphing comes into play in this reconciliation, with the same potential for spurious consequences. That is, if morphing aims at reconciling the grammatical number values of morphemes as they are bound to structural positions, pronouns will be vulnerable to influence from the grammatically reconciled number of their antecedents.

Consider *The witness to the murders has perjured himself.* Here the antecedent of the reflexive pronoun *himself* is *the witness to the murders.* The grammatical number of *the witness to the murders* is singular, and this number is reflected in the singular number of the verb *has.* The singularity of *himself* we attribute to the singular notional number of its referent, which is also the referent of *the witness to the murders*, following the argument in Bock et al. (1999). In addition, the singularity of *himself* may be reinforced by reconciliation with the singular subject noun phrase. The workings of reconciliation are highlighted in utterances like *The witness to the murders perjured themselves.* The morphing hypothesis is that if, prior to the selection of a pronoun's morphological form, the pronoun phrase's number is reconciled with its antecedent's number in a process similar to agreement, the same kind of noun–phrase–number reconciliation that leads to verb attraction should also lead to pronoun attraction and under exactly the same conditions (assuming that the pronoun has an accessible antecedent). If this hypothesis is right, it implies a uniformity in the implementation of verb and pronoun agreement that explains some of the similarities in their behavior: The same kind of grammatical number information is accessible to both pronouns and verbs at the same point in sentence formulation. It also implies that attraction occurs in a grammatical or structural representation where grammatical or morphological number features are in play.

To summarize, there are two predictions from the marking and morphing approach to agreement about pronoun number and about the relationship of pronoun number to verb number. The first is that pronouns are more sensitive to notional number because their primary formulation is lexical and not syntactic, and their lexical specifications reflect notional number. The second is that pronouns are equally vulnerable to attraction from grammatical number, because they are influenced at a different point in formulation by the reconciled number of their antecedents. When a pronoun's antecedent and a verb's controller are the same, the attraction consequences should be the same, with both of them different from the grammatically expected number.

Experimental tests. Marking and morphing predictions about verb and pronoun number were tested by Bock, Eberhard, and Cutting (2004) in experiments that examined the incidence of singular and plural pronouns compared with singular and plural verbs in similar sentence contexts. Rather than looking for rare cases of overt disagreement between verb and pronoun number like those in Table 1, the experiments created parallel environments for verb and pronoun agreement and examined the differences in production that arose between verb and pronoun number within those similar environments.

For both pronouns and verbs, the experiments assessed the number that was used when speakers completed a designated subject, a preamble such as *The army with the incompetent commanders*, with material to create a complete sentence. Making a complete sentence using this subject required a verb, and the verb often displayed a number (e.g., *The army with the incompetent commanders was* or *The army with the incompetent commanders*

tapraid1/z2q-psycho/z2q-psycho/z2q00305/z2q0641d05g | stambauj | S=11 | 5/20/05 | 19:38 | Art: 2003-0071-RRR

were). Pronouns were elicited by presenting the same preambles along with past-tense intransitive verbs (e.g., *The army with the incompetent commanders retreated*) and having speakers complete them with tag pronouns (e.g., *The army with the incompetent commanders retreated, did not it?*).

Tag pronouns agree in number and gender with the subject of the previous clause. However, being outside of the previous clause, and in fact being the subjects of their own clauses, their coreference possibilities are treated differently from those of reflexives in formal linguistic theories (Chomsky, 1981; though note that tag and reflexive pronouns have been found in two studies to be the same in susceptibility to plural attraction as well as in sensitivity to notional plurality; Bock, Butterfield, et al., 2004; Bock et al., 1999). The difference between tag pronouns and verbs in clause membership would seem to make tag pronouns less likely, a priori, to reflect the same agreement mechanisms that verbs do. Tag pronouns thus constitute a more challenging test than reflexives of the marking and morphing predictions about similarities between verb and pronoun attraction and a more favorable environment for constraint satisfaction predictions.

Five experiments evaluated two key questions about the relationship between verb and pronoun number. The first question was whether pronouns and verbs exhibited the same variations in agreement with respect to grammatical and notional number. Particularly important were cases with discordant notional and grammatical number. If the differences between verbs and pronouns in sensitivity to notional number are as predicted from the theory, pronouns should have exhibited more notional agreement than verbs. Figure 3 summarizes the results over all experiments, with the conditions on the right side of the graph representing notionally plural agreement controllers. The first thing to note is that, relative to controllers that were both notionally and grammatically singular (the singular head, singular local noun condition [SS] in the figure), all of the conditions in which the controllers carried notionally plural construals elicited more plural agreement targets, both verbs and pronouns. Pronoun targets were more likely to be plural than verb targets were, with gradations in the relative strength of their notional sensitivity. As expected, plural agreement tended to occur when the head nouns were collectives (collective singular head, plural local noun [CsP]; collective singular head, singular local noun [CsS]) and when the subject noun phrases and pronoun antecedents had distributive construals (distributive phrase, singular head with invariant plural local noun [D,SPT]; distributive phrase, singular head, plural local noun [D,SP]).

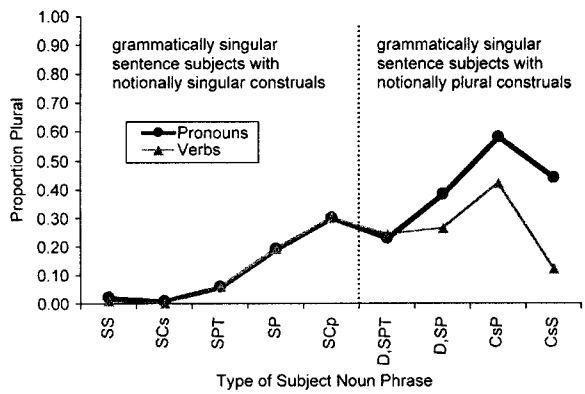

Figure 3. Mean proportions of plural agreement targets associated with nine types of subject noun phrases. SS = singular head, singular local noun; SCs = singular head, collective singular local noun; SPT = singular head, invariant plural local noun; SP = singular head, plural local noun; SCp = singular head, collective plural local noun; D,SPT = distributive phrase, singular head with invariant plural local noun; D,SP = distributive phrase, singular head, plural local noun; CsP = collective singular head, plural local noun; CsS = collective singular head, singular local noun. From "Producing Number Agreement: How Pronouns Equal Verbs," by J. K. Bock, K. M. Eberhard, and J. C. Cutting, 2004, *Journal of Memory and Language, 51*, p. 274. Copyright 2004 by Elsevier. Reprinted with permission.

A second question concerned the patterns of attraction after local nouns that varied in their grammatical and notional properties. The relevant results are shown on the left side of the figure. In contrast to their behavior in agreement, in attraction pronouns were no more likely than verbs to be influenced by the notional properties of attractors and were as likely as verbs to be influenced by the grammatical properties of attractors. So, pronouns were as strongly attracted to grammatically plural local nouns as verbs were (singular head, plural local noun [SP]) and were no less attracted to notionally singular grammatical plurals than verbs were (singular head, invariant plural local noun [SPT]). That is, verb and pronoun attraction were roughly the same.

The findings from two experiments using collective nouns illustrate the data behind these general patterns. Figure 4 summarizes the comparisons. The top panel shows the results from an experiment in which the head nouns were either grammatically singular collectives (which can carry a notionally plural sense; e.g., *choir*) or grammatically singular individual nouns (which were notionally singular; e.g., *singer*). The local nouns were grammatically singular or plural. The bottom panel shows what happened when the same collective and individual nouns served as local nouns in grammatically singular (*choir*, *singer*) and grammatically plural (*choirs*, *singers*) versions.

With head noun variations in collectivity (top panel), both verbs and pronouns exhibited sensitivity to plural notional properties, although pronouns were decidedly more sensitive to these properties than verbs were. In contrast, local noun variations in collectivity (bottom panel) affected verbs and pronouns in the same ways: There was attraction to plural local nouns, to the same extent for verbs and pronouns, and neither the verbs nor the pronouns were influenced by the notional number of the collectives. This patterning of notional effects (and noneffects) suggests a dissociation between controllers and attractors in the properties to which their targets are sensitive. Put differently, there is a dissociation in the workings of notional and grammatical number in agreement and attraction.

The fact that verbs and pronouns both exhibit this dissociation, albeit to different degrees, suggests that there are substantial but not complete parallels in how verbs and pronouns acquire number in the course of language production. The parallels are incomplete because verbs are less susceptible than pronouns to notional effects in agreement. In the next section, we consider how the processes of agreement and attraction might be modeled in order to predict the number behaviors of verbs and pronouns.

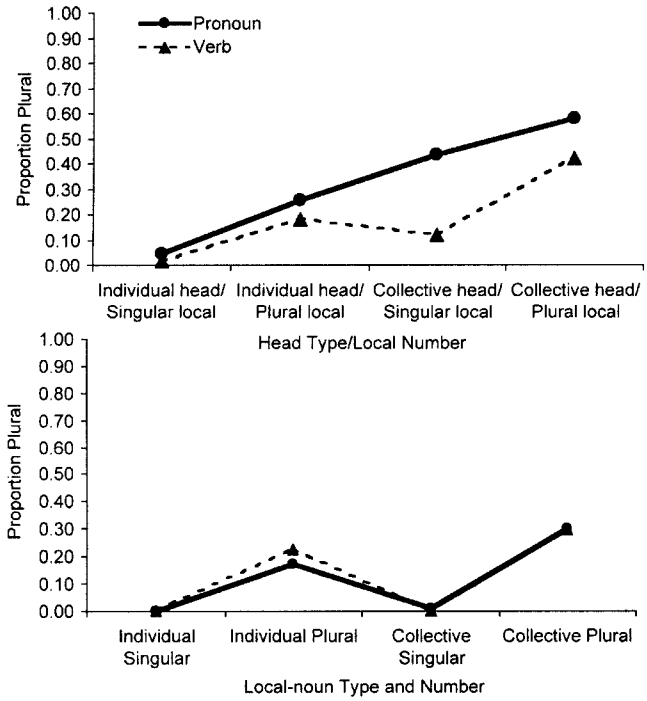

Figure 4. Overall proportions of plural pronouns and verbs produced with collectives as head nouns (top panel) and the same collectives as local nouns (bottom panel). From "Producing Number Agreement: How Pronouns Equal Verbs," by J. K. Bock, K. M. Eberhard, and J. C. Cutting, 2004, *Journal of Memory and Language, 51*, p. 266. Copyright 2004 by Elsevier. Adapted with permission.

Predicting Number Agreement: A Model of Marking and Morphing

To more precisely evaluate the adequacy of the marking and morphing account of number agreement and attraction, we developed a simple model of the process by which verbs acquire number. Then, we examined an extension of the model to pronouns. Like all models, the ones we present are not intended to instantiate every proposed mechanism from the marking and morphing theory. The purpose was to assess the sufficiency of the proposed sources of number information and the proposed workings of agreement and attraction in accounting for the observed number values of verbs and pronouns under the kinds of conditions that have been experimentally tested.

The aim of the verb model was to quantify the contributions from each hypothesized source of number information (subject phrase marking and lexical number specifications) and to calculate the predicted consequences of the hypothesized number reconciliation (the morphing process) that operates during structural integration. The model was constructed on the basis of findings from experiments on verb number agreement in the literature and then used to predict the verb data from Bock, Eberhard, and Cutting (2004). The pronoun model was created by minimally modifying the verb model so as to implement a marking and morphing account for pronoun number in tag questions and then used to predict the pronoun results from Bock, Eberhard, and Cutting (2004). Figure 3 summarizes the verb and pronoun data for which the model was directly accountable.

As illustrated in Figure 5, there were two sources of number information in the model: (a) the initial marking of notional number on the subject noun phrase and (b) the lexical number specifications of head and local nouns and their inflections. Number information from both sources was represented in terms of real-valued numbers ranging from −1 to 1. The calculations in the model involved combining the notional and lexical sources of number and transforming the result into a probability of plural agreement. F5

The model treats number information like a source of activation in activation-based cognitive models. When a source of number information is bound to a temporary structural network for an utterance, it transmits its information to the structure. Within the structure, the information moves or spreads according to principles of structural organization, assembly, and dissolution. Because these principles are at best poorly understood, only one of them, structural distance, is represented in the model. Figure 5 illustrates movement of number information along the dotted-line branches.

Number information in the model is dubbed SAP for singular and plural. Negative values are more singular, and positive values are more plural, implying that gradations of number underlie the discrete singular and plural linguistic distinctions. The next section describes SAP values in more detail.

SAP Values

The SAP values for number marking, S(n) in the model, were 1 for unambiguously multitude, 0 for unit, and −1 for cases of specific individuation (e.g., singling out by a quantifier, e.g., *one*, or a proper name). There was also a value representing ambiguous notional number, such as subject phrases denoting masses (including integrations of objects or substances; Solomon & Pearlmutter, 2004), collections, or distributions. This ambiguity value was a free parameter that was constrained to be in the interval (−1, 1).

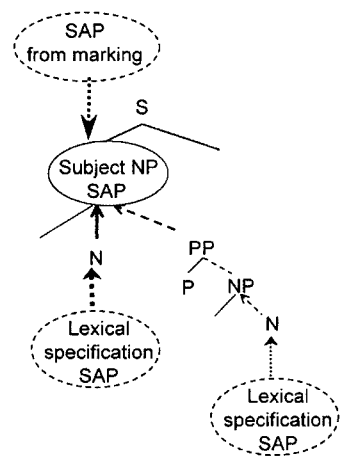

Figure 5. Sources of singular and plural (SAP) accumulating at root of subject noun phrase in basic marking and morphing model. The difference between the solid arrow and dashed arrow leading directly to the Subject NP in the phrase-structure tree reflects the greater weight of the lexical specification SAP from the head noun than from the local noun. S = sentence; N = noun; NP = noun phrase; P = preposition; PP = prepositional phrase.

tapraid1/z2q-psycho/z2q-psycho/z2q00305/z2q0641d05g | stambauj | S=11 | 5/20/05 | 19:38 | Art: 2003-0071-RRR

The value that produced the best fit to the empirical data was .48 (see Table 4, which will be discussed later in the text).

Variations in lexical number specification were treated as variations in the SAP values of morphemes, or S(m). In most current models of the production lexicon, lexical–grammatical features like number specifications are argued to be attached to lemmas (abstract lexical entries; Foygel & Dell, 2000; Levelt et al., 1999; see Dell & Sullivan, 2004, for review). Our approach is compatible with this assumption, but to keep the model simple, it is agnostic with respect to architectural details of the lexicon itself. Beyond lexical–grammatical features, what is minimally necessary for a model of existing agreement data is a competitive lexical network with entries that are frequency sensitive, and these are elements of all contemporary models. The values of S(m) were calculated as follows:

$$S(m) = \text{Specification} \times C_{freq}, \quad (1)$$

where C_{freq} refers to contrastive frequency.

Specification varied according to the type of noun. Plural count nouns, invariant plural nouns, and plural pronouns had the maximum value of 1. The uninflected form of collective nouns had a value of .07, which is the proportion of plural agreement targets that occurred with collective nouns as controllers in an analysis of a text corpus of American English by Bock, Butterfield, et al. (2004). Singular count nouns, singular pronouns, and mass nouns had specification values of 0; therefore, their S(m) was also 0.

The specification values for the other types of nouns were adjusted by the relative frequencies of the nouns' contrasting singular and plural forms, or C_{freq} in Equation 1. This adjustment was motivated in part by the observation that plural local nouns that have a contrasting singular form create more attraction than invariant plural local nouns (cf. *bubble–bubbles* vs. *suds*; Bock et al., 2001), and higher relative frequencies of the singular and plural forms increase attraction proportionately (Bock, Eberhard, & Cutting, 2004). Linked to these attraction effects is a trend toward decreased control of plural agreement when invariant plural nouns are heads of subject phrases (Middleton & Bock, 2004).

For modeling purposes, CELEX frequencies (Baayen, Piepenbrock, & van Rijn, 1993) were obtained for both the singular and plural forms of the head and local nouns used in experiments from the agreement literature for which materials were available. Because invariant plural nouns lack a singular form, the frequency of their singular form was zero. For each type of noun, C_{freq} was estimated using the formula in Equation 2, dividing the log of the summed average frequencies of the singular and plural forms by the log of the average frequency of the plural forms:

$$C_{freq} = \log_{10} \times (\text{frequency}_{singular} + \text{frequency}_{plural}) / \log_{10}(\text{frequency}_{plural}). \quad (2)$$

T2 Table 2 shows the values of S(m), specification, and C_{freq} for the different types of nouns used in the agreement model.

Table 2
Specifications, Average Contrastiveness, and Average S(m) Values for Controller and Attractor Types in the Agreement Model

Controller-attractor type	Specification	Mean contrastiveness frequency (C_{freq})[a]	S(m)
Singular count noun	0.00	1.21	0.00
Plural count noun	1.00	1.16	1.16
Invariant plural noun	1.00	1.00	1.00
Singular collective noun	0.07	1.27	0.09
Plural collective noun	1.00	1.25	1.25

Note. S(m) = variations in the average total lexical specification values for various types of singular and plural morphemes.
[a] Actual contrastiveness estimates depended on the samples of items used as heads or local nouns in individual experiments.

Verb Model

The combinatory mechanisms of morphing were modeled by pooling the SAP (S[n]) that is initially marked on the root of the subject noun phrase with the lexical specification SAPs (S[m]) that are transmitted from the morphemes bound to terminals of the subject phrase in the structural network. As noted above, the transmission of SAP was treated as an activation-like process, with the weights of the connections or branches in the structural network modulating the amount of SAP that is transmitted across them (Stevenson, 1994). Because structural depth or distance matters to agreement (Bock & Cutting, 1992; Franck, Vigliocco, & Nicol, 2002; Hartsuiker, Antón-Méndez, & van Zee, 2001; Solomon & Pearlmutter, 2004; Vigliocco & Nicol, 1998), the weights decreased as a function of the distance from the root of the subject noun phrase. Because SAP may flow unobstructed throughout a structural network, number information bound anywhere within a structure has the potential to influence agreement processes. For this reason, even number information outside a subject or antecedent noun phrase (as in Hartsuiker et al., 2001) can affect agreement, to a degree that is negatively correlated with its structural distance from the locus of agreement control.

The total amount of SAP at the root of the subject noun phrase, or S(r), was calculated by adapting a simple formula for spreading activation (from Dell, 1986), as shown in Equation 3:

$$S(r) = S(n) + \sum_j w_j \times S(m_j), \quad (3)$$

where $S(m_j)$ are the lexical specification SAPS of the morphemes bound to the subject noun phrase, and wj are the weights of the binding sites. For complex subject phrases consisting of a head noun and one local noun, the SAP from the morphemes (i.e., the second term in Equation 3) is calculated as

$$[w_H \times S(m_H)] + [w_L \times S(m_L)], \quad (4)$$

where $S(m_H)$ and $S(m_L)$ are the SAPs of the head noun and local noun, respectively, calculated using Equation 1, and w_H and w_L are the weights of the head noun's and the local noun's, respectively, distances from the root of the subject noun phrase. The values of the weights were free parameters in the model and constrained so that $w_H > w_L$.

The model was fit to the verb-agreement data by transforming S(r) into a probability of plural agreement using the logistic transformation:

$$1/\{1 + \exp -[S(r) + b]\}, \quad (5)$$

where b refers to a constant bias.

Because higher SAP values reflect heightened plurality, they transform to increasing probabilities of plural agreement. In Equation 5, a constant bias (b) is added to S(r) to predispose the model to default to singular (zero plural probability) in the absence of evidence for plurality. The bias was a free parameter in the model and had a value of −3.42 in all evaluations of the model.

Evaluation of the Verb Model

The verb model was evaluated in two steps. The first involved using a set of verb metadata to estimate the best-fitting values for the model's four free parameters. The metadata came from 17 studies that provided plural verb proportions or the raw numbers of singular and plural verbs for 17 types of subject noun phrases (see T3 Table 3). The four free parameters were the value of S(n) for subject phrases with ambiguous notional number, the weights of the head and local nouns (w_H and w_L), and the bias (b) in the logistic transformation. The notional ambiguity parameter had only one value in the model, despite the several types of notional ambiguity represented by the subject phrase conditions in Table 3. The only subject phrase condition in Table 3 that had two sources of notional ambiguity, the distributive collective, was modeled by doubling the value of the notional ambiguity parameter.

A conjugate gradient descent method was used to find the parameter values that yielded the smallest root-mean-square error (RMSE) for the difference between the plural verb proportions in the metadata and the model's estimate of plural probabilities. The T4 best-fitting values for each parameter are given in Table 4. Because the search function for the best-fitting values of the free parameters can be influenced by the initial values assigned to the parameters, we set the initial values and constrained the final values in terms of theoretically justifiable ranges, which are also shown in Table 4 (different start values did not affect the outcome of the fitting procedure). There was one constraint on the weights. The head noun branch of the structural network (w_H), the highest noun phrase in the structure, was constrained to be greater than the weight of the local noun branch (w_L). This weight difference represents the structural distance between the head and local nouns.

F6 Figure 6 illustrates the correspondence between the model's calculations and the hypothesized marking and morphing processes of verb agreement for the phrase *The key to the cabinets* T5 (see Table 5 for the relevant lexical specifications yielding the S[m] values in the figure). The outcome of the best-fitting values F7 for the verb metadata is charted in Figure 7 against the means from Table 3. With these values, the RMSE for the metadata was .032.

The second step was fitting the model to the verb results of Bock, Eberhard, and Cutting (2004). We examined the model's fit to the average proportions of plural verb agreement in the 11 conditions of Experiments 1–5 with the parameters fixed to the values from fitting the model to the metadata. The result is also shown in Figure 7. The RMSE was .077, and the correlation between the model and data were .980. The largest difference between the model's predictions and the data occurred for singular collective nouns in head position, because of a reduced magnitude of plural agreement with collective heads relative to the metadata. This in turn may be attributed to the different compositions of the collectives in the two data sets, with more inanimate collectives used in Bock, Eberhard, and Cutting (2004) than in previous studies. When the model was fit to just the Bock, Eberhard, and Cutting (2004) data and only the notional ambiguity parameter was allowed to vary, the best-fitting value for this parameter was .177, which yielded only a modest improvement in the fit (RMSE = .071).

Pronoun Model

The critical test for the verb model was its ability to fit pronoun data with minimal adjustments. Accordingly, the parameters and values for the pronoun model were identical to those for the verb model fit to the metadata. Pronoun number was assumed to be equal to the total SAP at the root of the pronoun phrase, $S(r_{PRO})$, that resulted from combining three SAP sources as follows:

$$S(r_{PRO}) = S(n) + S(r) + [w_H \times S(m_{PRO})]. \quad (6)$$

The first source of SAP, S(n), is from the direct marking of number on the root of the pronoun phrase. The value of S(n) is equivalent to the SAP from marking at the root of the antecedent subject noun phrase, because the referent of both phrases is the same. The second source of SAP, S(r), is the total SAP at the root of the antecedent subject noun phrase in the preceding clause (calculated by Equation 3). This represents the agreement of the pronoun with its accessible antecedent. Because S(r) includes the SAP from a local noun attractor, the effect of the attractor on the calculation of pronoun number is the same as the effect on the calculation of verb number. The third source of SAP, $S(m_{PRO})$, is from the lexical specification of the pronoun morpheme that is selected for binding to the terminal of the head of the pronoun phrase. It is modulated by the weight of the branch (w_H) between the terminal and the root of the pronoun phrase.

The model assumes that the initial selection of a singular or plural pronoun is based on the effect of notional number on the process of selecting lexical items within the lexicon (as depicted in the left sides of Figures 1 and 2). In particular, if the notional number is unambiguously multitude, then a plural pronoun should be selected from the lexicon, yielding a $S(m_{PRO})$ value of 1. If, however, the notional number is either ambiguous or unit, then a singular pronoun morpheme with an $S(m_{PRO})$ value of 0 should be selected from the lexicon. The outcome of the combinatory mechanisms of morphing, modeled by Equation 6, is responsible for changes to pronoun selection.

Figure 8 illustrates the sources of SAP that are hypothesized to F8 contribute to the calculation of pronoun number for a tag question following the clause *The key to the cabinets fell.* As in the verb model, $S(r_{PRO})$ was transformed into a plural probability using the logistic transformation in Equation 7, with a bias, b, value of −3.42.

$$1/\{1 + \exp -[S(r_{PRO}) + b]\}. \quad (7)$$

Figure 9 shows the relationship between the model's estimated F9 probabilities of plural pronoun use and the data for pronouns from

Table 3
Proportions of Plural Verbs From Previous Studies of English Subject-Verb Agreement (Verb Metadata)

	Subject phrase components			Source of data																
Notional valuation	Head	Local	Label	SP04	HM	BM	BC	BE	E37	VN	VBG	BNC	HB	BECMS	E	PE	BBCCEH	MB	TM	BCMO	*M*
Unit	S Cn	S Cn	SS	.04	.00	.03	.01	.00	.01	.00		.02		.01	.01		.01	.00	.01	.00	.01
Unit	S Cn	S Cl	SCs					.01						.01							.01
Mass (ambiguous)	Mass	S Cn	MS						.03									.04			.04
Unit	S Cn	IP	SPT											.12							.12
Unit	S Cn	P Cn	SP	.13	.01	.09	.08	.22	.30	.16	.10	.10		.17	.15	.11	.16	.09	.15	.08	.13
Mass (ambiguous)	Mass	P Cn	MP						.16									.15			.15
Integrated (ambiguous)	S Cn	P Cn	I,SP	.21																	.21
Distributed (ambiguous)	S Cn	IP	D,SPT											.19							.19
Distributed (ambiguous)	S Cn	P Cn	D,SP			.12			.35		.11			.31	.24	.16				.16	.21
Unit	S Cn	P Cl	SCp					.33						.13							.23
Collective (ambiguous)	S Cl	S Cn	CsS		.03							.36	.29				.24				.23
Collective (ambiguous)	S Cl	P Cn	CsP		.40							.60	.68				.52				.55
Distributed-collective (ambiguous)	S Cl	P Cn	D,CsP										.75								.75
Unit	IP	S Cn	PTS															.96			.96
Multitude	P Cn	S Cn	PS			.97	.97	.95	.99	.94		.99	.97				.99	.99	.95	.95	.97
Unit	IP	P Cn	PTP															.97			.97
Multitude	P Cn	P Cn	PP			.99	.98	1.00	.99	.94		.99	1.00				.99	.98	.94	.94	.98

Note. S = singular; P = plural; Cn = count; Cl = collective; IP = invariant plural; SS = singular head, singular local noun; SCs = singular head, collective singular local noun; MS = mass head noun, singular local noun; SPT = singular head, invariant plural local noun; SP = singular head, plural local noun; MP = mass head noun, plural local noun; I,SP = semantically integrated phrase, singular head, plural local noun; D,SPT = distributed phrase, singular head, invariant plural local noun; D,SP = distributed phrase, singular head, plural local noun; SCp = singular head, collective plural local noun; CsS = collective singular head, singular local noun; CsP = collective singular head, plural local noun; D,CsP = distributed phrase, collective singular head, plural local noun; PTS = invariant plural head, singular local noun; PS = plural head, singular local noun; PTP = invariant plural head, plural local noun; PP = plural head, plural local noun; SP04 = Solomon and Pearlmutter (2004); HM = Haskell and MacDonald (2003); BM = Bock and Miller (1991); BC = Bock and Cutting (1992); BE = Bock and Eberhard (1993); E37 = Eberhard (1993, 1997); VN = Vigliocco and Nicol (1998); VBG = Vigliocco, Butterworth, and Garrett (1996); BNC = Bock et al. (1999); HB = Humphreys and Bock (in press); BECMS = Bock et al. (2001); E = Eberhard (1999); PE = J. K. Potter and Eberhard (1999); BBCCEH = Bock, Butterfield, et al. (2004); MB = Middleton and Bock (2004); TM = Thornton and MacDonald (2003); BCMO = Bock, Carreiras, et al. (2004).

tapraid1/z2q-psycho/z2q-psycho/z2q00305/z2q0641d05g stambauj S=11 5/20/05 19:38 Art: 2003-0071-RRR

Table 4
Free Parameter Values for the Verb Model

Parameter	Constraint	Initial value	Best fit values, verb metadata
Marking: Notional number ambiguity (x)	$-1 \leq x \leq 1$	0.50	0.48
Weights (w)			
w_H	$w_H > w_L$	1.00	18.31
w_L	$w_L < w_H$	0.00	1.39
Logistic transformation: bias		−1.00	−3.42

Note. H = head noun; L = local noun.

Bock, Eberhard, and Cutting (2004). The RMSE was .089, and the correlation between the model's estimates and the data was .970. Again, as for the verb model, the largest deviation between model and data was for collectives, and for the same reasons.

Further Tests

Additional tests were carried out to assess how the model parameters contributed to its fit to the data. One test examined how variations of S(n) due to notional number affected the fit, and another looked at the consequences of eliminating the effect of contrasting frequencies in singular and plural forms on lexical number specifications (C_{freq}). Figure 10 shows the model's fits to the verb metadata without each of these two components in comparison with the complete model's fit. The figure shows that notional input contributes to fitting the data from conditions with distributive and collective subjects in particular (without notional input, RMSE = .080), and C_{freq} contributes most heavily to fitting conditions with plural local nouns and collective heads (without contrastiveness, RMSE = .067).

F10

A third variant of the model examined the effects of contributions from the head and local noun phrases' notional number, to explore the hypothetical impact on attraction from notional properties of local nouns. This variant involved modifying Equation 1 so that the calculation of the lexical specification SAP of nouns, S(m), added a value equivalent to the marking from notional number, S(n):

$$S(m) = (\text{Specification} \times C_{freq}) + S(n). \quad (8)$$

The value of S(n) was 0, corresponding to unit, for singular count nouns and invariant plural nouns, except when the latter were local nouns of a distributive subject phrase. In this case, the value of S(n) for the invariant plurals was 1, corresponding to multitude. The value of S(n) was also 1 for plural count nouns and plural collective nouns, and it was equal to the value of the ambiguous notional number parameter for the singular form of collective nouns and for mass nouns.

F11

Figure 11 shows the modified model's estimates of plural verb agreement compared with the actual proportions when the metadata and data from Bock, Eberhard, and Cutting (2004) are combined. The modified model overestimated plural attraction in all conditions with plural local nouns except for the condition with plural collective local nouns. The modified model also overestimated plural agreement in conditions with mass and collective nouns as heads.

To further examine the modified model's ability to fit the data, a search for new values for all four free parameters was conducted in the same manner as the search for the original model. The outcome of the search, however, failed to provide a better fit to the data (RMSE = .048). In particular, whereas the values of the two weight parameters and the bias parameter were similar to the original model's values, the best-fitting value for the ambiguous notional number parameter in the modified model was 0. As a consequence, the modified model predicted little or no effect of distributivity, producing nearly equal estimates of plural verb agreement for the pairs of conditions that contrasted with respect to unit versus distributive notional number (e.g., singular head, plural local noun [SP] vs. distributive, singular head, plural local noun [D,SP]; singular head, invariant plural local noun [SPT] vs. distributive, singular head, invariant plural local noun [D,SPT]; collective singular head, plural local noun [CsP] vs. distributive, collective singular head, plural local noun [D,CsP]).

Discussion and Extensions

The immediate aim of the model was to assess whether an explicit instantiation of key marking and morphing claims could account for the range of pronoun number values observed in the experiments by Bock, Eberhard, and Cutting (2004). Specifically, the model had to incorporate notional number (the values behind marking) and lexical number specifications (the values behind morphing), and show how these sources of number information combine. A major challenge was to see whether the same marking

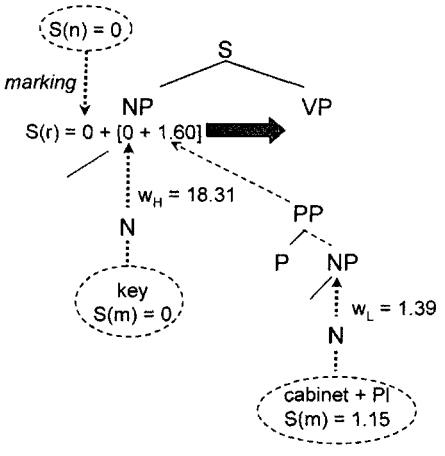

Figure 6. Calculation of S(r), the total singular and plural at the root of the subject noun phrase, for the phrase *The key to the cabinets*. The value of S(r) is transformed into a plural probability by a logistic function, which for this example yields a .14 probability of a plural agreement target. The gray arrow indicates that the value of S(r) is transmitted to the verb phrase (VP) node to determine the number of the verb. S(n) = singular and plural from the initial marking of notional number; S = sentence; NP = noun phrase; w_H = weight of the head noun; w_L = weight of the local noun; N = noun; S(m) = lexical specification singular and plural from the morphemes, which is multiplied by the weight (w_H or w_L) of the link between the morpheme and the root; PP = prepositional phrase; P = preposition; Pl = plural.

Table 5
Examples of Phrases Representing Quantifier (Determiner) Conditions in Eberhard (1997) With Values for Notional Number (S[n]) and Lexical Specifications of Determiners (S[m_D]) and Nouns (S[m_H], S[m_L]) Used to Examine the Model's Fit

			Head noun phrase		Local noun phrase		
Example	Label	S(n)	S(m_D)	S(m_H)	S(m_D)	S(m_L)	Plural verb
The label on the bottle–The key to the cabinet	SS	0.00	0.00	0.00	0.00	0.00	0.01
One key to the cabinet	QSS	0.00	−1.00	0.00	0.00	0.00	0.01
Every–Each label on the bottle	D,QSS	0.48	−1.00	0.00	0.00	0.00	0.05
One key to the cabinets	QSP	0.00	−1.00	0.00	0.00	1.20	0.12
The key to the cabinets	SP	0.00	0.00	0.00	0.00	1.15	0.13
The label on the bottles	D,SP	0.48	0.00	0.00	0.00	1.19	0.21
The label on many–several bottles	D,SQP	0.48	0.00	0.00	1.00	1.18	0.25
The key to many cabinets	SQP	0.00	0.00	0.00	1.00	1.26	0.29
Every–Each label on the bottles	D,QSP	2 × 0.48[a]	−1.00	0.00	0.00	1.21	0.30
The keys to one cabinet	PQS	1.00	0.00	1.15	−1.00	0.00	0.95
The labels on the bottle–The keys to the cabinet	PS	1.00	0.00	1.18	0.00	0.00	0.97
The labels on every–each bottle	D,PQS	1.00	0.00	1.27	−1.00	0.00	0.98
The labels on the bottles–The keys to the cabinets	PP	1.00	0.00	1.18	0.00	1.00	0.98

Note. S(n) = singular and plural values for number marking; S(m_D) = lexical specification value of the determiner or quantifier; S(m_H) = singular and plural values for the head noun; S(m_L) = singular and plural values for the local noun; SS = singular head, singular local noun; QSS = quantified singular head, singular local noun; D,QSS = distributive phrase, quantified singular head, singular local noun; QSP = quantified singular head, plural local noun; SP = singular head, plural local noun; D,SP = distributive phrase, singular head, plural local noun; D,SQP = distributive phrase, singular head, quantified plural local noun; SQP = singular head, quantified plural local noun; D,QSP = distributive phrase, quantified singular head, plural local noun; PQS = plural head, quantified singular local noun; PS = plural head, singular local noun; D,PQS = distributive phrase, plural head, quantified singular local noun; PP = plural head, plural local noun.

[a] The ambiguous notional number parameter was multiplied by two because there were two sources of distributivity in this condition.

values and the same lexical specifications used to account for verb number could accurately predict corresponding variations in pronoun number, including (a) the tendency for pronouns to behave differently from verbs when an antecedent's covert notional number diverged from its overt grammatical number and (b) the tendency for pronoun number attraction to behave the same as verb number attraction.

To predict the impact of marking, we estimated the value of a free parameter representing notional ambiguity from previous results for verb number. Lexical specifications were fixed for plurals and singulars, with the contributions of these specifications to SAP modulated by the relative frequencies of singular and plural forms. Two other parameters instantiated features of the structural representation in which agreement features are hypothesized to be reconciled: One estimated the impact of the head noun's lexical specifications on the reconciled number of the subject noun phrase, and another estimated the impact of the local noun. The values of these parameters were also estimated from previous results for verb number.

With the free parameters set to values estimated from previous data on verb agreement, the model was used to predict the verb and pronoun results from Bock, Eberhard, and Cutting (2004). The fits between the verb and pronoun models and the verb and pronoun data, shown in Figures 7 and 9, lend credence to the theoretical claims that the model was designed to evaluate. In particular, the pronoun model was a minimal modification of the verb model, with identical parameters and parameter values. The only additions to the pronoun model were specifications for singular and plural pronouns in the lexical vocabulary, set to the same values used for other singular and plural words. Hypothesized differences between pronoun and verb agreement were instantiated by (a) marking notional number directly on the root of the pronoun phrase, to capture the referential properties of pronouns, and (b) entering the lexical number specification of the pronoun into a reconciliation with the number of the subject noun phrase, simulating antecedent–pronoun number agreement in the presence of an accessible antecedent. This represents the hypothesis that pronouns carry number in a way that differs from how verbs carry number, with lexical specifications of number that allow pronouns to be retrieved directly from the lexicon in response to number meanings in the message. Verbs, in contrast, may lack these directly accessible number properties, making it impossible for them to be selectively retrieved from the lexicon and requiring them instead to gain morphological number via agreement control.

We can contrast this result with the predictions from a model in which verb number is directly controlled from the message (along lines sketched in work by Vigliocco, Butterworth, & Garrett, 1996). A model in which SAP from notional number, S(n), is marked on both the root of the subject noun phrase and the root of the verb phrase can fit existing verb data just as well as the marking and morphing model does and has similar best-fitting values for all of the free parameters except for one: A contribution of SAP from notional number to both the subject and the verb results in a best-fitting value of .24 for the ambiguous notional parameter, which is half of the value of .48 for this parameter in the marking and morphing model. With this lower notional number parameter, the model no longer fits the pronoun data. Specifically, the model underestimates the probabilities of plural pronouns when notional number is ambiguous. Fixing this would demand different notional number parameters for verbs and pronouns, making the unparsimonious assumption that the number meanings which motivate verb and pronoun number agreement have different conceptual properties.

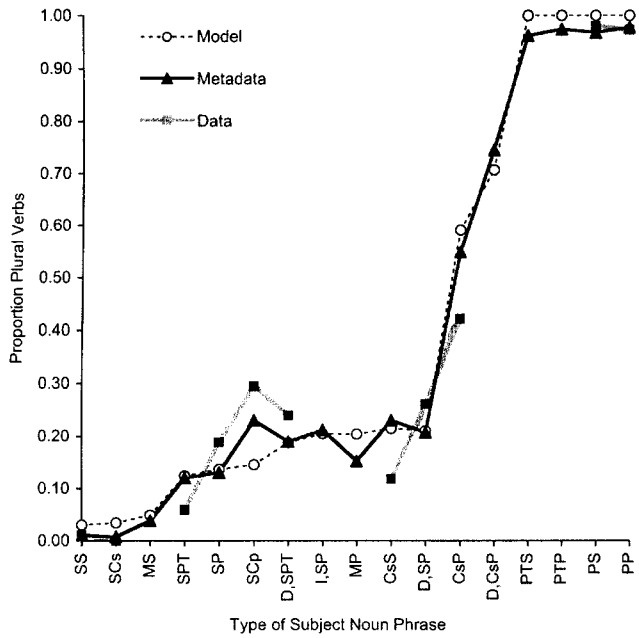

Figure 7. Fit between verb model, verb metadata from Table 3, and verb data from Bock, Eberhard, and Cutting (2004). SS = singular head, singular local noun; SCs = singular head, collective singular local noun; MS = mass head noun, singular local noun; SPT = singular head, invariant plural local noun; SP = singular head, plural local noun; SCp = singular head, collective plural local noun; D,SPT = distributive phrase, singular head with invariant plural local noun; I,SP = semantically integrated phrase, singular head, plural local noun; MP = mass head noun, plural local noun; CsS = collective singular head, singular local noun; D,SP = distributive phrase, singular head, plural local noun; CsP = collective singular head, plural local noun; D,CsP = distributive phrase, collective singular head, plural local noun; PTS = invariant plural head, singular local noun; PTP = invariant plural head, plural local noun; PS = plural head, singular local noun; PP = plural head, plural local noun.

A related approach to agreement argues for more pervasive effects of meaning throughout the agreement process. In particular, Vigliocco and colleagues' maximal input hypothesis (e.g., Vigliocco & Franck, 1999, 2001; Vigliocco & Hartsuiker, 2002) logically predicts that notional correlates of local nouns should contribute to attraction. An evaluation of this prediction in terms of a modification of the present model, illustrated in Figure 11, shows that an assumption of effects of the number meanings of local nouns selectively overestimates the observed likelihood that verbs will be plural.

The model makes it possible to extend some of the elements of the marking and morphing theory to other kinds of agreement relations, to other kinds of agreement features, and to other languages. For instance, in addition to subject–verb and antecedent–pronoun number agreement, there is agreement in number between determiners and nouns. In English, words like *a*, *each*, and *this* occur with singular nouns, whereas *some*, *many*, and *these* occur with plurals. We might assume that these words, like personal pronouns, carry number features that make them accessible for lexical selection from number meaning. This would make their agreement with the nouns they accompany a matter of concord, as in the pronoun model, rather than control, as in the verb model.

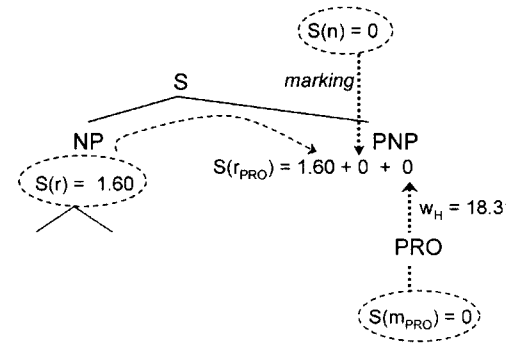

Figure 8. Calculation of $S(r_{PRO})$, the total singular and plural at root of pronoun phrase (PNP), following the clause *The key to the cabinets fell.* The value of $S(r_{PRO})$ is transformed into a plural probability by a logistic function. Because the values of both S(n) and $S(m_{PRO})$ are 0 in this example, the probability of producing a plural pronoun is .14, which is the same as the probability of producing a plural verb. S(r) = the total singular and plural of the antecedent subject noun phrase (see Figure 6); S(n) = the singular and plural from the marking of notional number; S = sentence; NP = noun phrase; PRO = pronoun; $S(m_{PRO})$ = the lexical specification singular and plural from the pronoun morpheme, which is multiplied by the weight (w_H) of its distance to the root of the pronoun phrase.

With data from Eberhard (1997) on the effects of quantifiers on number agreement, we created a version of the model that takes into account the contributions of determiners to verb agreement in English. Examples of subject phrases representing 13 conditions are given in Table 5 along with the notional number values and lexical specification values that were used to examine the model's

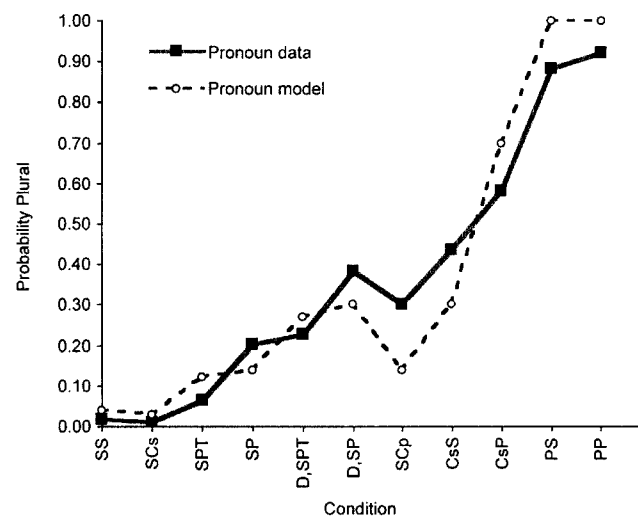

Figure 9. Model's fit to pronoun data from Bock, Eberhard, and Cutting (2004). SS = singular head, singular local noun; SCs = singular head, collective singular local noun; SPT = singular head, invariant plural local noun; SP = singular head, plural local noun; D,SPT = distributive phrase, singular head with invariant plural local noun; D,SP = distributive phrase, singular head, plural local noun; SCp = singular head, collective plural local noun; CsS = collective singular head, singular local noun; CsP = collective singular head, plural local noun; PS = plural head, singular local noun; PP = plural head, plural local noun.

tapraid1/z2q-psycho/z2q-psycho/z2q00305/z2q0641d05g | stambauj | S=11 | 5/20/05 | 19:38 | Art: 2003-0071-RRR

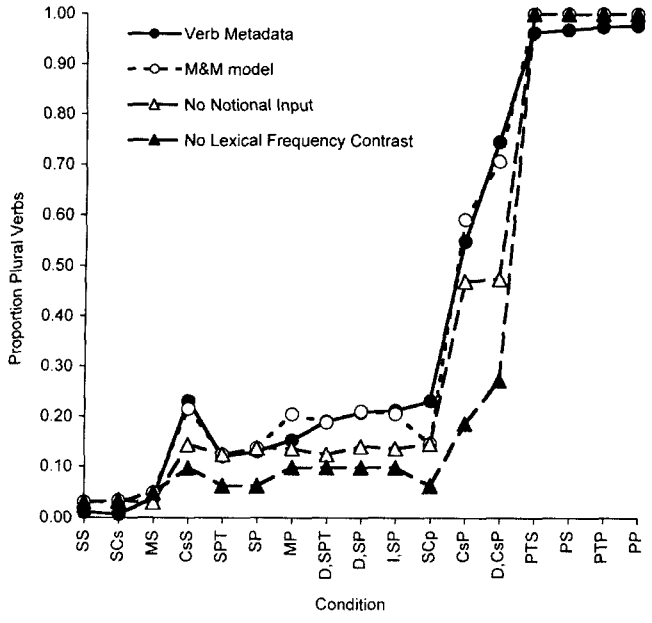

Figure 10. Contributions of notional input and lexical frequency contrast to model's fit. M&M = marking and morphing; SS = singular head, singular local noun; SCs = singular head, collective singular local noun; MS = mass head noun, singular local noun; CsS = collective singular head, singular local noun; SPT = singular head, invariant plural local noun; SP = singular head, plural local noun; MP = mass head noun, plural local noun; D,SPT = distributive phrase, singular head with invariant plural local noun; D,SP = distributive phrase, singular head, plural local noun; I,SP = semantically integrated phrase, singular head, plural local noun; SCp = singular head, collective plural local noun; CsP = collective singular head, plural local noun; D,CsP = distributive phrase, collective singular head, plural local noun; PTS = invariant plural head, plural local noun; PS = plural head, singular local noun; PTP = invariant plural head, plural local noun; PP = plural head, plural local noun.

fit to the data. The values of the free parameters came from fitting the model to the metaverb data. Specifications and notional values were calculated as in Equation 3, with the second term of the equation ($\Sigma_j w_j S[m_j]$) expanded to include the effects of determiner number on the total SAP transmitted from the head and local noun phrases, as shown in Equations 9 and 10, respectively:

$$w_H \times \{S(m_H) + [w_D \times S(m_D)]\} \quad (9)$$

and

$$w_L \times \{S(m_L) + [w_D \times S(m_D)]\}. \quad (10)$$

Here, w_D is the weight of the determiner and $S(m_D)$ is its lexical specification. The notional values S(n) were treated as unambiguous units or multitudes. The value of the one new parameter, w_D, was .28. Otherwise, the model and model parameters were identical to the verb model, with the parameters fixed at the original values. Its fit to the verb metadata and the eight quantifier conditions from Eberhard (1997) is shown in Figure 12 and yielded a RMSE of .040.

F12

This extension hints at how the model can be used to predict variability in the use of determiners in experiments on determiner agreement and selection, including determiners in other languages (e.g., Spalek & Schriefers, 2005). In Dutch, for example, the forms of definite determiners vary depending on the gender and number of their accompanying nouns. The production of an appropriate determiner must therefore take gender and number specifications (as well as notional gender and number, in some circumstances) into account. When determiner selection incorporates elements of agreement concord, as can occur in English, the additive relations from the pronoun model should apply (shown in Equations 9 and 10 incorporated into the verb model); whenever selection is a form of pure control, the equality relation of the verb model should yield a better fit. In either case, any competition among the forms of controlling nouns (cf. Alario & Caramazza, 2002; Janssen & Caramazza, 2003; Spalek & Schriefers, 2005) would enter the model as contrastiveness (C_{freq}) affecting the SAP of the noun's S(m), as in Equation 1.

As this implies, agreement in other languages and agreement features other than number can be used in evaluating the model

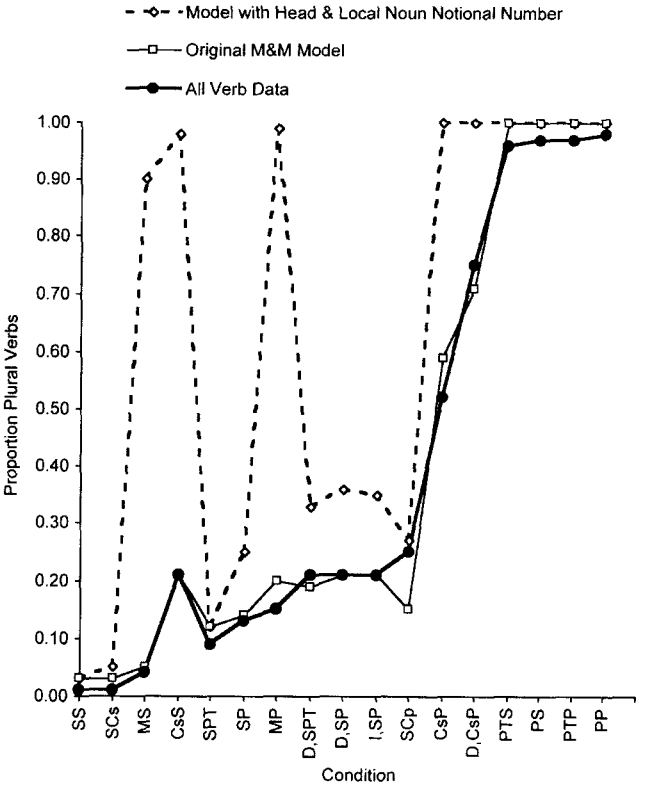

Figure 11. Effect of notional number contribution from the head and local nouns. M&M = marking and morphing; SS = singular head, singular local noun; SCs = singular head, collective singular local noun; MS = mass head noun, singular local noun; CsS = collective singular head, singular local noun; SPT = singular head, invariant plural local noun; SP = singular head, plural local noun; MP = mass head noun, plural local noun; D,SPT = distributive phrase, singular head with invariant plural local noun; D,SP = distributive phrase, singular head, plural local noun; I,SP = semantically integrated phrase, singular head, plural local noun; SCp = singular head, collective plural local noun; CsP = collective singular head, plural local noun; D,CsP = distributive phrase, collective singular head, plural local noun; PTS = invariant plural head, plural local noun; PS = plural head, singular local noun; PTP = invariant plural head, plural local noun; PP = plural head, plural local noun.

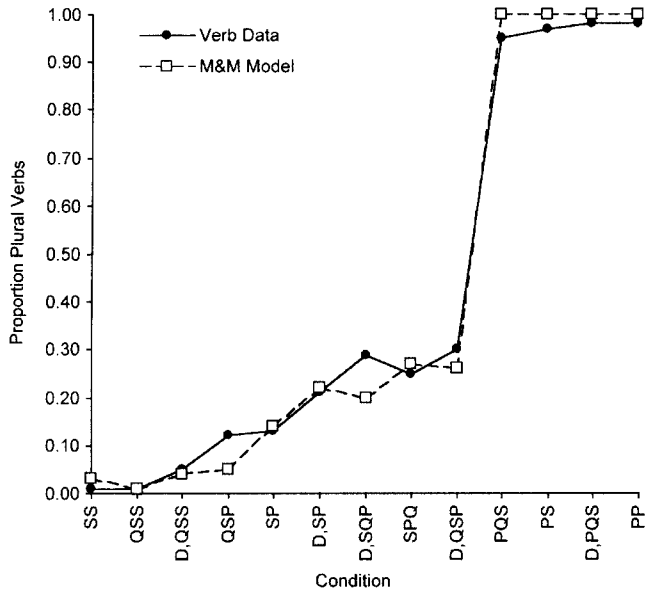

Figure 12. Extension of model to effects of quantifiers on verb agreement. SS = singular head, singular local noun; QSS = quantified singular head, singular local noun; D,QSS = distributive phrase, quantified singular head, singular local noun; QSP = quantified singular head, plural local noun; SP = singular head, plural local noun; D,SP = distributive phrase, singular head, plural local noun; D,SQP = distributive phrase, singular head, quantified plural local noun; SPQ = singular head, quantified plural local noun; D,QSP = distributive phrase, quantified singular head, plural local noun; PQS = plural head, quantified singular local noun; PS = plural head, singular local noun; D,PQS = distributive phrase, plural head, quantified singular local noun; PP = plural head, plural local noun.

and the underlying theory. With language-appropriate contrastiveness estimates and lexical specifications, it is a straightforward matter to adapt the model to predict the Dutch verb–number agreement and attraction data of Bock et al. (2001) and the Dutch pronoun–gender agreement and attraction data in Meyer and Bock (1999, Experiment 1), as well as the Spanish number agreement and attraction data from Vigliocco, Butterworth, and Garrett (1996) and Bock, Carreiras, Meseguer, and Octigan (2004).

We illustrate using Spanish number agreement. With contrastiveness estimates derived from Spanish word frequency counts (the Linguistic Data Consortium's online Spanish text corpus of over 65 million words), we fit the model to the results of five conditions tested in Vigliocco, Butterworth, and Garrett (1996) and in Bock, Carreiras, et al. (2004). The conditions were number matched singular or plural heads and local nouns (singular head, singular local noun [SS]; plural head, plural local noun [PP]), number mismatched heads and local nouns (singular head, plural local noun [SP]; plural head, singular local noun [PS]), and a condition in which distributed notional number was in play (distributive singular head, plural local noun [D,SP]). All of the free parameters were fixed at the same values shown in Table 4 for the English verb metadata. The outcomes are shown in Figure 13: The model's fits to the Vigliocco, Butterworth, and Garrett (1996) and Bock, Carreiras, et al. (2004) data had RMSEs of .038 and .044, respectively. So, even though the model's free parameters were derived from fitting English agreement data, the model also fit the Spanish data well with only an adjustment to capture Spanish lexical frequencies. This begins to make a case for the cross-linguistic promise of the model and the theory behind it.

An important task for the future is to incorporate a better constrained account of notional variations in agreement into the model. The current version treated notional variations in terms of a single-valued free parameter that introduced the consequences of notional number ambiguity. Although adequate for present purposes, it is unlikely that all notional ambiguities are resolved in the same ways or with the same consequences. Among the questions that remain open are (a) whether notional number ambiguity is resolved probabilistically in favor of singular or plural marking and (b) how and when the resolution occurs (see Frazier, Pacht, & Rayner, 1999, for work on related questions in language comprehension). Obviously, the morphology of English as a spoken language does not seem to admit degrees of singular or plural: Words are one or the other. But the production system could carry notional information forward in some guise to the point at which morphemes must be selected (see Vigliocco & Hartsuiker, 2002, for a review and discussion of this possibility).

The model is incomplete in many respects. It takes no account of time, incrementality, or variations in syntactic complexity apart from structural distance. It does not directly address discourse or pragmatic control of pronoun number (although we assume that as the lexical specifications of an antecedent become inaccessible, their impact on pronoun number dissipates). Its extendability to languages other than English, to agreement features other than number, and to agreement targets other than pronouns and verbs requires substantially more attention and further data. Such omissions are likely to make the model inadequate in accounting for broader ranges of agreement results than those available to us. Against these weaknesses, however, it has the strength of being

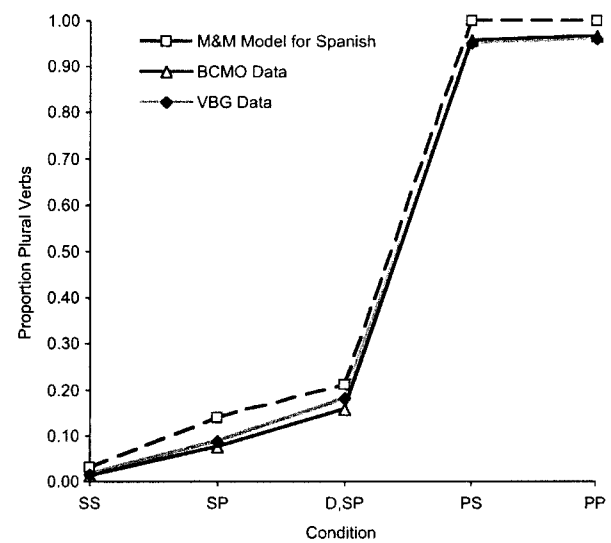

Figure 13. Extension of model to data on verb number agreement in Spanish from Bock, Carreiras, et al., (2004; BCMO) and Vigliocco, Butterworth, and Garrett (1996; VBG). M&M = marking and morphing; SS = singular head, singular local noun; SP = singular head, plural local noun; D,SP = distributive phrase, singular head, plural local noun; PS = plural head, singular local noun; PP = plural head, plural local noun.

explicit. Given estimates of lexical number specifications or gender specifications, and notional number marking or gender marking, it makes specific, verifiable predictions about verb and pronoun agreement in phrase and sentence contexts. No other approach has yet been made explicit enough to be evaluated against the increasing range of agreement results in the psycholinguistic literature.

General Discussion

The model offers support for two sets of predictions from the marking and morphing account of number agreement in language production. One set of predictions has to do with the ways in which pronoun number is the same as verb number. The fundamental similarity is due to a uniform, message-based source of number meaning. Whether the meaning behind an utterance motivates the marking of a subject or the selection of a number-specified pronoun from the lexicon, the relevant referential distinctions can be the same in both cases. That is, when the message supports some notional number valuation, the valuation affects both the syntax and the lexicon. In the syntax, marking leads to plural verb agreement; in the lexicon, selected pronouns carry number specifications with them. Notional plurality thus yields increases in the usage of plural verbs as well as plural pronouns. In the model, identical parameter values represented this contribution from notional number to both verb and pronoun agreement.

Pronouns and verbs can also be the same in where and how a number relationship to a controller is morphologically implemented. Morphing takes place within a structural representation of an utterance where agreement features are reconciled. This claim has two implications. One involves the integration and reconciliation of lexical information within and across phrases. In realizing the uniformities of number specification that English normally exhibits, the production system tries to bring the grammatical number features of pronouns and verbs, as agreement targets, into alignment with the number features of accessible phrases that are grammatically or anaphorically linked to these targets. This alignment occurs at a point when most of the lexical and structural features of the utterance have been determined and the lexical and structural features themselves are the primary focus of processing.

The second implication of the uniform structural locus for pronoun and verb morphing is their similar susceptibility to attraction. In experiments in which the morphological features of local nouns varied, the strength of attraction was comparable for pronouns and verbs (see Figure 3). Moreover, attraction changed in magnitude with changes in the morphological properties of the elements bearing spurious number features, with the same variations occurring for pronouns as for verbs. In the model, the lexical and structural contributions to morphing and attraction come from morphological number specifications and contrastiveness (which vary over individual morphemes) and from links between number sources and number targets within a structural network.

Another set of marking and morphing predictions for which the model must account has to do with the ways in which pronoun and verb number differ. A well-known contrast between pronouns and verbs is their relative sensitivity to notional number (Corbett, 2000). Although pronouns and verbs both reflect notional number, in controlled comparisons pronouns are consistently more likely than verbs to be plural as a consequence of notional plurality in the message (Bock, Eberhard, and Cutting, 2004; Bock et al., 1999). This was evident when head nouns or subject noun phrases as wholes had misaligned semantic and morphological properties, as with collective head nouns or distributively biased subject noun phrases.

The marking and morphing account for this difference is in terms of how pronouns and verbs get their number values. Though their nonlinguistic number origins can be the same, as described above, their linguistic implementations differ. Verb number agreement occurs under the control of syntactic processes; pronoun number is inherent in lexical entries, making number part of their semantics. When the syntax sets verb (or pronoun) number equal to the morphologically reconciled number of the subject noun phrase, that is structural control. When the lexicon bears the burden of selecting and retrieving number-congruent words for representing message elements in coreferential expressions, the result is lexical concord. In the model, the difference between control and concord corresponds to the difference between the structural transmission of number features in the syntax and the lexical satisfaction of number requirements from the message.

Behind many of the disparities that arise between control and concord are variations in the grammatical number of words, represented as lexical specifications in the model. Consider again the satisfaction of multitude or unit properties in the message by words with contrasting grammatical number, such as *clothing* and *binoculars*. Because number meanings are not perfect predictors of grammatical number, agreement differences arise. *Clothing* can satisfy multitude features without being grammatically plural, conveying plural meaning while being grammatically singular. *Binoculars* can satisfy unit features without being grammatically singular, conveying singular meaning while being grammatically plural. When such nouns are incorporated into a subject noun phrase, they can change its feature marking and thereafter the verb's number. There is no such variation for pronouns: Plural pronouns are morphologically specified as plurals.

These patterns of convergence and divergence pose challenges to accounts of agreement that make something analogous to concord the basis of all relationships among agreeing elements. The constraint satisfaction account of Thornton and MacDonald (2003; see also Haskell & MacDonald, 2003) predicts that the properties of head nouns that affect agreement should reliably correlate with the properties of local nouns that affect attraction. Arguing against this prediction are two well-established results. First, plural head nouns create plural agreement, and plural local nouns create plural attraction, but singular head nouns create singular agreement without reliably creating singular attraction. Second, the notional properties of head nouns can have substantial effects on agreement without having any discernible effect on attraction. This has been observed for both number (Bock, Eberhard, & Cutting, 2004) and biological gender (Vigliocco & Franck, 1999, Experiment 2).

The maximal input hypothesis (Vigliocco & Franck, 1999, 2001; Vigliocco & Hartsuiker, 2002) emphasizes the exploitation of conceptual information within the agreement process, asserting that available conceptual and referential information permeates the grammatical encoding process. A challenge to this view that goes beyond the other challenges to constraint satisfaction is the difference between verb and pronoun agreement in sensitivity to notional properties. The difference suggests that some kinds of processes must be more permeable than others, which runs against the

spirit of maximal input. Without an explicit account of agreement processes, it is unclear whether more conceptual information is accessible to pronouns than to verbs, whether pronouns are better able than verbs to capture differences in notional number, or if something else makes pronoun production more maximal, oxymoronically, than verb production.

Marking and morphing offers explanations for these differences, which the model successfully instantiates. First, the singular–plural asymmetry is attributed to a difference between singulars and plurals in lexical specifications, a difference that affects number reconciliation (a component of morphing) in noun phrases. Local nouns are less likely than similarly specified heads to affect the number of an agreement target to the degree that the local nouns are more embedded in a structural representation. Second, the absence of attraction to the notional properties of local nouns is due to the absence from local nouns of marking information. Finally, the difference between pronouns and verbs in sensitivity to notional number is explained in terms of a difference between verbs and pronouns in lexical support: Pronouns, unlike verb inflections, carry number as part of the lexical representation that is selected from the message. The consequence is that when notional singularity or plurality motivates the selection of a singular or plural pronoun, the pronoun itself serves to maintain a correlate of notional number within the utterance.

No other models have yet been developed to address in any detail the range of findings generated in the literature on grammatical agreement, so there is ample room for improvement to what we have done. We see one promising approach as building on the learning models developed by Chang (2002; Chang, Dell, & Bock, 2005) and J. K. Gordon and Dell (2003). The J. K. Gordon and Dell model is designed to account for variations in the use of semantically light (e.g., *do*, *go*) and heavy (e.g., *write*, *walk*) verbs by aphasics, and it does so in terms of trade-offs between syntactic and semantic sources of information. These trade-offs, or divisions of labor, are in many respects analogous to what we have proposed for verb and pronoun number. The meaning-bearing character of pronoun number implies involvement in the semantic system as it is implemented in J. K. Gordon and Dell's model, whereas the relative absence of meaningfulness of verb inflections in English implies involvement in the syntactic system. Because the J. K. Gordon and Dell model learns to divide the labor between semantics and syntax, it supports the kind of flexibility that is likely to be needed for variations in the meaningfulness of agreement morphology and agreement systems, within and across languages.

A logical step in the development of a cross-linguistically general approach to the production of agreement, then, would be a model that learns to rely differentially on the lexicon and syntax. However, progress toward such a model of agreement rests on having viable characterizations of the representations for and the likely interactions among different kinds of information. This is what we have aimed to provide, in terms of the model's assumptions about notional contributions to agreement, about the representations of number, and about a structural implementation of agreement that accounts for the variability that is known to exist.

Even as its stands, the proposed model of marking and morphing and the theory behind it help to bring together a substantial but largely unconnected set of findings in psycholinguistics. In the following sections, we consider some of the links from the psycholinguistics of number agreement in language production to other kinds of agreement, and we compare our findings and conclusions about production with other viewpoints. We begin with the literature on grammatical gender agreement in language production, surveying its relevance for the marking and morphing account.

Number and Gender, Natural and Grammatical

Grammatical gender systems are widespread in the languages of the world (Corbett, 1991). In English, gender's grammatical role is minimal. The only kind of gender specification that occurs reliably is based on natural (biological) gender and is found on pronouns alone. In many other languages, however, grammaticized gender categories partition the entire noun lexicon, without much consistency regarding conceptual distinctions apart from (and occasionally even extending to) natural gender. When a determiner, adjective, verb, pronoun, or other word must agree with such a noun, it most often does so not on the basis of the noun's meaning but on the basis of its grammatical gender specification.

There are obvious similarities between grammatical gender agreement and number agreement, but there is one crucial difference: Number on most nouns has a semantic motivation. For gender in grammatical gender-marking languages, the situation is reversed. Apart from the classes of nouns whose grammatical gender reflects the natural gender of their referents, the gender of most nouns has no clear semantic motivation. This means that number specification in language tends to be morphologically extrinsic (semantically motivated and inflectional, with the source of the number information extrinsic to the word), whereas gender specification in grammatical gender languages tends to be morphologically intrinsic (lexically motivated and noninflectional, with the source of the gender information intrinsic in the word itself).

What happens when number lacks semantic motivation or gender has it? For number in English, we have proposed that the plurals on words such as *scissors* and *suds* are lexically specified and noncontrastive. An analogous arrangement can be imagined for gender: Natural gender might be structurally marked in grammatical gender languages but be overridden, in exceptional cases, by a lexical specification. For instance, the Dutch word for *girl* (*meisje*) is grammatically neuter and takes neuter agreement, overriding the natural feminine gender that would be carried by marking. If so, the architecture could be parallel to that for extrinsic and intrinsic (or contrastive and noncontrastive) number in English. One might then expect parallels in the behavior of meaning-motivated contrasts in gender and number against noncontrastive gender and noncontrastive number. For example, when the gender of an adjective is motivated by the natural gender of a discourse antecedent or a deictic referent, the dynamics of agreement should be similar to those of pronoun agreement in English.

Such parallels have been reported for speech errors in Spanish. In an analysis of hesitations in spontaneous speech, Eccardt (2000) found more disfluency associated with the production of gender than of number agreement targets. However, when only natural gender was considered, the rates of disfluency for gender and number were the same. Igoa, García-Albea, and Sánchez-Casas (1999) also found contrasts between gender and number in the incidence, distribution, and types of errors involving number and gender. On the basis of their results, they concluded that gender

agreement is more likely to be lexically driven, whereas number agreement involves "the grammatical encoding operations that assemble the phrase structure frames of the sentence" (Igoa et al., 1999, p. 189). DeVincenzi (1999) argued for a similar sort of dissociation in Italian on the basis of results from language comprehension.

Because the production of gender has been examined in attraction paradigms that are similar to those used for studying number, contrasts between natural and grammatical number and natural and grammatical gender can be assessed under roughly comparable conditions. Gender attraction does in fact occur in French and Italian (Vigliocco & Franck, 1999, 2001). However, the magnitude of gender attraction appears to be uninfluenced by whether local nouns bear matching conceptual gender (Vigliocco & Franck, 1999, Experiment 2). This result is analogous to our findings for number: Local gender, like local number, affected the form of an agreement target irrespective of the local noun's notional properties. In contrast, Vigliocco and Franck (1999, 2001) found clear effects of notional support on gender agreement. When the grammatical gender of the head noun was congruent with the natural gender of the referent, grammatical gender agreement was less likely to be affected by the grammatical gender of the local noun. These findings are analogous to those for natural and grammatical number on head nouns: Middleton and Bock (2004) showed that when head nouns had natural (extrinsic) number, verb number agreement was less likely to be affected by local noun number than when the head noun's number was arbitrary (intrinsic).

Vigliocco and Franck (1999) explained the effects of conceptual gender on head nouns in terms of a combined impact of conceptual and grammatical information that influences the implementation of agreement. This is a plausible account that fits well with what occurs during the comprehension of grammatically gendered pronouns (Cacciari, Carreiras, & Cionini, 1997; Garnham, Oakhill, Ehrlich, & Carreiras, 1995) and verbs (Deutsch & Bentin, 2001) in gender-marking languages. Vigliocco and Franck's (1999) explanation is similar in spirit to the marking and morphing account in suggesting a role for feature redundancy, although the source of the redundancy is different. In Vigliocco and Frank's (1999) proposal, redundancy arises because meaning-based features are placed in tandem on the controller and the target. That is, notionally motivated gender features are placed both on the head of a subject noun phrase and on a predicate adjective (for example), and these conceptual features may then be reinforced by grammatical gender features.

In our framework, the mechanism is different, because there is no separate, message-driven marking of verbs in the syntax. Controllers (e.g., subject noun phrases) are marked, and a grammatically reconciled product of the marking is transmitted to an agreement target (e.g., a finite verb). The implication is that the agreement features of targets can be motivated by a meaning-based representation without the features bearing meaning themselves. If gender works like number during structural integration, grammatically gendered agreement controllers would be retrieved lexically and inserted into structural positions along with their morphological specifications. When the structural position is marked with a value congruent with the morphological specification, the controller gains a natural advantage over controllers for which marking is absent.

Despite the potential similarities in their behavior with respect to grammatical agreement, gender and number display two notable differences in attraction patterns. First, the magnitude of attraction is weaker for gender than for number. The clearest illustration of this comes from Vigliocco et al. (1995, Experiment 1), where there were just four gender-agreement errors in materials that elicited 70 number-agreement errors. A rough survey suggests that disparities between gender and number may also be present in Dutch (Hartsuiker, Kolk, & Huinck, 1999; Meyer & Bock, 1999; Vigliocco, Hartsuiker, et al., 1996), French (Fayol, Largy, & Lemaire, 1994; Vigliocco & Franck, 1999, 2001), and Russian (Lorimor, Bock, Zalkind, Sheyman, & Beard, 2005). Thus, number attraction in general appears to be more powerful than gender attraction in general. Inspected more carefully, though, the weakness of gender may not be a property of gender per se but of lexically inherent feature specifications and consequent differences in contrastiveness. Words with invariant features (such as inanimate nouns with grammatical gender as well as invariant plural nouns) can produce weak attraction (Bock et al., 2001) simply because they lack counterparts with opposing specifications.

A second difference in the attraction patterns for gender and number is the relative strength of morphological asymmetries. In English, plural attraction is a reliable phenomenon; singular attraction is weak to nonexistent. Singular–plural asymmetries have also been found in Dutch and German (Hartsuiker et al., 2003), French (Fayol et al., 1994), Italian (but weakly; Vigliocco et al., 1995), Russian (Lorimor et al., 2005), and Spanish (Vigliocco, Butterworth, & Garrett, 1996). Gender asymmetries over the same range of languages are considerably less striking (Igoa et al., 1999; Meyer & Bock, 1999; Vigliocco & Frank, 1999, 2001) and not well explained by the usual criteria for morphological specification (what is traditionally called *markedness*; Eckman, Moravcsik, & Wirth, 1986). This difference, too, may stem from the disparities between gender and number in contrastiveness: Grammatically gendered words are less likely to have counterparts in other genders.

Obviously, the degree to which gender works like number is an empirical question that remains largely unanswered. But for the present, we see an advantage to a marking and morphing approach to accounting for observed patterns of gender effects. It explains both the absence of conceptual-gender effects from the local noun in Vigliocco and Franck (1999, Experiment 2), which is analogous to the absence of conceptual number effects in the present work, as well as the presence of conceptual effects when natural gender is a property of the referent of the subject noun phrase (Vigliocco & Franck, 1999, 2001). This disparity is harder to handle in approaches where conceptual or notional effects on agreement are unconstrained.

The Underpinnings of Agreement in Language Production

Regarding the semantic, lexical, and structural underpinnings of agreement, two implications of our results for current theories of language production warrant further discussion. The first involves the meanings behind agreement, particularly with respect to the nature and the range of notional effects. The second has to do with what is called grammatical encoding and addresses the relative isolability of certain structural processes in production.

Notional agreement. In normal speaking, meaning is where everything begins. The meanings behind utterances may be vague, illogical, nonsensical, and so on, but whatever they may be, they are the inalienable possessions of the speaker. At the outset, then, semantic forces heavily constrain what happens in the transition from messages to functional assembly, so it is here that notional effects on agreement are proposed to arise.

Notional effects occur for both verb number and for pronoun number, but as Bock, Eberhard, and Cutting (2004) showed, they pattern differently. The notional impact on pronouns was substantially stronger than on verbs, yet there was a consistent effect on verbs, too. The existence of distributivity effects on verb agreement runs counter to findings of Bock and Miller (1991), where no difference in the magnitude of attraction for distributive and nondistributive preambles was found. In one respect, this result is consistent with the present account: Distributivity does not appear to influence attraction per se. In a more important respect, however, distributive properties do increase the incidence of plural verb agreement when other properties of noun phrases are well controlled (Bock et al., 1999; Eberhard, 1999; Humphreys & Bock, in press; Vigliocco & Hartsuiker, 2002). In Bock and Miller's materials, the nondistributive and distributive preambles were not matched in concreteness, and this matters to notionally motivated agreement (Eberhard, 1999).

The marking account of verb–number agreement in English approaches the explanation of distributivity effects differently than other accounts in the psycholinguistic literature. Vigliocco and colleagues (Vigliocco, Butterworth, & Garrett, 1996; Vigliocco et al., 1995) proposed, for Italian and Spanish, that distributivity directly affects the verb phrase. This seems plausible for languages that allow the regular elision of the subjects of verbs, in languages whose verbs carry number meanings on their own (Mithun, 1988) or in languages whose verbs encode the quantity of affected objects (Durie, 1986). In English, it is less evident that verb number morphology carries meaning by itself, and finite verbs rarely appear without overt subjects (apart from imperatives, where the subject is always the same).

There remains a puzzle about the status of distributivity in languages that, like English, do not readily omit subjects. Neither French nor Dutch reliably drop subjects, yet the findings for distributivity in these languages point to the same distributivity effects as Spanish and Italian (Vigliocco, Hartsuiker, et al., 1996). Vigliocco, Hartsuiker, et al. (1996) suggested that rich verbal morphology (rather than the omission of pronoun subjects) may lie behind the direct marking of number on verbs. If rich verbal morphology is correlated with the number meaningfulness of verbs, one could then argue that languages where verbal morphology carries a heavier semantic burden are more likely to have direct verb marking.

Berg (1998) made exactly the opposite claim: The impoverished number morphology of English makes speakers more sensitive to notional number. There is now good evidence that distributivity matters to agreement in English (Bock, Eberhard, & Cutting, 2004; Bock et al., 1999; Eberhard, 1999; Humphreys & Bock, in press). Most tellingly, Bock, Carreiras, et al. (2004) found that with translation-equivalent sentence subjects, using Spanish and English materials closely adapted from the Spanish items of Vigliocco, Butterworth, and Garrett (1996), distributivity effects on agreement occurred in both English and Spanish and to the same degree (see also Nicol & Greth, 2003). Spanish has rich verbal morphology and regularly allows elision of subjects; English has little verbal morphology and regularly disallows elision of subjects. The only evidence that Spanish and English differ in the effects of distributivity on number agreement comes from Vigliocco, Butterworth, and Garrett (1996), but they did not use equivalent Spanish and English materials. The implication, simply, is that there is no good support for cross-language variations in number agreement that are attributable to typological differences in the richness of agreement morphology or the omission of subjects.

A different sort of semantic effect on agreement involves the plausibility of the relationship between particular verbs and the heads and local nouns of subject noun phrases (Hupet, Fayol, & Schelstraete, 1998; Thornton & MacDonald, 2003). In Thornton and MacDonald's (2003) ingenious experiment, speakers were more likely to produce verb–number attraction when a verb was a plausible predication for a plural local noun (e.g., *The album by the classical composers were praised*) than when it was an implausible predication (e.g., *The album by the classical composers were played*).

A likely culprit in the increased tendency of verbs to agree with more plausible local nouns is the problem of what we will call *predication confusion*, which occurs when a nonsubject noun phrase is treated as making independent reference and serving as a subject. This is one of the traditional explanations for attraction that was evaluated by Bock and Miller (1991, Experiments 2 and 3). Bock and Miller tested a predication confusion account of simple attraction patterns by comparing the effects on verb agreement of animate head and local nouns within subject noun phrases (e.g., *The kings of the island–The island of the kings*) with their effects when they served in tandem as the subjects of main and embedded clauses (e.g., *The kings that the island–The island that the kings*). In local nouns, animacy had no effect on attraction. However, when animates and inanimates both were subjects (simulating the situation in which noun phrases compete for control of a verb and its number), the effect of animacy was substantial. Relative to the effect of animacy on attraction, speakers were over three times more likely to err in the direction of giving a verb the number appropriate for the animate subject rather than the number of the subject in the verb's own clause (see Bock & Miller, 1991, p. 79, Table 11). Plurality exacerbated this tendency, suggesting that plurality contributes to predication confusion as well as to attraction.

Like the task used by Thornton and MacDonald (2003), the task in Bock and Miller's (1991) third experiment was challenging. Both invited predication confusion. When predication confusion turns a nonsubject noun phrase into the subject in the mind of a speaker, predication confusion can mimic attraction. However, Bock and Miller's results imply that the semantic or notional factors that promote it are different. In attraction, notional features of the local noun have little impact; with predication confusion, their impact is substantial.

The nature of structural processes in production. Once a speaker proceeds to make a message public, the problem is to create a linguistic form for the utterance. By this time, however, the speaker's meaning making will have moved on to new and different challenges, and the message that motivated an utterance whose linguistic formulation is in progress will have lost its

tapraid1/z2q-psycho/z2q-psycho/z2q00305/z2q0641d05g | stambauj | S=11 | 5/20/05 | 19:38 | Art: 2003-0071-RRR

semantic moorings. Consequently, there are components of sentence production that must be able to carry on when the notions behind an unfolding utterance have faded.

The marking and morphing account identifies structural integration, when phrasal frames are created, as a point in processing when meaning differences are likely to have little force. This is not to say that meaning carries no force, which would be tantamount to denying an effect of gravity on an airborne plane. Rather, the idea is that there are things to be explained that cannot be explained solely or entirely in terms of the meanings that set the production process in motion, such as the relative weakness of the notional impact on verb agreement and the near absence of notional effects on attraction. Structural processes that are able to carry on without semantic guidance are functionally independent or isolable.

The criterion for isolability is simple, empirical, and a staple of experimental psychology. Posner (1978) described it in terms of being able to manipulate the time course of one process without changing the time course of others. Obviously, in the present work, we are not dealing with variables having the measurement properties that time does, and we are far from confident about what many of the other processes will turn out to be. So, we cannot sustain strong claims about what is and is not isolable within the production process, but we can point to some qualitative convergences between the present results and those from other studies of structural processes in production that make the isolability hypothesis tenable.

In research on structural priming in production, there is evidence to suggest that the structural arrangements of sentences can be influenced by the structural arrangements of other sentences recently experienced, despite differences in the words they contain, in the meanings behind the words and sentences, and even in the languages involved (Bock, 1986, 1990; Bock et al., 1992; Ferreira, 2003; Loebell & Bock, 2003; M. C. Potter & Lombardi, 1998; Smith & Wheeldon, 2001). Similarities on some of these dimensions increase the magnitude of priming effects (Cleland & Pickering, 2003; Pickering & Branigan, 1998), but substantial differences do not eliminate them (Bock & Loebell, 1990). This suggests that processes involved in creating structure may be primed to some extent separately from the contents of structures.

The present results likewise point to structural processes that are separable from the meanings behind them. Specifically, the morphing processes that integrate morphological values with syntactic structures seem to work within a representation that is not notably sensitive to features of meaning but is sensitive to the relative frequencies of word forms, consistent with findings that word forms encode frequency, not lexical entries (or lemmas; Griffin & Bock, 1998; Jescheniak & Levelt, 1994). Morphing is less sensitive to meaning than the processes that initiate the retrieval of words and morphemes (Dell et al., 1997; Levelt et al., 1999) or those that set structure building into motion (Bock et al., 1992). What matters most to the construction of this representation is not whether a phrase represents something that is animate or inanimate or unitary or multiple but what the order and relative dominance of phrases may be and which words and phrases bear morphological specifications.

Summary and Conclusion

The joint involvement of pronouns and verbs with the semantic and grammatical categories that underlie agreement systems begins to reveal how basic features of meaning are used in binding together the vocabulary and the syntax to create sentence structures in the course of normal speaking.

Agreement is a sort of transient linguistic glue that grammars and speakers can use to hold important pieces of utterances together. In English, it is used to link pronouns with antecedents and subjects with verbs. Marking and morphing proposes that the semantic underpinnings of number agreement are the same for pronouns as for verbs and found within the number meanings in speakers' messages. By relating these origins to the components of language production, the theory aims to explain some basic similarities and differences in the workings of English agreement and, more broadly, explain how number meaning comes to be expressed lexically and syntactically. Broadly, the theory hypothesizes that disparities between pronoun and verb number arise because pronouns are retrieved as lexical items, whereas verb number is formulated as part of the syntax. This distinction allocates syntactic influences on pronouns and verbs to mechanisms of language production that bind morphemes to positions in a syntactic structural frame.

To evaluate these hypotheses, we constructed a simple model to test the adequacy of the theory's basic proposals against experimental data on the elicitation of agreement in language production. The model assumes the same notional contributions to pronoun and verb number and the same agreement implementation during structural assembly but different lexical and syntactic operations in between. Differences between pronouns and verbs arise from how pronouns get their number specifications (through concord, as a result of coreference) and how verbs get theirs (under syntactic structural control). The fits of the model to a wide range of agreement data offered good support for the proposed mechanisms of marking and morphing.

The marking and morphing account of sentence production is a proposal about how speakers use basic and wide-ranging features of meaning in building the bare bones of utterances. It incorporates a specific role for structural configurations in order to deal with meanings that cannot be isolated in the contributions of individual words. These are the kinds of meanings that influence entire sentences. This takes the theory beyond grammatical encoding to the meanings behind the things people say to address how meanings are used to find words, create structures, and put them together.

References

Alario, F.-X., & Caramazza, A. (2002). The production of determiners: Evidence from French. *Cognition, 82,* 179–223.

Almor, A., MacDonald, M. C., Kempler, D., Andersen, E. S., & Tyler, L. K. (2001). Comprehension of long distance number agreement in probable Alzheimer's disease. *Language and Cognitive Processes, 16,* 35–63.

Anderson, S. R. (1992). *A-morphous morphology.* Cambridge, England: Cambridge University Press.

Baayen, R. H., Dijkstra, T., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual-route model. *Journal of Memory and Language, 37,* 94–117.

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database* [CD-ROM]. Philadelphia: Linguistic Data Consortium.

Barlow, M. (1991). The agreement hierarchy and grammatical theory. In L. A. Sutton & C. Johnson (Eds.), *Proceedings of the Seventeenth Annual Meeting of the Berkeley Linguistics Society* (pp. 30–40). Berkeley, CA: Berkeley Linguistics Society.

Bates, E., & MacWhinney, B. (1989). Functionalism and the competition model. In B. MacWhinney & E. Bates (Eds.), *The crosslinguistic study of sentence processing* (pp. 3–73). Cambridge, England: Cambridge University Press.

Berg, T. (1998). The resolution of number conflicts in English and German agreement patterns. *Linguistics, 36,* 41–70.

Bock, J. K. (1982). Toward a cognitive psychology of syntax: Information processing contributions to sentence formulation. *Psychological Review, 89,* 1–47.

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology, 18,* 355–387.

Bock, J. K. (1987). Coordinating words and syntax in speech plans. In A. Ellis (Ed.), *Progress in the psychology of language* (Vol. 3, pp. 337–390). London: Erlbaum.

Bock, J. K. (1990). Structure in language: Creating form in talk. *American Psychologist, 45,* 1221–1236.

Bock, J. K. (1995). Producing agreement. *Current Directions in Psychological Science, 8,* 56–61.

Bock, J. K. (1999). Language production. In R. Wilson & F. Keil (Eds.), *MIT encyclopedia of the cognitive sciences* (pp. 453–456). Cambridge, MA: MIT Press.

Bock, J. K. (2004a). [Gender attraction in English]. Unpublished raw data.

Bock, J. K. (2004b). Psycholinguistically speaking: Some matters of meaning, marking, and morphing. In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 44, pp. 109–144). San Diego, CA: Elsevier.

Bock, J. K., Butterfield, S., Cutler, A., Cutting, J. C., Eberhard, K. M., & Humphreys, K. R. (2004). *Disagreeing to agree collectively.* Manuscript submitted for publication.

Bock, J. K., Carreiras, M., Meseguer, E., & Octigan, E. (2004, November). *Number meaning and number agreement: A cross-language comparison.* Paper presented at the 45th Annual Meeting of the Psychonomic Society, Minneapolis, MN.

Bock, J. K., & Cutting, J. C. (1992). Regulating mental energy: Performance units in language production. *Journal of Memory and Language, 31,* 99–127.

Bock, J. K., & Eberhard, K. M. (1993). Meaning, sound, and syntax in English number agreement. *Language and Cognitive Processes, 8,* 57–99.

Bock, J. K., Eberhard, K. M., & Cutting, J. C. (2004). Producing number agreement: How pronouns equal verbs. *Journal of Memory and Language, 51,* 251–278.

Bock, J. K., Eberhard, K. M., Cutting, J. C., Meyer, A. S., & Schriefers, H. (2001). Some attractions of verb agreement. *Cognitive Psychology, 43,* 83–128.

Bock, J. K., & Loebell, H. (1990). Framing sentences. *Cognition, 35,* 1–39.

Bock, J. K., Loebell, H., & Morey, R. (1992). From conceptual roles to structural relations: Bridging the syntactic cleft. *Psychological Review, 99,* 150–171.

Bock, J. K., & Miller, C. A. (1991). Broken agreement. *Cognitive Psychology, 23,* 45–93.

Bock, J. K., Nicol, J., & Cutting, J. C. (1999). The ties that bind: Creating number agreement in speech. *Journal of Memory and Language, 40,* 330–346.

Brennan, S. E. (1995). Centering attention in discourse. *Language and Cognitive Processes, 10,* 137–167.

Butterworth, B. (1999). *The mathematical brain.* London: Macmillan.

Cacciari, C., Carreiras, M., & Cionini, C. B. (1997). When words have two genders: Anaphor resolution for Italian functionally ambiguous words. *Journal of Memory and Language, 37,* 517–532.

Chang, F. (2002). Symbolically speaking: A connectionist model of sentence production. *Cognitive Science, 26,* 609–651.

Chang, F., Dell, G. S., & Bock, J. K. (2005). *Becoming syntactic.* Manuscript submitted for publication.

Chomsky, N. (1981). *Lectures on government and binding.* Dordrecht, the Netherlands: Foris.

Cleland, A. A., & Pickering, M. J. (2003). The use of lexical and syntactic information in language production: Evidence from the priming of noun-phrase structure. *Journal of Memory and Language, 49,* 214–230.

Corbett, G. G. (1979). The agreement hierarchy. *Journal of Linguistics, 15,* 203–395.

Corbett, G. G. (1991). *Gender.* Cambridge, England: Cambridge University Press.

Corbett, G. G. (1998). Morphology and agreement. In A. Spencer & A. M. Zwicky (Eds.), *The handbook of morphology* (pp. 191–205). Oxford, England: Blackwell.

Corbett, G. G. (2000). *Number.* Cambridge, England: Cambridge University Press.

Dehaene, S. (1997). *The number sense: How the mind creates mathematics.* New York: Oxford University Press.

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review, 93,* 283–321.

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review, 104,* 801–838.

Dell, G. S., & Sullivan, J. M. (2004). Speech errors and language production: Neuropsychological and connectionist perspectives. In B. H. Ross (Ed.), *The psychology of learning and motivation* (pp. 63–108). San Diego, CA: Elsevier.

den Dikken, M. (2000). The syntax of features. *Journal of Psycholinguistic Research, 29,* 5–23.

Deutsch, A., & Bentin, S. (2001). Syntactic and semantic factors in processing gender agreement in Hebrew: Evidence from ERPs and eye movements. *Journal of Memory and Language, 45,* 200–224.

DeVincenzi, M. (1999). Differences between the morphology of gender and number: Evidence from establishing coreferences. *Journal of Psycholinguistic Research, 28,* 537–553.

Dryer, M. (1989). Plural words. *Linguistics, 27,* 865–895.

Durie, M. (1986). The grammaticization of number as a verbal category. In V. Nikiforidou, M. VanClay, M. Niepokuj, & D. Feder (Eds.), *Proceedings of the Twelfth Annual Meeting of the Berkeley Linguistics Society* (pp. 355–370). Berkeley, CA: Berkeley Linguistics Society.

Eberhard, K. M. (1993). *The specification of grammatical number in English.* Unpublished doctoral dissertation, Michigan State University.

Eberhard, K. M. (1997). The marked effect of number on subject–verb agreement. *Journal of Memory and Language, 36,* 147–164.

Eberhard, K. M. (1999). The accessibility of conceptual number to the processes of subject–verb agreement in English. *Journal of Memory and Language, 41,* 560–578.

Eccardt, T. (2000). *Speakers of Spanish know the gender before they know the noun.* Unpublished manuscript.

Eckman, F. R., Moravcsik, E. A., & Wirth, J. R. (Eds.). (1986). *Markedness.* New York: Plenum Press.

Fayol, M., Largy, P., & Lemaire, P. (1994). Cognitive overload and orthographic errors: When cognitive overload enhances subject–verb agreement errors. A study in French written language. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 47*(A), 437–464.

Ferreira, V. S. (2003). The persistence of optional complementizer mention: Why saying "that" is not saying "that" at all. *Journal of Memory and Language, 48,* 379–398.

Ferreira, V. S., & Humphreys, K. R. (2001). Syntactic influences on lexical

and morphological processing in language production. *Journal of Memory and Language, 44,* 52–80.

Foertsch, J., & Gernsbacher, M. A. (1997). In search of gender neutrality: Is singular *they* a cognitively efficient substitute for generic *he*? *Psychological Science, 8,* 106–111.

Foygel, D., & Dell, G. S. (2000). Models of impaired lexical access in speech production. *Journal of Memory and Language, 43,* 182–216.

Franck, J., Vigliocco, G., & Nicol, J. (2002). Subject–verb agreement errors in French and English: The role of syntactic hierarchy. *Language and Cognitive Processes, 17,* 371–404.

Frazier, L., Pacht, J., & Rayner, K. (1999). Taking on semantic commitments, II: Collective vs. distributive readings. *Cognition, 70,* 87–104.

Garnham, A. (2001). *Mental models and the interpretation of anaphora.* Hove, England: Psychology Press.

Garnham, A., Oakhill, J., Ehrlich, M.-F., & Carreiras, M. (1995). Representations and processes in the interpretation of pronouns: New evidence from Spanish and French. *Journal of Memory and Language, 34,* 41–62.

Garrett, M. F. (1975). The analysis of sentence production. In G. H. Bower (Ed.), *The psychology of learning and motivation* (pp. 133–177). New York: Academic Press.

Garrett, M. F. (1988). Processes in language production. In F. J. Newmeyer (Ed.), *Linguistics: The Cambridge Survey, III: Language: Psychological and biological aspects* (pp. 69–96). Cambridge, England: Cambridge University Press.

Gelman, R., & Gallistel, C. R. (1978). *The child's understanding of number.* Cambridge, MA: Harvard University Press.

Gillon, B. S. (1992). Towards a common semantics for English count and mass nouns. *Linguistics and Philosophy, 15,* 597–639.

Givón, T. (1976). Topic, pronoun, and grammatical agreement. In C. N. Li (Ed.), *Subject and topic* (pp. 149–188). New York: Academic Press.

Gordon, J. K., & Dell, G. S. (2003). Learning to divide the labor: An account of deficits in light and heavy verb production. *Cognitive Science, 27,* 1–40.

Gordon, P. C., & Hendrick, R. (1998). The representation and processing of coreference in discourse. *Cognitive Science, 22,* 389–424.

Griffin, Z. M., & Bock, J. K. (1998). Constraint, word frequency, and the relationship between lexical processing levels in spoken word production. *Journal of Memory and Language, 38,* 313–338.

Grimshaw, J. (1992). Subcategorization and selection. In W. Bright (Ed.), *International encyclopedia of linguistics* (Vol. 4, pp. 90–92). New York: Oxford University Press.

Harris, A. C., & Campbell, L. (1995). *Historical syntax in cross-linguistic perspective.* Cambridge, England: Cambridge University Press.

Hartsuiker, R. J., Antón-Méndez, I., & van Zee, M. (2001). Object attraction in subject–verb agreement construction. *Journal of Memory and Language, 45,* 546–573.

AQ: 1 Hartsuiker, R. J., & Barkhuysen, P. N. (in press). Language production and working memory: The case of subject–verb agreement. *Language and Cognitive Processes.*

Hartsuiker, R. J., Kolk, H. H. J., & Huinck, W. J. (1999). Agrammatic production of subject–verb agreement: The effect of conceptual number. *Brain and Language, 69,* 119–160.

Hartsuiker, R. J., Schriefers, H. J., Bock, J. K., & Kikstra, G. M. (2003). Morphophonological influences on the construction of subject–verb agreement. *Memory & Cognition, 31,* 1316–1326.

Haskell, T. R., & MacDonald, M. C. (2003). Conflicting cues and competition in subject–verb agreement. *Journal of Memory and Language, 48,* 760–778.

Humphreys, K. R. (1998, March). *The production of inflectional and derivational morphology: Evidence from elicited speech errors* Paper presented at the 11th Annual CUNY Conference on Sentence Processing, New Brunswick, NJ.

AQ: 2 Humphreys, K. R., & Bock, J. K. (in press). Notional number agreement in English. *Psychonomic Bulletin & Review.*

Hupet, M., Fayol, M., & Schelstraete, A.-M. (1998). Effects of semantic variables on the subject–verb agreement processes in writing. *British Journal of Psychology, 89,* 59–75.

Igoa, J. M., García-Albea, J. E., & Sánchez-Casas, R. (1999). Gender-number dissociations in sentence production in Spanish. *Rivista di Linguistica, 11,* 163–196.

Jackendoff, R. (1983). *Semantics and cognition.* Cambridge, MA: MIT Press.

Jackendoff, R. (1991). Parts and boundaries. *Cognition, 41,* 9–45.

Janssen, N., & Caramazza, A. (2003). The selection of closed-class words in noun phrase production: The case of Dutch determiners. *Journal of Memory and Language, 48,* 635–652.

Jescheniak, J.-D., & Levelt, W. J. M. (1994). Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 824–843.

Jespersen, O. (1933). *Essentials of English grammar.* London: George Allen & Unwin.

Keeney, T. J., & Wolfe, J. (1972). The acquisition of agreement in English. *Journal of Verbal Learning and Verbal Behavior, 11,* 698–705.

Landman, R. (1989). Groups, I. *Linguistics and Philosophy, 12,* 559–605.

Lapointe, S. G., & Dell, G. S. (1989). A synthesis of some recent work in sentence production. In G. N. Carlson & M. K. Tanenhaus (Eds.), *Linguistic structure in language processing* (pp. 107–156). Dordrecht, the Netherlands: Kluwer.

Lasersohn, P. N. (1990). Group action and spatio-temporal proximity. *Linguistics and Philosophy, 13,* 179–206.

Lehmann, C. (1988). On the function of agreement. In M. Barlow & C. A. Ferguson (Eds.), *Agreement in natural language: Approaches, theories, descriptions* (pp. 55–65). Stanford, CA: Stanford University, Center for the Study of Language and Information.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation.* Cambridge, MA: MIT Press.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22,* 1–75.

Link, G. (1991). Quantity and number. In D. Zaefferer (Ed.), *Semantic universals and universal semantics* (pp. 133–149). Berlin, Germany: Foris.

Loebell, H., & Bock, J. K. (2003). Structural priming across languages. *Linguistics, 41,* 791–824.

Lorimor, H., Bock, J. K., Zalkind, E., Sheyman, A., & Beard, R. (2005). *Gender and number attraction in Russian.* Manuscript in progress.

Meyer, A. S., & Bock, J. K. (1999). Representations and processes in the production of pronouns: Some perspectives from Dutch. *Journal of Memory and Language, 41,* 281–301.

Middleton, E., & Bock, J. K. (2004). *Peculiar plurals and senseless singulars: How meaning-full is grammatical agreement?* Manuscript submitted for publication.

Middleton, E. L., Wisniewski, E. J., Trindel, K. A., & Imai, M. (2004). Separating the chaff from the oats: Evidence for a conceptual distinction between count noun and mass noun aggregates. *Journal of Memory and Language, 50,* 371–394.

Mithun, M. (1988). Lexical categories and the evolution of number marking. In M. Hammond & M. Noonan (Eds.), *Theoretical morphology: Approaches in modern linguistics* (pp. 211–234). San Diego, CA: Academic Press.

Moravcsik, E. (1978). Agreement. In J. Greenberg, C. Ferguson, & E. Moravcsik (Eds.), *Universals of human language: Vol. 4. Syntax* (pp. 331–374). Stanford, CA: Stanford University Press.

Morgan, J. L. (1972). Verb agreement as a rule of English. In P. M. Peranteau, J. N. Levi, & G. C. Phares (Eds.), *Papers from the Eighth Regional Meeting, Chicago Linguistic Society* (pp. 278–286). Chicago: Chicago Linguistic Society.

Morgan, J. L. (1984). Some problems of determination in English number

agreement. In G. Alvarez, B. Brodie, & T. McCoy (Eds.), *Proceedings of the Eastern States Conference on Linguistics* (pp. 69–78). Columbus: Ohio State University.

Nicol, J., & Greth, D. (2003). Production of subject–verb agreement in Spanish as a second language. *Experimental Psychology, 50,* 196–203.

Nunberg, G. (2003, March 9). Machines make moral judgments, selectively. *The New York Times,* p. 5.

Osterhout, L., & Mobley, L. A. (1995). Event-related brain potentials elicited by failure to agree. *Journal of Memory and Language, 34,* 739–773.

Pearlmutter, N. J., Garnsey, S. M., & Bock, J. K. (1999). Agreement processes in sentence comprehension. *Journal of Memory and Language, 41,* 427–456.

Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language, 39,* 633–651.

Pinker, S. (1994). *The language instinct.* New York: Morrow.

Pinker, S. (1999). *Words and rules.* New York: Basic Books.

Pollard, C., & Sag, I. A. (1994). *Head-driven phrase structure grammar.* Chicago: University of Chicago Press.

Posner, M. I. (1978). *Chronometric explorations of mind.* Hillsdale, NJ: Erlbaum.

Potter, J. K., & Eberhard, K. M. (1999, March). *Number accessibility and verb agreement: Examining the influence of conceptual information during grammatical encoding.* Poster presented at the 12th Annual CUNY Conference on Human Sentence Processing, New York.

Potter, M. C., & Lombardi, L. (1998). Syntactic priming in immediate recall of sentences. *Journal of Memory and Language, 38,* 265–282.

Pullum, G. K. (1984). How complex could an agreement system be? In G. Alvarez, B. Brodie, & T. McCoy (Eds.), *Proceedings of the Eastern States Conference on Linguistics* (pp. 79–103). Columbus: Ohio State University.

Reid, W. (1991). *Verb and noun number in English.* London: Longman.

Safire, W. (1994, May 29). The coveted Bloopie Awards. *The New York Times Magazine,* pp. 12, 14.

Schriefers, H. (1993). Syntactic processes in the production of noun phrases. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 841–850.

Schwarzschild, R. (1992). Types of plural individuals. *Linguistics and Philosophy, 15,* 641–675.

Smith, M., & Wheeldon, L. (2001). Syntactic priming in spoken sentence production—An online study. *Cognition, 78,* 123–164.

Solomon, E. S., & Pearlmutter, N. J. (2004). Semantic integration and syntactic planning in language production. *Cognitive Psychology, 49,* 1–46.

Spalek, K., & Schriefers, H. (2005). Dominance affects determiner selection in language production. *Journal of Memory and Language, 52,* 103–119.

Stemberger, J. P. (1985). An interactive activation model of language production. In A. Ellis (Ed.), *Progress in the psychology of language* (pp. 143–186). London: Erlbaum.

Stevenson, S. (1994). *A competitive attachment model for resolving syntactic ambiguities in natural language parsing* (Tech. Rep. No. 18). New Brunswick, NJ: Rutgers University, Center for Cognitive Science.

Tasmowski-DeRyck, L., & Verluyten, S. P. (1981). Pragmatically controlled anaphora and linguistic form. *Linguistic Inquiry, 12,* 153–154.

Thornton, R., & MacDonald, M. C. (2003). Plausibility and grammatical agreement. *Journal of Memory and Language, 48,* 740–759.

Vigliocco, G., Butterworth, B., & Garrett, M. F. (1996). Subject–verb agreement in Spanish and English: Differences in the role of conceptual constraints. *Cognition, 61,* 261–298.

Vigliocco, G., Butterworth, B., & Semenza, C. (1995). Constructing subject–verb agreement in speech: The role of semantic and morphological factors. *Journal of Memory and Language, 34,* 186–215.

Vigliocco, G., & Franck, J. (1999). When sex and syntax go hand in hand: Gender agreement in language production. *Journal of Memory and Language, 40,* 455–478.

Vigliocco, G., & Franck, J. (2001). When sex affects syntax: Contextual influences in sentence production. *Journal of Memory and Language, 45,* 368–390.

Vigliocco, G., & Hartsuiker, R. J. (2002). The interplay of meaning, sound, and syntax in language production. *Psychological Bulletin, 128,* 442–472.

Vigliocco, G., Hartsuiker, R. J., Jarema, G., & Kolk, H. H. J. (1996). One or more labels on the bottles? Notional concord in Dutch and French. *Language and Cognitive Processes, 11,* 407–442.

Vigliocco, G., & Nicol, J. (1998). Separating hierarchical relations and word order in language production: Is proximity concord syntactic or linear? *Cognition, 68,* 13–29.

Vrouw bijt hond [Woman bites dog]. (2001, June 18). *Het Laatste Nieuws,* p. 1.

Wertheimer, M. (1923). Untersuchungen zur Lehre von der Gestalt, II [Principles of perceptual organization, II]. *Psychologische Forschung, 4,* 301–350.

Received October 28, 2003
Revision received December 8, 2004
Accepted December 8, 2004 ■