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Subject-verb agreement errors in French and English: The role of syntactic hierarchy

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We report two parallel experiments conducted in French and in English in which we induced subject-verb agreement errors to explore the role of syntactic structure during sentence production. Previous studies have shown that attraction errors (i.e., a tendency of the verb to agree with an immediately preceding noun instead of with the subject of the sentence) occur when a preverbal local noun disagrees in number with the subject head noun. The attraction effect was accounted for either by the proximity of the local noun to the verb in the linearised sentence (*linear distance hypothesis*) or by the processing simultaneity of the head and local nouns situated in the same clause (*clause packaging hypothesis*). In the current experiments, speakers were asked to complete complex sentential preambles. Contrary to

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the predictions of these two hypotheses, we found that agreement errors were more frequent following an intermediate modifier (e.g., **The threat-S to the presidents-P of the company-S ARE serious*) than an immediately preverbal modifier (e.g., **The threat-S to the president-S of the companies-P ARE serious*). It is suggested that attraction is determined by the *syntactic distance* between the interfering noun and the head noun at a stage of the grammatical encoding of the sentence during which syntactic units are organised into a hierarchical structure.

For the past century, many researchers have believed that errors provide us with a particularly well-suited window from which to observe many aspects of mental life. In the psycholinguistic literature, the primary data upon which models of language production are based are slips of the tongue (Dell, 1986; Fromkin, 1971; Garrett, 1976, 1980, 1982, 1990; Stemmer, 1985). In this paper, we deal with a particular type of speech error: failures in number agreement between the sentential subject and the verb. We focus on the organisation of syntactic segments during the realisation of agreement to understand how syntactic structure contributes to the occurrence of errors.

Agreement is a very widespread phenomenon that can be found in most natural languages. This makes it a key tool for comparing languages and for elaborating general principles about how syntactic relationships are ensured in sentence production. Two languages were studied: French and English. The basic characteristics of syntactic encoding are expected to be the same in the two languages, but differences may be found as to the way they deal with syntactic number, as a consequence of potentially different conceptual representations (at a higher level) and morphophonological realisations (at a lower level). The parallel study of these two languages will allow us to draw general principles about mechanisms and units of grammatical encoding as well as to detect eventual language-specific aspects of sentence production.

In French as in English, subject–verb agreement in number is governed by a simple rule: a singular subject requires a singular verb while a plural subject requires a plural verb. Despite the simplicity of this rule, errors sometimes occur, as illustrated in (1) and (2).

- (1) *The influence of some contemporary writers and fashions are allowed to enter
- (2) *Je souhaite que la mention de ces quelques conférences vous seront utiles
(I hope that the mention-S of these conferences-P will be-P useful for you)

In (1) the verb (“are”) agrees with the plural nouns (“writers and fashions”) which are closer to the verb, instead of the singular subject head

noun (“influence”). Similarly, in (2) there is agreement between the verb (“seront”) and the plural noun that precedes it (“conférences”), rather than agreement between the verb and the singular subject head noun (“mention”).

Many recent experimental studies carried out in different languages have attested to the role of an intervening *local noun* (i.e., a noun embedded in a prepositional phrase or in a clause that modifies the subject NP) which disagrees in number with the subject head noun in inducing erroneous number agreement in oral production (e.g., Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Vigliocco, Butterworth, & Garrett, 1996a; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996b). In a typical experiment, participants are visually or acoustically presented with sentence preambles in which the number of the head and local nouns is manipulated (e.g., The editor(s) of the book(s)) and their task was to repeat the preamble and provide a sentence completion. Written number agreement production in French has also been studied using a dictation task; this allows for the examination of verbs that have the same plural and singular ending when spoken (Fayol & Got, 1991; Fayol, Largy, & Lemaire, 1994; Hupet, Fayol, & Schelstraete, 1998). Errors in number agreement between the subject head noun and the verb were computed and analysed. All studies, conducted in different languages, report a reliable increase in agreement errors when the local noun mismatched in number with the head noun.

Importantly, the same influence of a local noun was found on the production of gender agreement in French and Italian. It was reported that gender agreement between a subject head noun and a predicative adjective was significantly more disrupted when a local noun with a different gender from the head noun was present in the sentence (Vigliocco & Franck, 1999; in press). In (3), the predicative adjective (*délicat*) should agree with the masculine subject head noun (*le travail*) and not with the feminine local noun (*la couturière*).

- (3) *Le travail de la couturière est délicate
(The handwork (M) of the dressmaker (F) is delicate (F))

INTERPRETING THE ATTRACTION EFFECT

To describe agreement errors such as the ones reported above, grammarians such as Quirk, Greenbaum, Leech, & Svartvik (1972) introduced the *principle of proximity*, also termed *attraction*. The term “proximity” emphasises the closeness of the verb to the mismatching local noun. Attraction denotes agreement with a closely preceding noun phrase in preference to agreement with the head of the noun phrase that functions

as subject. Quirk et al. (1972) noticed that a conflict between grammatical concord and proximity concord tends to increase with the distance between the head noun and the verb. In 1924, Jespersen proposed the first processing account of erroneous agreement with a preverbal local noun, venturing the hypothesis that “if the verb comes long after the noun, there is no more mental energy left to remember what was the number of the subject” (Jespersen, 1924, p. 345). Again, this suggests that the probability of finding proximity concord rather than grammatical concord increases with the distance between the subject and the verb in the uttered sentence. This account supposes that in cases where the subject and verb are discontinuous, such as when the subject is followed by a modifying expression, mental energy is required to keep track of the information about the agreement source until the target becomes available.

Along these lines, Fayol and collaborators studied the relation between agreement and working memory in language production by adding a concurrent task to the sentence completion task described above. Fayol, Largy, and Lemaire (1994) reported that agreement errors in written French were more common when working memory was overloaded by a concurrent task. In their experiments, erroneous agreement with a local noun was more likely when the participant was engaged in remembering a series of 3–4 unrelated words than when working memory was not involved in a concurrent task. According to Fayol et al., subject–verb agreement is computed automatically on the basis of spreading activation of the number feature from the closest preceding noun to the verb. In most cases, the subject noun immediately precedes the verb; this ensures correct and rapid agreement (because it is automatic). However, when there is a preverbal local noun, activation will spread from this too. In order to guarantee correct agreement with the head noun, a non-automatic checking mechanism is assumed to be activated, which consumes working memory resources. A concurrent memory load task would reduce resources available for the checking procedure, and therefore increase the probability of agreement of the verb with a local noun.

This view that the agreement operation errs because the verb is directly preceded by a local noun that disagrees in number with the subject noun, will be referred to as the *linear distance hypothesis*. On this account, the crucial factor that influences the occurrence of errors is the linear proximity between words in the sentence, specifically between the local noun and the verb. In this theoretical framework, the structure in which syntactic segments are framed when agreement takes place is assumed to be a linear chain that parallels the uttered word string. As a consequence, linear distance between words is a determining factor in the agreement operation, as well as working memory which is assumed to keep track of the segments positioned first in the sentence.

Although this account seems to cover the majority of the available data, it is inconsistent with some experimental results of agreement error induction reported by Bock and Cutting (1992). In three experiments, they found that errors were significantly more common when the preamble contained a prepositional phrase (PP) modifier, as in the examples in (4), than when the preamble contained a relative clause or a complement clause modifier, as in the examples in (5).

- (4) a. The editor of the history books
 b. The report of the destructive fires
 (5) a. The editor who rejected the books
 b. The report that they controlled the fires

Note that crucially, the preambles in (5) are syntactically more complex than those in (4). The linear distance hypothesis would therefore predict even more errors for preambles such as (5) than for preambles such as (4) because the presence of a clausal modifier should involve greater working memory demands than a prepositional phrase modifier.

Bock and Cutting argued that the different error rates for prepositional phrases and clausal modifiers suggest a “clause packaging” organisation of production units during sentence planning. A mismatching local noun would be more likely to interfere with agreement computation if it is encoded simultaneously with the head noun, i.e., within the same encoding unit (the clause). The presence of a clausal boundary (as in 5) would reduce the probability of an agreement error by insulating the head noun from the number feature of the local noun. In contrast, in (4) both nouns are within the same clause. We will refer to this view as the *clause packaging hypothesis*. The general framework of sentence production in which this hypothesis can be integrated assumes that the processing of building a syntactic structure for the sentence, also called “grammatical encoding”, occurs in two steps: a stage at which the functional structure is built and a stage at which words are positioned in their left-to-right order in a string (Garrett, 1976). The processes at the functional level involve the integration of abstract lexical units into a syntactic frame that specifies their grammatical function, as well as syntactic relations between them. Agreement is thought to take place at this stage of production. Because at this level a sentence such as (6) is assumed to be encoded in two separate units, i.e., “the claim was rejected” and “that wolves were stealing babies”, agreement would be less disrupted by the local noun, since this latter would be in a different processing unit.

- (6) The claim {that wolves were stealing babies} was rejected

Such a framework assumes that lexical units, before being positioned in the final left-to-right order, are inserted into higher-level syntactic constituents structured hierarchically, i.e., clauses, over which syntactic

operations proceed in relative insulation from one clause to another (Bock, 1987; Dell, 1986; Garrett, 1982, 1988). As the different constituents are assembled, the information they contain becomes available for positional-level processing. This stage involves the retrieval of phonological representations for words and their positioning in a left-to-right order.

The hypothesis of a mode of operation constrained by higher-level constituents is widely shared by modern theories of sentence production (Bock, 1987; Dell, 1986; Fromkin, 1971; Garrett, 1988; Levelt, 1989; Stemberger, 1985). However, these theories divide over how selective the mechanisms are and therefore how strong the hierarchy of control is. If one assumes that the functional level processes operate over a tree-like constituent structure in which smaller units are the phrases, this hierarchical structure may have finer grained control over a syntactic operation like agreement than what is assumed by the clause packaging hypothesis. In this paper, we adopt a theoretical view of sentence production as proposed by the IPG (Incremental Procedural Grammar, Kempen & Hoenkamp, 1987) and IPF (Incremental Parallel Formulator, De Smedt, 1990) models. These models conceive syntactic construction as a process of assembling segments into a tree-like architecture using a single combinatorial operation: unification. In IPF, each segment is composed of two nodes, representing syntactic categories, related by an arc, representing the syntactic function that relates the nodes (e.g., S-subject-HN, HN-head-N). Unification of the different segments would result in the formation of a syntactic structure for the sentence. Unification in this model is conceived as a process that merges features from the different segments, allowing, therefore, the computation of long-distance dependencies such as agreement.

In previous work (Vigliocco et al., 1995; Vigliocco & Franck, 1999) we have proposed that for both number agreement between the subject and the verb and gender agreement between the subject and a predicative adjective, features such as number and gender can be independently retrieved from conceptual structures (see Figure 1).

Because the segment containing the head noun and the segment containing the verb are specified independently for the syntactic property of number on the basis of the conceptual number, unification would act as a checking procedure to ensure that they will bear the same number. Hence, and importantly, in a model such as IPF, agreement is the result of assembling the different segments into a hierarchical structure. As a consequence, the hierarchical organisation of syntactic segments plays a key role in the way agreement is realised.

Relevant to agreement computation, the number feature for the noun, specified in the segment with the noun as head, would have to be "passed"

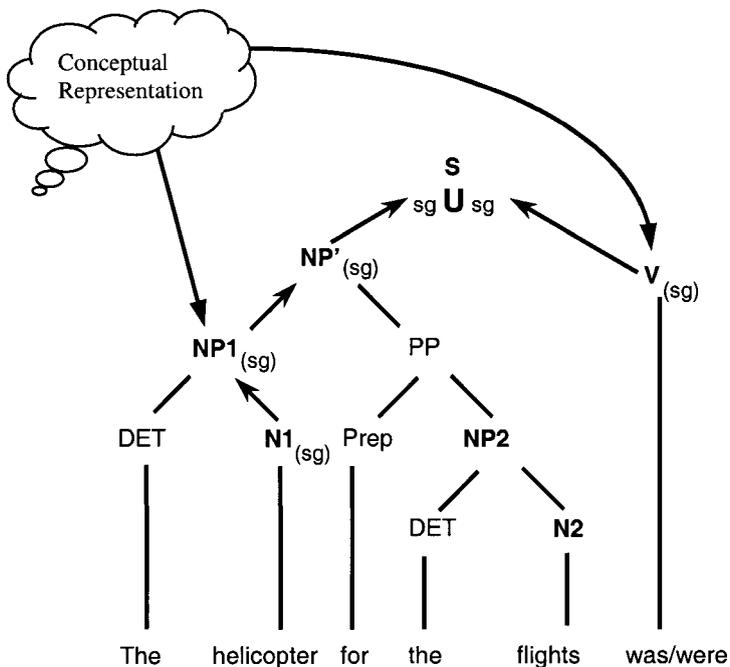


Figure 1. Agreement by means of unification according to the IPF model.

via successive unifications to the sentential S-node that can unify with the verb segment in order to be available for subject–verb agreement, as illustrated in Figure 1. If there is a NP modifier, the number feature of the noun contained in the modifier (the local noun) can also be passed to “mother nodes”, and can therefore sometimes be erroneously used to compute agreement with the verb. In this framework, an attraction error results from an incorrect unification between the verbal segment and the nominal segment containing the local noun. Nevertheless, such a failure in the unification process is an unlikely event because the syntactic path from the local NP to the S-node is always longer than the path from the subject NP to the S-node, the subject NP being always situated higher in the tree structure (as can be seen in Figure 1). As a consequence, features on the local NP are always less likely to enter the unification process than features on the head NP.

Consider now the structures associated to examples (4a) and (5a) illustrated in Figure 2. For relative or complement clauses (5a, The editor who rejected the books), the tree structure includes an extra-node for the NP modifier, in comparison to the structure with a phrasal modifier (4a, The editor of the history books). Therefore, the syntactic distance between

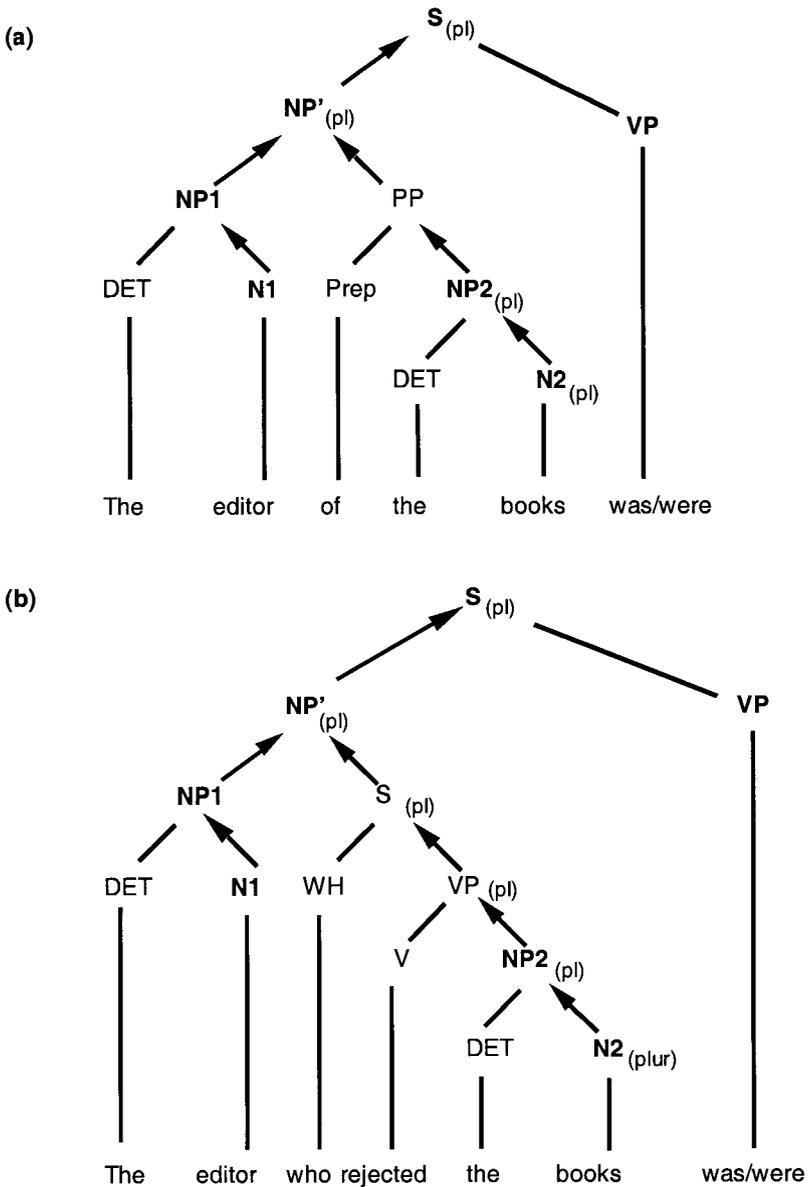


Figure 2. An account of the different error rates for prepositional phrases and clausal modifiers obtained by Bock and Cutting (1992) in terms of syntactic distance. The syntactic path that a mismatching local plural feature has to cover in order to interfere with agreement construction is shorter in (a), where from N2 to NP' there is just a PP node, than in (b) where from N2 to NP' there are two nodes (VP and S).

the local noun and the S-node is shorter when the local noun is part of a NP modifier, as shown in Figure 2a, than when it is part of a relative clause, as shown in Figure 2b.¹ The shorter the path, the more likely it is that the mismatching feature will affect agreement.

In this theoretical framework, the crucial factor in agreement error production is the position of the potentially interfering local noun in the hierarchical structure of the sentence, before it is linearised. The presence of a clause boundary does not completely insulate the matrix clause from the modifying relative or complement clause but it creates a longer syntactic path from the mismatching noun to the head noun. Hence, one would expect fewer errors with clauses than with prepositional phrase modifiers, but one would still expect a substantial number of errors. This is what Bock and Cutting found in their study (they report 37 errors with prepositional phrase modifiers and 25 errors with relative clause modifiers in the mismatching conditions in Experiment 1).

Bock and Cutting also reported that more agreement errors occurred when the subject pronoun embedded in the complement clause modifier mismatched in number with the head (e.g., *The report that they controlled the fire(s)*), than when it matched (e.g., *The report that he controlled the fire(s)*). This result is consistent with an account in which the syntactic distance between a nonhead NP and the head NP affects erroneous agreement.

To summarise, according to the *syntactic distance hypothesis*, agreement errors occur at a stage during grammatical encoding in which a syntactic tree structure is realised and features such as number are passed to different portions of this tree structure. The probability that a mismatching local feature interferes with agreement computation is dependent upon its position in the hierarchical sentence structure. The crucial factor is the syntactic distance the number feature on the local noun has to travel to influence verb agreement. On this account, the clause boundary has an effect because it makes the path substantially longer, not because it insulates the local noun from the treatment of the subject head noun. Like the clause packaging hypothesis, this account is grounded on the view that the syntactic frame for the sentence is elaborated in two steps: a first step during which syntactic constituents are organised hierarchically (at the functional level), a second step that ensures the linearisation of the constituents in their left-to-right order for

¹ Note also that, according to a number of accounts in syntactic theory, while adding adjectives does add syntactic nodes to the sentence representation, these are primarily in a left branch, and not in the path between the local noun and the highest NP projection.

articulation (at the positional level). However, in contrast to the clause packaging hypothesis, the syntactic distance hypothesis assumes that the relevant units over which syntactic operations like agreement proceed at the functional level are phrases. These rather small units would ensure a finer-grained control of the syntactic hierarchy over operations such as agreement.

Experimental evidence in favour of the syntactic distance hypothesis and falsifying a linear distance view has been reported by Vigliocco and Nicol (1998). They presented participants with preambles containing a phrasal modifier (*The helicopter for the flight*) and asked them to make up questions with subject–auxiliary inversion (*Is the helicopter for the flight safe?*). Phenomena like word order inversion, as in the case of questions, are assumed to occur after syntactic relations between the different segments have been established. Interrogative and declarative structures are therefore supposed to share the same hierarchical tree, although they differ as to the linear order of words. The authors found an agreement error pattern for interrogative sentences that was the same as the error pattern for declarative sentences. In other words, errors were equally common when the local noun was adjacent to the verb in the linear word chain and when it was separated from the verb by the subject head noun. This result was expected if one considers that agreement takes place when the sentence is structured hierarchically before it is linearised. These data are compatible with the hypothesis that agreement errors arise as a consequence of the position of the local NP in the hierarchical sentence structure.

However, although this result is incompatible with the linear distance hypothesis, it is still compatible with a more restrictive view of how hierarchy can control syntactic operations, like the one suggested by the clause packaging hypothesis. The clausal organisation is the same for declarative and interrogative structures and a similar attraction effect is expected because the local noun is part of the subject clause. Furthermore, the use of interrogative sentences does not allow a direct comparison with data reported in the literature, which were all obtained with declarative sentences. In this paper, we report two experiments which explore the effect of the local noun's position within the subject clause using declarative sentences. In contrast with previous studies, *two* phrasal subject modifiers were introduced in the preambles and their respective effects on agreement were analysed (e.g., *The statue(s) in the garden(s) by the mansion(s)*). The use of these particular preamble structures containing two potentially interfering nouns allow us to directly test a prediction of the syntactic distance hypothesis, namely that increasing the syntactic distance between a mismatching feature and the subject head noun, errors should decrease.

EXPERIMENT 1 (FRENCH)

In Experiment 1 (French), as well as in the parallel Experiment 2 (English), we presented speakers with preambles of the type illustrated in (7) and (8).

- (7) L'ordinateur avec le programme des expériences
The computer with the program of the experiments
- (8) L'ordinateur avec les programmes de l'expérience
The computer with the programs of the experiment

These preambles contained three nouns: a head noun (computer), an intermediate noun (program) and a local noun (experiment). The number of each noun was manipulated. The intermediate and local NPs were both within modifying prepositional phrases. The intermediate NP was part of a PP modifying the head NP, while the local NP was contained within a modifier of the intermediate NP.² Therefore, the two “modifying” nouns occupied two different positions in the hierarchical syntactic structure, with the local NP being the most embedded in the tree.

The use of these materials allowed us to put to the test the three hypotheses presented above. The syntactic distance hypothesis predicts that *more* verb agreement errors will occur when the intermediate noun disagrees in number with the head (The computer with the programs of the experiment) than when the local noun disagrees with the head (The computer with the program of the experiments). The reason for this is that the intermediate noun is higher in the tree structure than the local noun and therefore has more chance to have its number feature percolate up to the maximal projection of the head NP and unify with the verb's feature. Note that this prediction is totally unexpected given the widespread view of agreement in terms of linear distance, which predicts that *fewer* errors will occur when the intermediate noun disagrees with the head than when the local noun disagrees with the head. The hypothesis of clause packaging (as presented in Bock & Cutting, 1992) predicts *no difference* between the intermediate noun and the local noun in the way they will attract verb agreement. In this framework, both nouns are part of the same clause as the head noun and there is no reason to assume that they will have a different impact on the agreement process. These three hypotheses are illustrated in Figure 3.

² Attachment preferences were evaluated by native speakers of French and English. We selected only those preambles containing a local noun within a modifier that preferentially—or exclusively, in some cases—attached low, as a modifier of the intermediate NP.

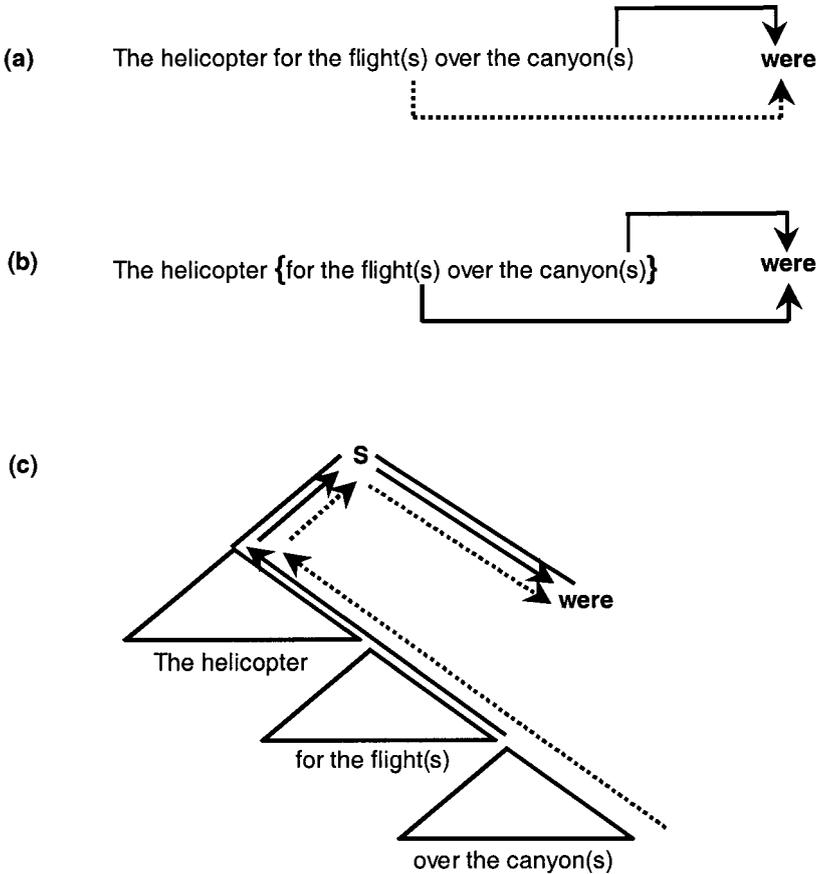


Figure 3. Predictions for double modifiers. Plain arrows represent high interference whereas dotted arrows represent low interference. In (a), the *linear distance hypothesis* predicts that the local noun (canyons) has a greater probability of influencing agreement than the intermediate noun (flights) since it occupies a linear position closer to the verb. In (b) a *clause packaging* view predicts that a feature has the same probability of disrupting agreement computation if it is on the local or on the intermediate noun since these nouns belong to the same clause and are encoded simultaneously. In (c), the *syntactic distance hypothesis* predicts more agreement errors when the intermediate noun mismatches the head than when the local noun mismatches because the syntactic distance between the potentially disruptive feature and the verb is shorter.

Method

Participants. Fifty-six students, aged between 18 and 45, of the Université catholique de Louvain took part in the experiment. They were paid 100 BF for their participation.

Materials. The experimental materials were sentence preambles containing a head noun (N1), an intermediate noun (N2) and a local noun (N3), as illustrated in Table 1. Both N2 and N3 were embedded in prepositional phrases. The variables which were experimentally manipulated were: (1) the number of N1 (singular vs. plural), (2) the number of N2 (singular vs. plural), and (3) the number of N3 (singular vs. plural). For each item, eight different versions were created to represent the different combinations of singular and plural (SSS, SSP, SPS, SPP, PPP, PPS, PSP, PSS with S and P representing the number of N1, N2, and N3). Experimental items are listed in Appendix 1.

Eight 96-item lists were created. In each list there were 32 experimental items and 64 fillers. All the experimental conditions were represented within each list. Each condition was represented by four preambles. In each list there was only one of the eight possible versions of the same item. The filler items contained a head NP followed by a single PP modifier; half had a singular head noun and half had a plural head noun. For all filler items, the modifying noun matched in number with the head noun. Preambles were arranged in a pseudo-random order: each list started with five fillers and there were no more than three consecutive experimental preambles.

TABLE 1
Different versions of a sentential preamble in Experiment 1

<i>Condition</i>	<i>Sentence preamble</i>
SSS	L'inscription sur la porte de la toilette <i>The inscription on the door of the toilet</i>
SSP	L'inscription sur la porte des toilettes <i>The inscription on the door of the toilets</i>
SPS	L'inscription sur les portes de la toilette <i>The inscription on the doors of the toilet</i>
SPP	L'inscription sur les portes des toilettes <i>The inscription on the doors of the toilets</i>
PPP	Les inscriptions sur les portes des toilettes <i>The inscriptions on the doors of the toilets</i>
PPS	Les inscriptions sur les portes de la toilette <i>The inscriptions on the doors of the toilet</i>
PSP	Les inscriptions sur la porte des toilettes <i>The inscriptions on the door of the toilets</i>
PSS	Les inscriptions sur la porte de la toilette <i>The inscriptions on the door of the toilet</i>

Note: S = singular noun, P = plural noun.

Procedure. Each participant was tested individually in a session lasting approximately 30 min. Participants were instructed to read the sentence beginnings, then to repeat and complete them. They were asked to speak as quickly as possible and to use the verb “to be” (*être*) (this maximised the number of inflected verb forms produced collected). The stimuli were presented visually via Superlab software on an Apple Macintosh. Presentation times were 3000 ms for both experimental and filler items. The experimenter regulated the appearance of the items on the screen.

Scoring. The completions were transcribed and then assigned to one of the following scoring categories: (1) *Correct responses* were scored when the participant correctly repeated the preamble and completed the sentence with a correctly inflected verb. (2) *Agreement errors* were scored when the completion met the criteria above but the verb form failed to agree in number with the subject of the sentence. (3) *Number repetition errors* were scored when the participants changed the number marking of N1, N2, or N3. Note that an agreement error after a repetition error was considered separately from other agreement errors as the conditions in which they appeared have been modified by the number repetition error. (4) *Miscellaneous errors* were scored when the participant failed to apprehend the preamble (or parts of it), when he/she failed to repeat some words in the preamble, and when he/she produced a completion lacking the main verb. If two different utterances were produced in succession, only the first was scored, including those cases in which an agreement error was produced and immediately corrected.

Design and data analyses. For the production experiment, the main statistical tests were carried out using the number of agreement errors, the number of errors in the repetition of number, and the number of miscellaneous errors as the dependent measures. For each dependent variable, we conducted: (a) a repeated measures ANOVA, where the three orthogonal factors were: number of N1, number of N2, and number of N3, both with subjects (F_1) and items (F_2) as random factors; (b) pairwise comparisons between conditions.

Results

Application of the scoring criteria yielded 1150 (64.2%) correct responses, 79 (4.4%) subject-verb agreement errors, 417 (23.3%) repetition errors and 146 (8.2%) miscellaneous errors. The proportion of errors in the different conditions is presented in Table 2.

TABLE 2
 Mean proportions of errors and standard deviations (in parentheses) per condition in Experiment 1 (French)

<i>Condition</i>	<i>Agreement errors</i>	<i>Repetition errors</i>	<i>Miscellaneous errors</i>
SSS	.013 (.115)	.094 (.321)	.071 (.258)
SSP	.000 (.000)	.188 (.455)	.103 (.319)
SPS	.098 (.298)	.326 (.618)	.058 (.234)
SPP	.045 (.207)	.326 (.541)	.089 (.286)
PPP	.013 (.115)	.183 (.431)	.085 (.279)
PPS	.031 (.174)	.268 (.576)	.080 (.273)
PSP	.094 (.292)	.295 (.495)	.085 (.279)
PSS	.058 (.234)	.183 (.410)	.080 (.273)

Agreement errors. There was no main effect of the number of any of the nouns ($F_s < 1$). Tests on the interactions revealed significantly more agreement errors when the number of N1 was in mismatch with the number of N2 ($F_1(1, 55) = 31.05, p < .001$; $F_2(1, 31) = 40.48, p < .001$) and when the number of N2 was in mismatch with the number of N3 ($F_1(1, 55) = 9.19, p = .004$; $F_2(1, 31) = 11.48, p = .002$). There were more agreement errors when N1 and N3 matched in number than when they mismatched ($F_1(1, 55) = 5.49, p = .023$; $F_2(1, 31) = 8.80, p = .006$).

Relevant contrasts with regard to the linear distance hypothesis showed no difference between SSP and its baseline SSS and between PPS and its baseline PPP. Relevant contrasts with regard to the clause packaging hypothesis showed significantly more errors in SPS than SSP ($t(55) = 4.96, p < .001$) and in PSP than PPS ($t(55) = 2.8, p = .007$). Finally, relevant contrasts with regard to the syntactic distance hypothesis revealed significantly more errors in SPS than its baseline SSS ($t(55) = 4.15, p < .001$) and in PSP than its baseline PPP ($t(55) = 4.43, p < .001$). Conditions SPP and PSS also induced more errors than the control conditions SSS and PPP (respectively $t(55) = 1.99, p = .05$ and $t(55) = 2.01, p = .04$). PSP did not differ significantly from PSS but there were more agreement errors in SPS than SPP ($t(55) = 2.57, p = .013$).

Repetition errors. ANOVAs revealed a significant effect of the number of N2, with more errors produced when N2 was plural than when it was singular ($F_1(1, 55) = 13.32, p = .001$; $F_2(1, 31) = 10.97, p = .002$). The interaction between the number of N1 and the number of N2 was significant, indicating that more repetition errors occurred when both nouns mismatched in number compared to when they matched ($F_1(1, 55) = 25.80, p < .001$; $F_2(1, 31) = 11.39, p = .002$). A mismatch between the

numbers of N2 and N3 was also a significant source of error, as indicated by the significant interaction between these two numbers ($F_1(1, 55) = 10.49, p = .002$; $F_2(1, 31) = 6.55, p = .016$).

Miscellaneous errors. There were no significant effects or interactions ($F_s < 1$).

Discussion

Experiment 1 shows that in contrast with the traditional view of attraction errors, when two potentially interfering nouns were present in the preamble, subject–verb agreement was not disturbed by the local noun (N3), preceding the verb, but rather by the intermediate noun (N2), which was further from the verb. No attraction at all was reported when the number feature on the local noun mismatched the feature on the head noun. In contrast, an important attraction effect was found with the feature of the intermediate noun when it mismatched in number with the head. This finding is in line with the predictions of the syntactic distance hypothesis, and cannot be accounted for by the linear distance nor by the clause packaging hypotheses.

Nevertheless, an alternative explanation to the syntactic distance hypothesis could be that the items which induced high error rates were actually more difficult to interpret. The different conditions may have different degrees of comprehension difficulty or difficulty in the assignment of concepts to the appropriate sentence roles (see for example Bock & Miller, 1991; Hupet et al., 1996) due to differences in plausibility or other variables. Parallel to the on-line production experiment, two off-line rating tests were conducted on the experimental items to estimate their plausibility and their imageability. The aim of these tests was to make sure that the differences found between conditions in agreement errors do indeed reflect differences in agreement computation and not differences in the apprehension of the preambles. The results of the plausibility and imageability judgement tasks show no evidence that one condition is conceptually more difficult than another. Scores showed little variation between the eight conditions, as shown in Table 3.

We also examined whether there was a correlation for the items between the occurrence of agreement errors and either plausibility or imageability. These were nonsignificant: we found (Pearson's correlation) $r = .292$ and $r = .139$, for plausibility and imageability respectively. This is not to say that there was no difference at all between conditions: it was found that items in the SSS condition were judged more imageable than items in any other condition. But conditions inducing a high number of agreement errors did not receive lower plausibility and imageability scores.

TABLE 3
 Mean scores and standard deviations (in parentheses)
 for the plausibility and imageability judgement tasks
 in Experiment 1 (French)

<i>Condition</i>	<i>Plausibility</i>	<i>Imageability</i>
SSS	5.9 (1.7)	4.7 (2.1)
SSP	5.6 (1.9)	4.3 (2.1)
SPS	5.5 (2.0)	4.3 (2.1)
SPP	5.5 (1.9)	4.4 (2.1)
PPP	5.3 (2.2)	4.3 (2.2)
PPS	5.4 (2.1)	4.4 (2.2)
PSP	5.4 (2.1)	4.5 (2.1)
PSS	5.5 (2.0)	4.1 (2.2)

It is also worth noting here that miscellaneous errors, which are also a measure of the difficulty participants had in apprehending the preambles, did not differ across conditions.

Before turning to general theoretical considerations, we wanted to ensure that the particular pattern of results we obtained is a widespread phenomenon, not specific to French. This was the aim of Experiment 2, which we conducted in English.

EXPERIMENT 2 (ENGLISH)

Method

Participants. Forty undergraduate students from the University of Arizona participated in this experiment. They received course credit or \$3 for their participation.

Materials. Materials were constructed as in Experiment 1. Conditions are illustrated in Table 4. Experimental items are listed in Appendix 2.

TABLE 4
 Different versions of a sentential preamble in Experiment 2

<i>Condition</i>	<i>Sentence preamble</i>
SSS	The threat to the president of the company
SSP	The threat to the president of the companies
SPS	The threat to the presidents of the company
SPP	The threat to the presidents of the companies
PPP	The threats to the presidents of the companies
PPS	The threats to the presidents of the company
PSP	The threats to the president of the companies
PSS	The threats to the president of the company

Procedure. Lists were recorded on a digital recording system by a female speaker. Participants were instructed to listen to the sentence beginnings, then to repeat and complete them. They were asked to speak as quickly as possible, but no other constraint was put on the form or content of the completions. Eight practice preambles (of the filler type) were presented to the participants at the beginning of the session. If the participant failed to understand a preamble, the experimenter repeated it.

Scoring. Same as in Experiment 1, except for the addition of category *uninflected verb responses*. These responses were scored when the completion met the criteria for a correct response but the verb form produced was uninflected for number (i.e., a past tense of a regular verb).

Design and data analysis. Same as in Experiment 1.

Results

Application of the scoring criteria yielded 784 (60.1%) correctly inflected verbs, 80 (6.2%) agreement errors, 129 (10.1%) number repetition errors, 118 (9.2%) miscellaneous errors and 184 (14.4%) uninflected verb forms. Table 5 reports the distribution of errors in the experimental conditions.

Agreement errors. Errors were more common when N1 was singular than when it was plural ($F_1(1, 39) = 7.4, p = .009$; $F_2(1, 31) = 8.1, p = .008$) and when N2 was plural than when it was singular ($F_1(1, 39) = 11.04, p = .002$; $F_2(1, 31) = 7.94, p = .008$). There were more errors when N1 and N2 mismatched in number, as indicated by the significant interaction between N1 and N2 ($F_1(1, 39) = 34.89, p = .001$; $F_2(1, 31) = 33.8, p = .001$). Finally, the interaction between N2 and N3 was also significant ($F_1(1, 39) = 5.42,$

TABLE 5
Mean proportions of errors and standard deviations (in parentheses) per condition in Experiment 2 (English)

<i>Condition</i>	<i>Agreement errors</i>	<i>Repetition errors</i>	<i>Miscellaneous errors</i>
SSS	.013 (.221)	.025 (.304)	.094 (.667)
SSP	.031 (.404)	.063 (.543)	.088 (.533)
SPS	.156 (.667)	.138 (.815)	.069 (.506)
SPP	.131 (.716)	.119 (.716)	.069 (.599)
PPP	.031 (.335)	.056 (.480)	.150 (.778)
PPS	.025 (.304)	.119 (.784)	.088 (.628)
PSP	.100 (.545)	.169 (.944)	.075 (.464)
PSS	.013 (.221)	.013 (.221)	.100 (.709)

$p = .02$; $F_2(1, 31) = 4.3$, $p = .04$), indicating that more errors were produced when they were in number mismatch. The interaction between N1 and N3 was not significant ($F_s < 1$).

The relevant contrasts with regard to the linear distance hypothesis showed that errors in SSP were not significantly more common than in SSS and that there were no more errors in PPS than in the baseline PPP. With regard to the clause packaging hypothesis, SPS yielded significantly more errors than SSP ($z = 2.72$, $p = .006$) and PSP yielded more errors than PPS ($z = 2.7$, $p = .007$). Relevant comparisons for the syntactic distance hypothesis were the following: there were more errors in SPS and SPP than in the SSS baseline (respectively $z = 3.41$, $p < .001$ and $z = 2.95$, $p = .003$) and PSP yielded more errors than the baseline PPP ($z = 2.4$, $p = .02$), however PSS did not. There was no difference between SPS and SPP.

Repetition errors. The analysis of variance showed a significant main effect of the number of N2, with more errors for plurals than for singulars ($F_1(1, 39) = 8.13$, $p = .007$; $F_2(1, 31) = 7.15$, $p = .01$), a significant interaction between the numbers of N1 and N2 ($F_1(1, 39) = 6.7$, $p = .01$; $F_2(1, 31) = 12.1$, $p = .001$) and between the numbers of N2 and N3 ($F_1(1, 39) = 13.3$, $p < .001$; $F_2(1, 31) = 16.9$, $p < .001$), indicating that more errors occurred when these numbers differed.

Pairwise comparisons on singular N1s showed significantly more errors for SPS and SPP than the baseline SSS ($z = 2.9$, $p = .005$; $z = 3.2$, $p = .001$, respectively). Number repetition errors were equally likely in SPS and SPP ($z = .45$, $p = .64$), but they were more common for SPS than SSP ($z = 2.5$, $p = .01$). For plural NP1s, errors were more common in PSP than in the base-line PPP condition ($z = 2.78$, $p = .005$). Finally, errors were equally common for SPS and PSP.

Miscellaneous errors. None of the variables had an effect on miscellaneous errors ($F_s < 1$).

Discussion

Experiment 2 in English confirms the results obtained in French: the attraction effect depends entirely on the presence of a number mismatch between the head noun and the intermediate noun. The number feature on the local noun appears to have no control over the subject–verb agreement process.

As for the French materials, two off-line tests were conducted in order to evaluate the potential impact of the plausibility and imageability of the items over the realisation of agreement. Scores for the two tests are reported in Table 6.

TABLE 6
 Mean scores and standard deviations (in parentheses)
 for the plausibility and imageability judgement tasks
 in Experiment 2 (English)

<i>Condition</i>	<i>Plausibility</i>	<i>Imageability</i>
SSS	6.0 (.75)	5.3 (1.0)
SSP	5.9 (.76)	4.9 (.90)
SPS	5.8 (.71)	4.9 (.96)
SPP	5.7 (.78)	4.9 (.77)
PPP	6.0 (.74)	5.0 (1.0)
PPS	5.8 (.91)	4.9 (.83)
PSP	5.8 (.69)	4.7 (.85)
PSS	6.1 (.52)	5.0 (.89)

As for French, neither plausibility nor imageability significantly correlated with the agreement error rates ($r = .123$ for plausibility and $r = .06$ for imageability).

Furthermore, miscellaneous errors did not differ across conditions suggesting that the comprehensibility of the preambles was not responsible for the different agreement error rates.

These results suggest again that the determining factor in the occurrence of attraction is not the presence of a mismatching noun close to the verb in the linear sentence structure, nor potential biases in our materials related to plausibility, imageability or complexity, as attested by the balanced distribution of miscellaneous errors over experimental conditions. Rather, attraction appears to be determined by the syntactic distance between the local noun and the head noun in the hierarchical structure at the stage of grammatical encoding.

Although the main predictions with regard to the syntactic distance hypothesis are supported in both French and English, other aspects of the data, which were found in both languages, require discussion. A first noteworthy aspect of the data concerns the asymmetry between singular and plural heads. An interesting cross-linguistic pattern of nearly all studies on agreement is that, in conditions of number mismatch, errors with plural head nouns and singular local nouns (e.g., *The babies on the blanket*) were far less common than errors with singular head nouns and plural local nouns (e.g., *The baby on the blankets*). Hence, in most studies, the attraction effect only occurred in the conditions with singular head nouns and plural local nouns (Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Fayol & Got, 1991; Fayol et al., 1994; Hupet et al., 1996; Vigliocco et al., 1995; Vigliocco et al., 1996). Bock and Eberhard (1993; see also Eberhard, 1997; Tiersma, 1982) suggested that this asymmetry reflects a difference in the *markedness* of the nouns: plural

nouns possess a marked grammatical feature for number that singular nouns lack. The probability that a marked local noun interferes with an unmarked head noun is greater than the opposite: a feature with a specified value (i.e., the plural form), being more salient, is more likely to replace a feature with no value (i.e., the singular form) than vice versa. However, in Experiment 1 (French), we found no hint of such an asymmetry, as attested by the absence of a main effect of the subject's number. In the English experiment, there was a main effect of head number, indicating that, overall, more errors were produced when N1 was singular than when it was plural. Nevertheless, in contrast to previous studies, a large number of errors were produced in the condition with a plural head and a double number mismatch, i.e., PSP (vs. PPP), which contrasts with the usual absence of an attraction effect with plural heads.

The second unexpected finding is that the mismatch effect found between the head noun and the intermediate noun is increased when there is an additional mismatch between the intermediate noun and the local noun, i.e., SPS (vs. SPP) and PSP (vs. PSS) conditions. In the condition with plural heads, such a double mismatch (PSP) yielded significantly more errors than the single mismatch (PSS) in both languages. A similar pattern was found for singular heads in French, where significantly more errors were produced in SPS than SPP; however, there was no difference between these two conditions in English. The syntactic distance hypothesis predicted no difference between PSP and PSS, nor between SPS and SPP; if anything, a small difference should have been found in the other direction, since incorrect feature percolation from the local noun, although deep in the tree, might still have influenced agreement realisation.

Our interpretation of these aspects of the data lies in the concept of processing complexity that we assume is involved in the treatment of plural features. This is discussed in more detail in the General Discussion.

GENERAL DISCUSSION

We conducted two experiments, one in French and one in English, which induced subject-verb agreement errors. Our main goal was to establish the role of syntactic structure in inducing attracting errors. The use of particular preamble structures containing two potentially interfering nouns allowed the emergence of a novel, particularly counterintuitive pattern of results: we found that proximity of a mismatching NP to the verb was less important than proximity to the head NP. Furthermore, the manipulation of double modifiers allowed another novel result to appear: a high number of attraction errors in the condition with a plural head (PSP). This result contrasts with the traditional asymmetry reported between singular and plural heads. In this section, we first review the arguments in favour of the

syntactic distance hypothesis, then we put forward a hypothesis to account for some secondary aspects of the data, and finally we suggest a theoretical account for cross-linguistic aspects of the observations collected.

The role of syntactic structure

The main finding of the two experiments we conducted, i.e., the strong impact of the intermediate noun on verb agreement in conjunction with the absence of an impact of the local noun, was found to be very similar in French and in English. It is important to note here that this effect was replicated in both languages in two further experiments we conducted that are not reported here. We can therefore securely claim that the intermediate noun effect is a reliable effect which is not limited to the structural peculiarities of one specific language.

Three hypotheses were considered that account for the attraction effect widely reported in the literature. In the framework of the *linear distance hypothesis*, inspired by linguistic accounts of agreement (Quirk et al. 1972; Quirk & Greenbaum, 1973), the local noun effect is interpreted in terms of proximity concord. In this view, speakers would “rely spontaneously on proximity criteria, making the verb agree with the closest noun or pronoun” (Fayol et al., 1994). In most cases, the verb immediately follows the subject and agreement is correct. When another noun separates the verb from the head noun, it has been suggested that a checking procedure would ensure the relevance of the agreement relation. Different properties of the preverbal noun may influence the triggering of the editing-check process, like, for example, the presence of a plural feature or the presence of a preverbal noun that is a semantically implausible subject of the verb (Hupet et al., 1996). The two experiments showed that when two potentially interfering number features were manipulated in the preamble, the local noun, i.e. the preverbal noun that immediately preceded the verb in the word string, had no impact on subject–verb agreement. In contrast, the intermediate noun situated further from the verb but proximal to the head noun considerably disturbed agreement computation. The “intermediate noun effect” we report closely parallels the “local noun effect” found in studies that manipulated only one interfering, preverbal noun. This result clearly falsifies the linear distance hypothesis, as we found no effect of the local noun in our experiments.

The second hypothesis we reviewed was *clause packaging*, as suggested by Bock and Cutting (1992). In this framework, elements that share similar structural properties within a clause are potentially interfering in their competition for the same mechanisms. The prediction of this view was that the number feature on the intermediate noun and on the local noun would have the same impact on verb agreement, because both nouns are part of

the same clause. Results show that the syntactic position of the segments within the clause plays a role in that only features on segments situated high enough in the tree may interfere with the agreement process. This is not to say that clausal structure does not constitute a functional unit of sentence production (Bock & Levelt, 1994), however, it appears that with respect to subject-verb agreement, it is relevant to distinguish finer-grained units on which syntactic mechanisms operate, such as the position in the hierarchical phrasal structure. Our data show that indeed the syntactic position of a number feature *within the clause* influences the grammatical process of agreement.

Our results are compatible with the idea that agreement is computed at the level of grammatical encoding when abstract lexical representations are retrieved and organised hierarchically before they are positioned in left-to-right order for articulation. The relevant factor for agreement errors would not be the linear distance between a local noun and the verb, nor the clausal organisation during agreement computation, but the position of the local noun in the hierarchical structure at this level of production, as predicted by the syntactic distance hypothesis. A local noun embedded low in the tree has no chance to influence the agreement process, whereas a local noun situated high in the tree creates serious interference in the process. In the introduction, we presented a model of sentence production, called the Incremental Parallel Formulator (De Smedt, 1990), which considers syntactic construction as an operation of constituent assembly within a hierarchical structure. In this framework, the mechanism for computing agreement is described in terms of feature percolation from the head noun to the S-node where the features are assumed to unify with features from the verb (Vigliocco et al., 1995). On this view, errors would occur when features from a nonhead noun situated high in the tree structure erroneously percolate through the tree to unify with verb number. In contrast, the number feature of a nonhead situated low in the syntactic structure would be too far from the S-node to influence the unification process. In such a model based on unification, the relevant factor explaining the attraction effect is the syntactic distance between the local noun and the S-node where unification is supposed to take place.

However, the syntactic distance effect we report is also compatible with the conception of agreement as a copying/checking procedure from the noun's features onto the verb, as for example developed by Chomsky in the Minimalist Program (1995). Agreement in such a framework involves two asymmetrically marked elements: whereas the noun bears a number feature with semantic correlates (in Logical Form), the number feature on the verb is considered as purely formal, and hence eliminated in the course of the syntactic derivation. Being "noninterpretable", the number feature on the verb entirely depends on the noun's number feature. These formal

notions have a natural interpretation in sentence comprehension and production. During sentence comprehension, checking of the verb's number feature is ensured by moving it into a position in the tree occupied by a functional head (e.g., Infl or AGR) which bears the subject's number feature. During sentence production, the subject's number, specified at the Infl position, is assumed to be copied onto the verb. As the economy conditions of the Checking theory favour locality (i.e., the shortest distance for such operations), a nonhead noun has more chance to pass its number feature onto the Infl position, and therefore determine the number specification of the verb, if it is close to it in the tree structure, i.e., if it is situated higher.

It is also important to note that the syntactic distance hypothesis can also account for the results of other subject-verb agreement studies reported in the literature, and is consistent with observations of speech errors which suggest that agreement errors originate during grammatical encoding and, more specifically, at a stage in which the syntactic structure of the sentence is computed, after grammatical functions have been assigned, but before words are placed in their left-to-right order in the to-be-uttered string.

The potential role of processing complexity related to plurality

In contrast to previous studies, we used rather complex materials in which the subject head noun was separated from the verb by two modifying noun phrases. This manipulation of processing complexity revealed some interesting new information about agreement that the structural factor of syntactic distance alone cannot account for. A first observation was that the PSP condition yielded a high rate of errors which was similar to the error rate for the SPS condition in French. This finding contrasts with the small attraction effect for plural head nouns (PS) compared to singular heads (SP) reported throughout the literature using the paradigm with only one local noun. Moreover, although there was a high error rate in PSP, no or little attraction was reported when the plural head noun was followed by two singular nouns, i.e., PSS. Finally, we found a tendency towards a smaller attraction effect when the singular head noun was followed by two plural nouns (SPP) compared to when the intermediate noun only was plural (SPS). These three aspects of the agreement pattern were observed consistently in the two experiments reported in this paper.

To account for these findings, we suggest that a more general factor related to processing complexity influenced the error pattern, in combination with the structural factor of syntactic distance. First, plural forms may be more complex to deal with than singular forms. Evidence for greater

complexity associated with plurality comes from different data on language acquisition, production, and comprehension (for a detailed review, see Eberhard, 1997). Developmental studies have shown that in children's speech, nouns appear in their singular form before the plural form (Cazden, 1968; Mervis & Johnson, 1991). It has also been found that children understand singular items before their plural counterparts (Clark, 1973; Lapointe, 1986). In his study of spontaneous errors, Stemberger (1985) reports a strong asymmetry, with more errors in the production of a plural than a singular. It also appears that when people are asked to memorise nouns, plural forms tend to be remembered as singulars while no errors of number arise for singular forms (Van der Molen & Morton, 1979). It has also been found that elderly people, who often show a reduction of working memory resources, seem to be more sensitive to the presence of plurals than young adults (Fayol, Hupet, & Largy, 1999).

Furthermore, a closer look at the various data on subject-verb agreement reveals that in many experiments, when the subject head noun and the local noun have the same number, errors are more common for plural heads with a plural local noun (PP) than for singular heads with a singular local noun (SS) (e.g., in French, Fayol et al., 1994; Franck, 1998; in English, Bock & Miller, 1991; Bock & Cutting, 1992; in Italian, Vigliocco et al., 1995; in Spanish, Vigliocco et al., 1996a). Fayol et al. (1994) also found that verb agreement with plural head nouns was more disrupted by a secondary task than agreement with singular head nouns (such as when a memory load task was added to the sentence dictation task).

Plural forms would be more complex than singular ones because plural nouns are "marked" both semantically (as "more than one") and morphologically (by the final "s").³ It is therefore possible that the traditional asymmetry between singular and plural heads would emerge from greater *complexity* in preambles with plural nouns than with singular nouns. On this view, it is not the presence of marking per se that explains the pattern of errors, but rather, the fact that marking increases processing load. For agreement computation, a plural feature situated on the subject head noun would be more difficult to process than a singular feature, as attested by the higher error rate in P or PP sentences than in S or SS sentences. Plurality would be even more difficult to deal with when combined with other factors of complexity, as for example when the plural feature is situated on a potentially interfering noun in agreement

³ It may be that the concepts of markedness and complexity are also both closely linked to the fact that plural forms are less frequent than singular forms (Greenberg, 1966). Furthermore, the presence of more than one plural noun can also create difficulties in establishing relationships between the nouns bearing the plural features (e.g., *the keys to the cabinets* can reflect a mapping between the keys and the cabinets that is one-to-one, many-to-one, one-to-many or some combination).

computation. Error patterns indeed reveal that a plural local noun, as in SP, yields more agreement errors than a singular local noun, as in PS.

Although the concept of markedness per se suffices to account for these two patterns of errors, it does not predict the absence of asymmetry between SPS and PSP we reported in French, nor the high error rate observed on PSP in English. In contrast to previous studies, our experiments used longer preambles with an additional noun phrase modifier. This manipulation created the conditions for an increased error rate with plural head nouns in the PSP condition, due to the presence of the additional plural feature on N3. This finding, combined with the low error rate in PSS and in the PS conditions previously reported in the literature, could result from the presence of the additional plural mark on N3 in PSP. Figure 4 shows a schematic representation of the impact of singular and plural features on agreement errors according to their position in the sentence. It illustrates the effect of the two factors in the induction of errors: the *structural factor*, i.e., syntactic distance, that determines the probability of interference with the agreement process as a function of the position of the plural feature in the syntactic tree, and the factor of *processing complexity*, i.e., plurality.

The lower layer represents the “base” level, i.e., agreement errors produced with a single singular (S) or plural (P) head noun. The middle layer illustrates the increase of error rate related to the addition of a second number feature. This increase is particularly important when the second (number-mismatching) noun is plural (SP) compared to when it is singular (PS) as it combines two difficulties, i.e., interference, as accounted for by the syntactic distance hypothesis, and plurality. The upper layer

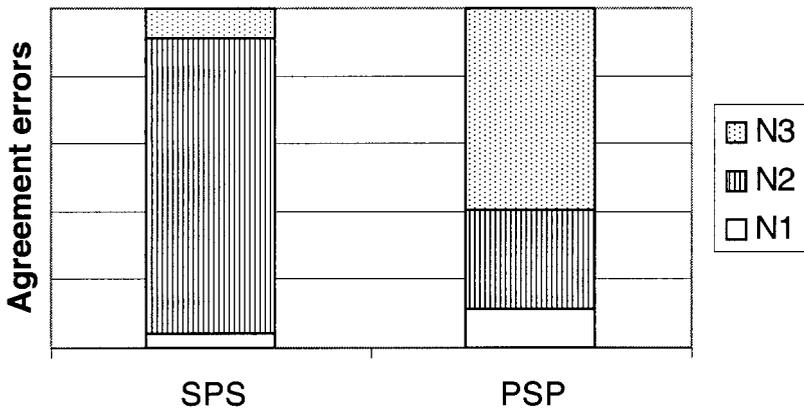


Figure 4. Schematic representation of the impact of singular and plural features on agreement errors according to their position in the sentence.

represents the increase of error rate related to the addition of a third number feature. The increase is more important when the third noun is plural (PSP) than when it is singular (SPS), however, it is smaller than the increase related to the plural second noun as it does not involve the interference factor.

However, one observation remains unexplained by this framework, which is the high error rate observed for SPS items compared to SPP items in French and in English.⁴ One would expect to find a high error rate in SPP, at least as high as in SPS (if not higher because of the additional plural feature on N3). It is possible that the SP (and SPS) condition has already reached a ceiling level of difficulty, as attested by the very high error rate it yields, in which case the additional plural feature would not have any effect. It is also possible that it is harder to build and use a representation for the sentence in which the mappings are changing or switching from one morpho-phonological form to another, as is the case in SPS but not in SPP. In addition to the factor of syntactic distance at play in these two conditions, number alternation would increase the error rate in SPS whereas the additional plural feature would increase the error rate in SPP. These explanations remain speculative; further studies will need to be conducted in order to establish the nature of the complexity related to plurality, as well as the apparent difficulty related to number alternation.

Cross-linguistic considerations

The main aim of the present study was to put to test, in a cross-linguistic perspective, the syntactic distance hypothesis. This hypothesis comprises two important assumptions: (1) agreement takes place at a stage of sentence production where syntactic segments are structured hierarchically before linearisation, and (2) features from the subject percolate through the syntactic tree to reach the S-node, where agreement is ensured by a mechanism of unification between subject and verb features. Very similar error patterns were found in both languages, supporting the syntactic distance account of agreement errors. For the most part, the general pattern of results was the same in both languages. Nevertheless, three differences did emerge. We first review these three points and then interpret them within a theoretical framework.

⁴ Other experiments have been led using complex NPs in French and in English that also show a consistent strong tendency towards a high error rate in SPS when compared to SPP. This excludes any interpretation in terms of an artifact related to the items or to the conditions of presentation.

The first difference concerns the overall number of errors (agreement and repetition). More errors were produced in French (27.7%) than in English (16.3%). Although this difference is only due to repetition errors in the present two experiments, an overview of the results reported in the literature (and of our own results) clearly indicates that French speakers tend to produce more agreement errors than English speakers.

Second, for agreement errors, we found a different effect of the number of the head noun: an asymmetry was shown in English, with more errors for singular head nouns, but not in French. Looking at particular conditions, both languages showed a strong mismatch effect in PSP; however the counterpart SPS condition tended to yield more errors than PSP in English but an equivalent number of errors in French. Furthermore, while in English both SPS and SPP induced a large and similar number of errors, in French SPP induced fewer errors than SPS. In other words, proportionally more errors were produced on PSP in French than in English. Finally, in Experiment 1 (French), there was a rather high number of errors in PSS which was not the case in Experiment 2 (English). In sum, errors for plural head nouns appeared to be more common in French than in English. This pattern concords with scattered results in the literature on French agreement which often reports an attraction effect with plural heads, though most of the time it is smaller than the effect with singular heads (Fayol & Got, 1991; Fayol et al., 1994; Franck, 1998; Hupet et al., 1996; Hupet et al., 1998).

Along these lines, the third variation concerns the global tendency to produce erroneous singular forms versus plural forms. We found that English speakers produced more erroneous plural verbs than singular verbs (27 singulars vs. 53 plurals), which yielded the reported asymmetry on agreement errors. A different pattern was found for French speakers who even showed a preference for singular verbal forms compared to plural ones (44 singulars vs. 35 plurals).

We suggest that these three cross-linguistic differences may all be related to a single factor. This factor is not related to syntactic processes per se but to the morpho-phonological realisation of number features in French and English. In French, there exist many different ways of marking morphophonologically plurality on verbs. Most of them are audible in oral French in the present and future tenses. Singular/plural oppositions on verbs consist in vocalic alternations (e.g., [a]/[ô], [ɛ]/[ô]) but most commonly in a multitude of zero/consonant oppositions (e.g., Ø/[t], Ø/[s], Ø/[v], etc.) (Dubois, 1965). In contrast, for most English verbs, number is signalled by variations in the third-person present forms and is morphologically simple: it consists in the single [s]/zero opposition. Two major differences between English and French appear from this brief description of number morpho-phonology in the two languages which are

relevant to the complexity of the verb's number. First, the morpho-phonology of complex verbal forms is by far richer in French than in English, in that there is a multitude of number oppositions in French, whereas there is only one in English. A simple principle guides our interpretation here, which is that the *probability* of making an error is a function of the *possibility* of making an error: the probability of producing the right form by chance is smaller when there are many forms than when there are only two. In other words, one expects to find more errors relative to number (agreement and repetition errors) in a language that presents a greater variability of number morphophonological marking, like French, than in a language with a smaller variability, like English. This is what we found.

Second, plural verbal forms are morpho-phonologically simpler than singular ones in English whereas it is the opposite in French. We suggested in some previous work (see Vigliocco & Franck, 1999) that adding an inflection may be computationally more expensive than changing it. This hypothesis was put forward to account for the finding that French speakers were particularly prone to produce gender agreement errors with feminine nouns compared to Italian speakers. In the Vigliocco and Franck (1999) study, we investigated subject–predicative adjective agreement in gender. In French, the feminine form of the adjective is obtained by adding a morpheme to the masculine form, whereas it consists in a vocalic variation in Italian ([o]/[a]). Data reported in the present study support this hypothesis: we found that French participants tended to produce more errors in PSP and PSS preambles than English ones and that globally, the French tend to erroneously produce singular verbs while the English tend to erroneously produce plural verbs.

CONCLUSION

In this paper, we proposed an alternative theoretical account of the attraction phenomena. Our data brought clear evidence against the intuitively seductive hypothesis that speakers tend to make the verb agree with the noun that just preceded it in the uttered word string. We reported that in some structures, a noun preceding the verb has no impact at all on verb agreement, whereas a noun situated further from the verb in the linear structure may seriously compromise its realisation. The data provide further evidence for the psychological plausibility of assuming a stage during which hierarchical relationships among phrases are encoded. The position of a potentially interfering noun in this hierarchical structure would determine its influence over the agreement procedure: while such a noun situated high in the tree structure would interfere strongly with verb

agreement, no interference would occur with nouns situated low in the structure.

However, the creation of eight experimental conditions, motivated by the interest of manipulating the number of the three nouns, yielded unexpected side-effects that do not relate directly to the syntactic distance hypothesis. In particular, a relatively large number of errors were found with plural head nouns. We speculated that, given the fact we used materials which were longer and more complex than the materials previously used in agreement studies, processing complexity may have played an important role. Further research will be necessary to determine exactly how complexity influences agreement processing and which distance, i.e., between the local noun and the S-node or between the local noun and the verb, exactly matters in the phenomenon of attraction.

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REFERENCES

- Bock, J.K. (1987). An effect of the accessibility of word forms on sentence structures. *Journal of Memory and Language*, 26, 119–137.
- 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., & Levelt, W.J.M. (1994). Language production. Grammatical encoding. In M.A. Gernsbacher (Ed.), *Handbook of psycholinguistics*. San Diego: Academic Press.
- Bock, J.K., & Miller, C.A. (1991). Broken agreement. *Cognitive Psychology*, 23, 35–43.
- Cazden, C.B. (1968). The acquisition of noun and verb inflections. *Child Development*, 39, 433–448.
- Chomsky, N. (1995). *The minimalist program*. Cambridge, MA: MIT Press.
- Clark, E.V. (1973). What's in a word? On the child's acquisition of semantics in his first language. In T.E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 65–110). New York: Academic Press.
- Dell, G.S. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review*, 93, 283–321.
- De Smedt, K.J. (1994). Parallelism in incremental sentence generation. In G. Adriaens & U. Hahn (Eds.), *Parallel models of natural language computation*. Norwood, NJ: Ablex.
- Dubois, J. (1965). *Grammaire structurale du français*. Librairie Larousse, Paris.
- Eberhard, K.M. (1997). The marked effect of number on subject–verb agreement. *Journal of Memory and Language*, 36, 147–164.
- Fayol, M., & Got, C. (1991). Automatisme et contrôle dans la production écrite. *L'Année Psychologique*, 91, 187–205.
- Fayol, M., Hupet, M., & Largy, P. (1999). The acquisition of subject–verb agreement in written French: From novices to experts' errors. *Reading and Writing: An Interdisciplinary Journal*, 11, 153–174.

- Fayol, M., Largy, P., & Lemaire, P. (1994). When cognitive overload enhances subject-verb agreement errors. A study in French written language. *Quarterly Journal of Experimental Psychology*, 47, 437-464.
- Franck, J. (1998). *Object attraction in the production of subject-verb agreement in French*. Poster presented at the fourth AMLaP Conference on Architectures and Mechanisms for Language Processing, University of Freiburg, Germany.
- Fromkin, V.A. (1971). The non-anomalous nature of anomalous utterances. *Language*, 47, 27-52.
- Garrett, M.F. (1976). Syntactic processes in sentence production. In R. Wales & E. Walker (Eds.), *New approaches to language mechanisms*. Amsterdam: North-Holland.
- Garrett, M.F. (1980). Levels of processing in sentence production. In B. Butterworth (Ed.), *Language production, Volume 1: Speech and Talk*. London: Academic Press.
- Garrett, M.F. (1982). Production of speech: Observations from normal and pathological language use. In A.W. Ellis (Ed.), *Normality and pathology in cognitive functions*. London: Academic Press.
- Garrett, M.F. (1988). Processes in language production. In F.J. Nieuwmeier (Ed.), *Linguistics: The Cambridge survey, Vol. III, Biological and psychological aspects of language* (pp. 69-96). Cambridge, MA: Harvard University Press.
- Garrett, M.F. (1990). Sentence processing. In D.N. Osherson & H. Lasnik (Eds.), *Language: An invitation to cognitive science, Volume 1*. Cambridge, MA: MIT Press.
- Greenberg, J. (1996). *Language universals*. The Hague: Mouton.
- Hupet, M., Fayol, M., & Schelstraete, M.-A. (1998). Effects of semantic variables on the subject-verb agreement processes in writing. *British Journal of Psychology*, 89, 59-75.
- Hupet, M., Schelstraete, M.A., Demaeght, N., & Fayol, M. (1996). Les erreurs d'accord sujet-verbe en production écrite. *L'Année Psychologique*, 96, 587-610.
- Jespersen, O. (1924). *The philosophy of grammar*. London: Allen & Unwin.
- Kempen, G., & Hoenkamp, E. (1987). Incremental procedural grammar for sentence formulation. *Cognitive Science*, 11, 201-258.
- Lapointe, S.G. (1986). Markedness, the organisation of linguistic information in speech production, and language acquisition. In F.R. Eckman, E.A. Moravcsik, & J.R. Wirth (Eds.), *Markedness* (pp. 219-239). New York: Plenum Press.
- Levelt, W.J.M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.
- Mervis, C.B., & Johnson, K.E. (1991). Acquisition of the plural morpheme: A case study. *Developmental Psychology*, 27, 222-235.
- Quirk, R., & Greenbaum, S. (1973). *A university grammar of English*. London: Longman.
- Quirk, R., Greenbaum, S., Leech, G., & Svartvik, J. (1972). *A grammar of contemporary English*. London: Longman.
- Stemberger, J.P. (1985). An interactive activation model of language production. In A. Ellis (Ed.), *Progress in the psychology of language* (pp. 143-186). Hove, UK: Lawrence Erlbaum Associates Ltd.
- Tiersma, P.M. (1982). Local and general markedness. *Language*, 58, 832-848.
- Van der Molen, H., & Morton, J. (1979). Remembering plurals: Unit of coding and form coding during serial recall. *Cognition*, 7, 35-47.
- Vigliocco, G., Butterworth, B., & Garrett, M.F. (1996a). Cross linguistic variability in subject-verb agreement errors. *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. (in press). When sex affects syntax: context influences in sentence production. *Journal of Memory and Language*.
- Vigliocco, G., Hartsuiker, R.J., Jarema, G., & Kolk, H.H.J. (1996b). How many labels on the bottles? Notional concord in Dutch and French. *Journal of Language and Cognitive Processes, 11*, 407–421.
- Vigliocco, G., & Nicol, J. (1998). Separating hierarchical relations and word order in language production. Is proximity concord syntactic or linear? *Cognition, 68*, 13–29.

APPENDIX 1

Experimental items used in Experiment 1 (in the singular, singular, singular condition).

L'ordinateur avec le programme de l'expérience
 L'exposition avec la peinture de l'enfant
 Le trousseau avec la clé de la cellule
 Le livre sur la privatisation de l'entreprise
 La conférence sur l'histoire de la guerre
 L'étude sur l'effet de la drogue
 La théorie sur le chant du canari
 L'inscription sur la porte de la toilette
 Le dépliant sur l'enjeu de la communauté
 La ligne sur le bord de la route
 La nappe sur la table du banquet
 Le récit de la souffrance dans l'hôpital
 La visite au palais de l'artisanat
 La menace de la réforme dans l'école
 L'hélicoptère pour le vol au-dessus du canyon
 La soirée dans l'appartement du sous-sol
 Le producteur du film sur l'artiste
 Le chat sur le toit du voisin
 Le chien sur le coussin du bébé
 Le gréviste sur l'escalier du patron
 L'architecte du château de la millionnaire
 La victime du mensonge du policier
 Le voleur de la voiture du garagiste
 Le responsable du droit de l'immigré
 Le gamin du clochard près de la poubelle
 L'avocat de l'assassin du village
 Le cochon du laboureur du champs
 La copine du propriétaire de la villa
 L'accompagnatrice du musicien de la rue
 Le professeur de mon cousin sur la photo
 L'entraîneur du vainqueur du match
 Le possesseur du perroquet dans l'arbre

APPENDIX 2

Experimental items used in Experiment 2 (in the singular, singular, singular condition).

The advertisement from the office of the real estate agent
 The announcement by the director of the foundation
 The article by the writer for the magazine
 The author of the speech about the city
 The computer with the program for the experiment
 The contract for the actor in the film
 The discussion about the topic of the paper
 The dog on the path around the lake

The friend of the editor of the magazine
The gift for the daughter of the visitor
The helicopter for the flight over the canyon
The lesson about the government of the country
The letter from the friend of my cousin
The manual by the developer of the machine
The mast on the deck of the yacht
The meal for the guest of the inn-keeper
The museum with the picture of the poet
The new design for the engine of the plane
The payment for the service to the school
The photo of the girl with the baby
The post in the support for the platform
The prescription by the doctor from the clinic
The producer of the movie about the artist
The publisher of the book about the king
The setting for the movie about the astronomer
The statue in the garden near the mansion
The switch for the light on the stairway
The telegram to the friend of the soldier
The threat to the president of the company
The tour of the museum near the monument
The train to the city on the lake
The truck on the bridge over the stream