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Object interference in subject–verb agreement: The role of intermediate traces of movement

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ABSTRACT

The research presented here uses theoretical constructs of formal syntax to account for performance data in agreement production. The phenomenon examined is object interference in French, i.e., incorrect agreement of the verb with the object. In the first experiment, interference is shown to occur in object relative clauses despite the absence of any surface intervention on the subject–verb relation (e.g., *John parle aux patientes que le médicament guérissent; *John speaks to the patients-P that the medicine-S cure-P*). Critically, no interference is found in complement clauses, superficially identical to the relatives (e.g., John dit aux patientes que le médicament guérit; *John tells the patients-P that the medicine-S cures-S*). Experiments 1–4 tease apart the role, in interference, of three properties that distinguish relative clauses from complement clauses: argumenthood, participle agreement and movement. Results suggest that interference is caused by object movement, and more particularly by the intervention, on agreement, of the intermediate trace of the moved object postulated in theoretical syntax to account for independent phenomena.

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Introduction

Agreement provides a prototypical illustration of what syntax does: it links words together in structured hierarchical configurations related to, but distinct from, the semantic status and lexical properties of individual words, their phonological realization or their position in the linear word string. Agreement, i.e., the copy of features of one word onto another, can be considered as one of the best indexes of the syntax–internal dynamics, hence providing a privileged window on the structural specificities of human language.

This research builds upon and extends our previous work on interference effects in the production of subject–verb agreement (Franck, Lassi, Frauenfelder, & Rizzi, 2006). As in this study, the general approach adopted here combines the empirical tools of experimental psycholinguistics and the theoretical constructs of formal syntax. In psycholinguistics, the seminal paper of Bock and Miller (1991) paved the way to the experimental study of agreement, and more particularly of the conditions under which it can be derailed (e.g., Bock & Cutting, 1992; Bock & Eberhard, 1993; Eberhard, Cutting, & Bock, 2005; Vigliocco & Nicol, 1998). In linguistics, the framework of Principles and Parameters/Minimalism has proposed a detailed account of the agreement operations involved in the syntactic derivation of the sentence (e.g., Chomsky, 1981, 1995, 2000; Haegeman, 1994).

Unfortunately the strong influence from theoretical constructs in linguistics that characterized the initial

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developments of experimental psycholinguistics (see for example Fodor, Bever, and Garrett (1974), and many references cited there) has decreased considerably over the last 30 years. Early attempts to integrate grammatical theory and processing studies through the Derivational Theory of Complexity failed to obtain strong empirical support and were abandoned in favor of a strict division of labor between competence and performance models. This split is particularly regrettable in research on agreement given the important developments on this issue in both disciplines with virtually no link between them.

Our research aim is to bridge the gap between psycholinguistics and linguistics in the domain of agreement, by assuming a tight connection between the language processor and the grammar. We combine both approaches to unravel syntactic constraints at work in the process of agreement production. Linguistics provides theoretical constructs that appear instrumental in capturing aspects of the linguistic behavior as observed in psycholinguistic experiments. Furthermore, experimental psycholinguistics goes beyond off-line observations (such as grammaticality judgments and cross-linguistic comparisons) and thus provides novel types of evidence potentially having a bearing on the construction of formal syntactic models. Our past research has already shown the relevance, in the interpretation of interference data, of critical theoretical constructs such as intervention, the distinction between c-command and precedence, and the distinction between AGREE and Spec-Head checking (Franck et al., 2006). In this paper, a new series of experiments is reported which further explores object interference, teasing apart the role of movement, argumenthood and participle agreement in the occurrence of errors. We show that another construct from theoretical linguistics, the concept of intermediate traces of movement, appears to capture participants' performance in the laboratory. Our work is based on the assumption that some key notions of formal syntax, such as intermediate traces, is directly reflected in processing/memory constraints at play in on-line language production.

Interference as a structure-dependent phenomenon

At the heart of much of the experimental work on agreement production is the phenomenon of interference observed in spontaneous speech and illustrated in example (2).

- (2) *The son-S of the *neighbors*-P always COME-P back late

In (2), a noun (called a local noun, attractor or intervener) situated in the vicinity of the subject–verb agreement relation imposes its number on the verb; the verb ‘come’ erroneously agrees with the local noun ‘neighbors’ (in the following examples, the target verb is in capital letters while the potentially interfering noun is in italics). Bock and Miller (1991) first showed that interference could be elicited experimentally by presenting speakers with complex sentential subjects, and asking them to complete the sentence under time pressure. By providing the first study of agreement in the laboratory, Bock and Miller's

work paved the way for an entire research program based on the influence of semantics and phonology on syntax (e.g., Bock & Eberhard, 1993; Eberhard et al., 2005; Vigliocco, Hartsuiker, Jarema & Kolk, 2001), but more crucially for us in this case, on the identification of structural factors at work in agreement (e.g., Bock & Cutting, 1992; Bock, Eberhard, & Cutting, 2004; Vigliocco & Nicol, 1998; see Franck et al. (2006) for a review).

One structural factor that was first shown to affect interference is the constituent structure of the sentence. Elements that are part of the same clause as the subject head noun were found to interfere more than elements that are separated from the head by, for example, a clausal boundary (Bock & Cutting, 1992; Nicol, 1995). Further research showed that the critical factor was actually the depth of the interfering element's embedding in the syntactic hierarchy; the deeper an element (whether in a prepositional phrase modifying the subject or in a subject relative clause), the less interfering it is (Franck, Vigliocco, & Nicol, 2002). In their study on object interference, Hartsuiker and colleagues submitted additional evidence for the role of the structural proximity of the interfering element on the subject head noun (Hartsuiker, Antón-Méndez, & Van Zee, 2001). Crucially, evidence was found that interference occurs on a hierarchical structure, and not on the surface linear word string.¹ Similar error rates were found in different surface structures (declarative and interrogative sentences with verb–subject inversion, Vigliocco & Nicol, 1998; for a parallel finding in sentence comprehension see Pearlmutter (2000)) and interference was found with the object in object relative clauses, even though the object is before the subject and the verb in the linear word string (Bock & Miller, 1991).

Most psycholinguistic models of agreement assume that syntactic encoding is hierarchical in nature. These include those postulating feature-based processes like the Marking and Morphing model (Eberhard et al., 2005) and the Feature Percolation model (Franck et al., 2002; Vigliocco & Nicol, 1998) as well as those postulating cue-based retrieval in memory like the Working Memory Retrieval model (Badecker & Kuminiaik, 2007; Badecker & Lewis, 2007). These models provide detailed accounts of the mechanism of interference in agreement. Feature-based models assume that interference is the result of the incorrect copy or percolation of features from a number-marked element that is situated in the syntactic vicinity of the agreement relation. Copy failures critically depend upon the position of the interfering element in the hierarchical structure. The assumed interference mechanism in the Working Memory Retrieval model of Badecker and colleagues is retrieval cue-overlap in a content-addressable memory. The distractors that interfere with subject retrieval are representational elements that share properties that are used to retrieve the subject (candidate properties are: “X is nominative”, “X belongs to category NP”, “X occupies specifier position of a tensed verb”). Although all these models assume that agreement and interference take place in a hierarchical structure, they

¹ See Haskell and MacDonald (2005) for objections to this position.

take a rather simplistic view of that structure. This is essentially because they were designed to account for empirical studies manipulating simple syntactic structures. The question therefore arises as to whether finer aspects of the hierarchical structure as proposed in formal syntax can help capture more specific aspects of language performance.

Agreement in linguistic theory

Let us first summarize the constructs in linguistic theory relevant to our research and refer the reader to our previous paper for a more detailed account of agreement realization (Franck et al., 2006). The Principles and Parameters framework and the Minimalist Program (Chomsky, 1995, and much related work) view the generation or ‘derivation’ of syntactic structures as a succession of formal operations: MERGE, AGREE, MOVE. MERGE strings elements together to form a minimal phrase. Successive applications of MERGE assemble the thematic nucleus of the sentence (the verb and its arguments). For example, in the initial stage of the derivation the subject is merged as the specifier of the lexical verb within the verb phrase (VP); the position in which it receives its thematic role (Koopman & Sportiche, 1991; Sportiche, 1988). Further applications of MERGE introduce the functional structure of the sentence, including the specification of agreement. This configurational skeleton can then be further modified by MOVE, the option of displacing elements having already been introduced in the structure. Several intermediate representations are postulated that are the result of the so-called ‘cyclic’ derivation of the structure, as elements are moved from one position to another. These intermediate representations have a tree-like format that specifies relationships between nodes. Each movement creates a new configuration until the final configuration is reached. Each node in the tree is always involved both in vertical, hierarchical relationships with the other nodes (dominance relationships), and in horizontal

relationships (precedence relationships). A particularly important hierarchical dependency, built on the most elementary dominance relation, is the relation of *c*-command. This structural relation, originally introduced by Reinhart (1976), is defined in (1) (Chomsky, 2000).

- (1) X *c*-commands Y iff Y is dominated by the sister node of X

A classical assumption is that subject–verb agreement involves a special syntactic node in the functional structure of the clause, AgrS, expressing agreement morphology (Chomsky, 1995, and references quoted there). The functional structure, including AgrS, is merged with the thematic structure, and the functional node AgrS enters into an AGREE relation with the subject, still situated in the VP (see Fig. 1). AGREE ensures that the person, number and case features of the subject are “copied” onto AgrS. AgrS, the probe of AGREE, looks for a goal with matching features within its local domain of *c*-command (Chomsky, 2000). Once AgrS is specified for these features, the Verb moves to AgrS to receive its morphological specification of number and person (at least in some languages, see Pollock, 1989), leaving a trace behind it (t_v in Fig. 1). In English and other languages with Subject–verb order, the subject then moves out of the VP into its canonical, pre-verbal subject position which is the specifier of AgrS. The object may also move from its canonical position, as is described in the next section.

The formal constructs of the derivation, AGREE, movement, and the precedence/*c*-command distinction turned out to be crucial in accounting for performance data in agreement production. Our previous work has addressed four major questions (Franck et al., 2006). First, what is the structural condition that creates interference? We showed that interference results from *intervention* in the hierarchical structure, a construct that has been the focus of considerable work in syntactic theory, in particular

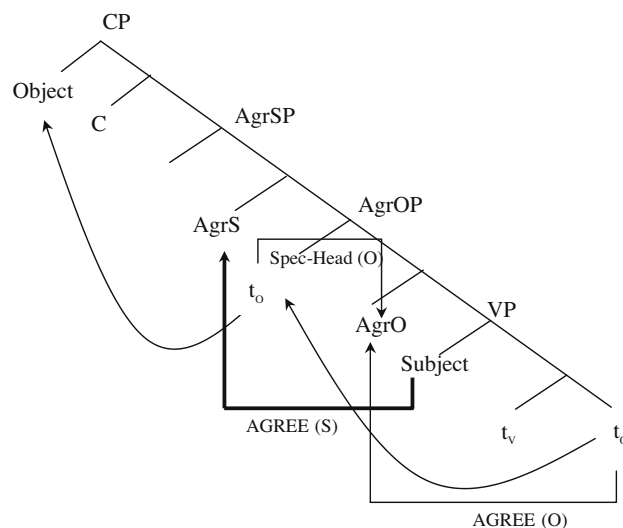


Fig. 1. Relevant aspects of the configuration of subject–verb agreement in a structure involving object movement to the left periphery. t_o refers to the trace of the displaced object and t_v refers to that of the displaced verb.

within the theory of locality. A core locality concept is that a local relation between two elements fails when a third element bearing some structural similarity to one of the related elements intervenes between them (e.g. Relativized Minimality, Rizzi, 1990). We can say that an element X intervenes between the subject and the verb when configuration (3) holds, where “>” is some relevant structural relation.

(3) Subject > X > Verb

Our work has shown that in the absence of intervention in this sense, no interference occurs (for instance, no interference was found with the subject modifier in the declarative VS structure in Italian, although significant interference had been found in the superficially identical interrogative VS structure in English by Vigliocco and Nicol (1998), see Franck et al. for discussion).

Secondly, we asked which structural relations of intervention trigger interference, and how. We already know from previous work that a *precedence* configuration of intervention (hence, with “>” meaning linear precedence) which characterizes prepositional phrase subject modifiers, creates interference. Our own results showed that an element intervening in terms of *c-command* (like a clitic pre-verbal object pronoun) generates significantly more interference than intervention in terms of precedence (see also Fayol, Largy, and Lemaire (1994) for a similar finding with clitics in written production in French). We will come back to the role of *c-command* in interference in the discussion of Experiment 3.

Thirdly, we addressed the question of whether VS constructions are more sensitive to interference than SV configurations. Guasti and Rizzi (2002) observed that, across languages, the morphological manifestation of agreement tends to be more stable when AGREE is associated with the movement of the subject into the specifier of AgrS (i.e., when the subject moves before the verb). For example, Standard Arabic shows agreement in person and number only in SV sentences, not in VS sentences. Similarly, we found interference both in OVS and OSV sentences, but it was significantly stronger in the OVS case. On the basis of this finding and of the cross-linguistic observation by Guasti and Rizzi, we suggested that agreement is more stable in SV structures because *features are checked twice*: (1) through AGREE, following the assumptions of Chomsky (1995), and (2) in the strictly local Spec-Head configuration, after the subject has moved.

Finally, we examined whether intermediate traces of movement intervening on the agreement relation trigger interference. Our preliminary observations suggested so; indeed, we reported interference in object cleft structures, either with object–subject–verb order (e.g., *C'est les boxeurs que l'adolescente séduisent; *It is the boxers-P that the adolescent-S seduce-P) or with Object–Verb–subject order involving stylistic inversion (e.g., *C'est les boxeurs que séduisent l'adolescente; *It is the boxers-P that seduce-P the adolescent-S). These observations were actually in line with those of Bock and Miller (1991) in English. Although their study was conducted in a different theoretical context, the authors reported significant interference

with the object in object relative clauses (e.g., The songs-P that the composer-S Verb-P). Interference in such structures cannot be accounted for by the linear intervention of the object on the subject–verb relation, since the object does not intervene in the surface string in OSV nor in OVS configurations. Hence, intervention appears to occur elsewhere in the derivation process. Since this is the target question of the present study, the next section outlines how formal syntax conceptualizes object movement and the empirical questions that this raises.

Object movement: theoretical assumptions and empirical challenges

Current syntactic analyses of object movement to the left periphery of the clause postulate a stepwise movement, with an intermediate step to the immediate periphery of the VP. In the classical analysis of Kayne (1989),² the object moves to the specifier (Spec) of a dedicated object agreement layer (AgrO), where gender and number participial agreement is triggered, and then continues onto the complementizer system. The motivation for this hypothesis was the observation that in French, the past participle has to agree with the object when the object has moved to a pre-verbal position but not when the object remains in its post-verbal position, in which case the past participle takes the default masculine, singular form (5) (note that the auxiliary verb always agrees in number with the subject).

- (4) Les maisons que le typhon a détruites (...)
The houses-F,P that the typhoon has-S destroyed-F,P
(5) La pluie a détruit les maisons.
The rain-F,S has-S destroyed-M,S the houses-F,P

This intermediate Spec of AgrO position where the object is assumed to pass on its way to the front of the sentence is not pronounced, but crucially, it intervenes in the AGREE relation between the verb (in AgrS) and the subject (in its base position) by *c-commanding* the latter (see Fig. 1). Hence, the interference effect we observed in OSV and OVS object cleft sentences (Franck et al., 2006) in which the object does not intervene on the surface relation between the subject and the verb finds a natural interpretation as an effect of the intervention of this Spec AgrO position in the AGREE relation. Under this hypothesis, it is Spec AgrO, i.e., the intermediate trace of the displaced object, that creates interference.

It is interesting to note that the assumption of intermediate traces of object movement is also supported by a number of linguistic facts described in syntactic theory. Many languages display clear manifestations of such intermediate steps in object movement, ranging from morpho-syntactic manifestations (e.g., wh-agreement with the moved object in Austronesian; Chung, 1998, and complementizer agreement in Celtic; McCloskey, 2002), to interpretive properties (“reconstruction sites” in the positions of intermediate traces; Legate, 2003), and to the fact that

² This analysis was later extended and also generalized to clauses not involving participial forms in Chomsky (1995, 2001).

in some languages intermediate traces are even pronounced in some positions (languages with overt wh-copies; Felser, 2004).

Psycholinguistic research also provides experimental evidence supporting the role of traces and intermediate traces in sentence comprehension. The hypothesis that base traces play a role in language processing was supported by a number of studies showing that the semantic properties of a moved element are reactivated at the position of its base trace in sentence comprehension (e.g., Nicol & Swinney, 1989; Stowe, 1986; Tanenhaus, Boland, Garnsey, & Carlson, 1989; Zurif, Swinney, Prather, Solomon, & Bushell, 1993), or that function word reduction is blocked following a gap in language production (Ferreira, 1988; Ferreira & Engelhardt, 2006). Evidence for a specific brain locus of traces has also been proposed (e.g., Ben Schachar, Hender, Kahn, Ben Bashat, & Grodzinsky, 2003; Fiebach, Schlesewsky, & Friederici, 2002; Grodzinsky, 2000; Kaan, Harris, Gibson, & Holcomb, 2000, but see e.g., Pickering and Barry (1991), for a trace-less account). However, these studies manipulated traces of thematic positions of moved elements, not intermediate traces, as we suggest here, which only play a role within syntax. To our knowledge, the only piece of evidence for the role of intermediate traces in language comprehension is that recently provided by Gibson and Warren (2004). The authors reported shorter reading times at the verb when the moved NP could transit via an intermediate position left empty (e.g., The manager who_i the consultant claimed that the new proposal had pleased t_i will hire five workers tomorrow) than when it could not because of the nature of the structural representation (e.g., The manager who_i the consultant's claim about the new proposal had pleased t_i will hire five workers tomorrow).

Hence, although intermediate traces are formal devices initially postulated to account for off-line, linguistic phenomena bearing on grammaticality constraints across languages, psycholinguistic research recently started to show that such traces are also relevant in on-line performance. Gibson and Warren (2004) suggested that intermediate structures facilitate processing by reducing the distance of integration between a moved element and its integration site. That is, locality in formal syntax reflects processing constraints by which elements are regularly reactivated in precise positions within the syntactic structure. Intermediate traces would play the role of memory buffers through which elements transit in order to remain active and available for further processes. The present study aims to provide a systematic investigation of the hypothesized role of the intermediate trace of the displaced object in interference during production.

Experimental investigation

The work presented here extends our preliminary observation that moved objects trigger interference. If this observation holds systematically in different test cases involving object movement, and if alternative interpretations can be discarded, this would provide experimental support for the relevance of intermediate traces of movement in on-line

production performance. The finding that intermediate traces influence such performance is critical since it answers the concern expressed by a number of authors that experimental evidence for thematic traces reflects semantic rather than syntactic processes. Whereas thematic traces do indeed have a semantic role, this is not the case for intermediate traces which are syntactic in nature.

A series of five experiments in French is reported, aimed at determining the factors at play in object interference. We first establish, in a minimal contrast between relative clauses and sentential complements, that interference arises with the object moved out of the relative clause but not with the minimally different complement clause in which no movement took place, even though the two structures are similar in the sequence of pronounced elements (Experiment 1). We then report four experiments that test whether the interference effect found with the moved object can be explained without assuming a critical role for the intermediate trace. The role of two alternative factors is examined:

- (1) *Argument structure*: the object of the relative clause is part of the argument structure of the target verb; hence, one could hypothesize that any element from the argument structure of the verb can interfere with agreement. The role of argument structure is examined in Experiments 2 and 5.
- (2) *Participial agreement*: the object of the relative clause triggers participial agreement; hence, one could hypothesize that any element involved in an agreement relation can interfere with subject–verb agreement. The role of participial agreement is examined in Experiments 3 and 4.

Experiment 1: object interference in relative clauses

Experiment 1 aims to replicate the object interference effect found in object clefts (Franck et al., 2006). It uses a minimal contrast between object movement as in relative clauses (6), and no object movement as in complement clauses (7). The two structures are identical in surface order; the main difference lies in the selection of the main verb which takes a single complement in (6) and two complements in (7).

- (6) Jean parle aux *patientes* que le médicament GUERIT
John speaks to the *patients* that the medicine CURES
- (7) Jean dit aux *patientes* que le médicament GUERIT
John says to the *patients* that the medicine CURES

Subject–verb interference is examined on agreement of the verb in the subordinate clause (to cure). In the relative clause, 'patients' is the object of the target verb, and can therefore be assumed to transit via the intermediate position AgrO intervening on AGREE (Kayne, 1989). In the complement clause, 'patients' is the unmoved object of the main verb and the embedded verb 'cure' is used intransitively. If, as we suggested in our previous study, the intermediate trace of the displaced object is responsible for the interference observed in the cleft construction, interference is also

expected to occur here in the relative construction, but no interference should occur in the complement clause in which the object does not move and therefore does not intervene on AGREE.

Method

Participants. Thirty-six students of the University of Geneva took part in the Experiment. All were native French speakers aged between 18 and 35. They received credits for their participation.

Materials. Twenty-four sentence preambles were built crossing two experimental variables: (1) Structure (Complement clause vs. Relative clause) and (2) Number (Match vs. Mismatch). Only the number feature of the potentially interfering noun was manipulated (Singular vs. Plural); subject head nouns were always singular. Plural head nouns were not introduced in the experiment to limit experimental conditions to 4 and because singular head nouns are known to trigger the clearest interference effects (e.g., Eberhard et al., 2005). Hence, each of the 24 items existed in four different versions: complement clause SS, complement clause SP, relative clause SS, relative clause SP. The same verbs were used intransitively in the complement clause condition and transitively in the relative clause condition. Each preamble was associated with an infinitival verb. Examples of sentence preambles in the different experimental conditions are provided in Table 1 and a full list of the items is in Appendix 1. In the examples given in the relative clause condition of Table 1, correct agreement amounts to producing the following sentence *Jeff a parlé aux prisonnières que le gardien sort* while incorrect agreement amounts to producing *Jeff a parlé aux prisonnières que le gardien sortent*.

A total of 72 filler items was built, mostly in order to balance the number of plural and singular verbs produced in the experiment; this precaution was necessary since all experimental items contained singular head nouns. Of the 72 fillers, 48 contained plural heads and 24 contained singular ones, such that of the total of 96 verbs produced by each participant (24 experimental + 72 fillers), half were singular and half plural.

The 72 fillers consisted of 4 sets of 14 sentences with different structures (complement clause, relative clause, clitic object and post-verbal object) plus 16 sentences with subject modifiers. Number on the head noun and on the

interfering noun was equally balanced across these five structures.

Items were divided into 4 between-participants lists of 96 items such that each participant only saw one version of each experimental item. Each list contained 6 experimental items per experimental condition.

Procedure. A variant of the sentence completion technique was used in which the preamble is preceded by the target verb in the infinitival form. Participants have to memorize the verb and the preamble, and then produce a full sentence combining the preamble and the verb as soon as the preamble has disappeared from the screen (note that the infinitival form of the verb corresponds neither to the singular nor to the plural verb form in French).

Participants were tested individually. Materials were presented on a computer screen using the E-prime experimental software for Windows. Each preamble was presented for 3000 ms followed by a verb in the infinitive form for 800 ms, with a blank screen of 500 ms in between the two. The experimenter controlled the appearance of the preamble on the screen as soon as the participant had finished completing the previous one. Each session started with an example and 10 warm-up trials. Instructions insisted on the importance of articulation speed. Answers were recorded on a minidisc.

Scoring. Participants' responses were scored into one of three scoring categories. Correct responses were scored when the preamble was correctly repeated and the verb correctly inflected. Agreement errors were scored when the sentence produced met all the above criteria for correct responses but the verb failed to agree in number with the subject of the sentence. Miscellaneous responses were scored when incorrect words were produced, the sentence was interrupted, a pronoun was added, or when no response was provided.

Design and data analysis. Analyses of variance with both participants and items as random factors were carried out using as dependent measure the arcsine transformation of the proportion of agreement errors and miscellaneous responses (given the Bernoulli distribution of the data, data were first drifted to 0 by applying a 2×-1 transformation before applying the arcsine transform). All

Table 1
Examples of items in the different experimental conditions of Experiment 1.

Type of structure	Number	Preamble	Verb
Complement clause	Match	Jeff a signalé à la prisonnière que le gardien Jeff has told the prisoner that the guard	SORTIR TO GO OUT
	Mismatch	Jeff a signalé aux prisonnières que le gardien Jeff has told the prisoners that the guard	SORTIR TO GO OUT
Relative clause	Match	Jeff a parlé à la prisonnière que le gardien Jeff has talked to the prisoner that the guard	SORTIR TO GO OUT
	Mismatch	Jeff a parlé aux prisonnières que le gardien Jeff has talked to the prisoners that the guard	SORTIR TO GO OUT

Note: Match indicates that both the head noun and the intervener were singular; Mismatch indicates that the head noun was singular and the intervener was plural.

variables manipulated were part of a within-participant, within-item design.

Results

A total of 864 sentence preambles were produced: 37 (4.3%) contained an agreement error and 74 (8.6%) contained a miscellaneous response. The distribution of errors in the different experimental conditions is presented in Table 2.

Agreement errors. The analysis of variance indicates a main effect of structure with more errors in the relative clause condition than in the complement clause condition ($F(1,135) = 20.6, p < .001$; $F(1,123) = 16.3, p < .001$) and a main effect of number attesting a higher error rate in the condition of number mismatch (SP) than in the condition of number match (SS) ($F(1,135) = 20.1, p < .001$; $F(1,123) = 14.0, p < .005$). The two variables interact significantly ($F(1,135) = 5.6, p < .05$; $F(1,123) = 3.9, p = .05$), indicating that the effect of number mismatch is significantly stronger in the relative clause than in the complement clause condition.

Miscellaneous responses. Miscellaneous responses were not significantly more frequent in the relative clause than in the complement clause condition (43 vs. 31 errors; $F(1,135) = 1.9, p = .2$; $F(1,123) = 2.6, p = .1$). Number mismatch did not generate significantly more errors (35) than number match (39) ($F_s < 1$) and there was no interaction between structure and number match ($F_s < 1$).

Discussion

Interference was significantly stronger in relative clauses than in complement clauses, in spite of the two structures being identical in surface order. We suggested that the displaced object, which transits via an intermediate position (AgrO) intervening on AGREE, has the potential to trigger interference like an element overtly intervening in its surface position (Franck et al., 2006). The object relative clause differs from the complement clause in that it exhibits such an intermediate position, while the complement clause does not given that it does not involve any movement of the object. Hence, the results support our hypothesis that object movement is a critical factor in object interference.

However, the two structures also differ in another respect. Although the potentially interfering element is the object of the target verb in the relative clause, it is not in the complement clause (in which it is the object of the main verb). Hence, one could hypothesize that the interference observed in relative clauses did not arise because of

object movement but simply because the object was part of the argument structure of the target verb.

Experiment 2: is argumenthood a sufficient condition for object interference?

Experiment 2 tests the possibility that interference occurs between elements of the same argument structure, without the involvement of theoretical constructs like intervention, object movement and intermediate traces. We examined whether unmoved, post-verbal objects (8) that do not intervene on the subject–verb agreement relation at any point in the derivation, trigger interference. This structure with the object in situ was contrasted to a construction in which the object has moved pre-verbally (9). This construction, in which the object is cliticized, was selected because it is syntactically simpler than the object relative and therefore provides a more minimal condition to compare the object in situ with.

- (8) Le sénateur RECOIT les députés
The senator RECEIVES the deputies
- (9) Le sénateur les RECOIT
The senator them RECEIVES (The senator RECEIVES them)

If being part of the argument structure is a sufficient condition for the object to interfere, interference is expected with the post-verbal object in situ, like what was previously reported with the pre-verbal clitic object (Fayol et al., 1994; Franck et al., 2006).

Method

Participants. Thirty-six students of the University of Geneva took part in the Experiment. All were native French speakers aged between 18 and 35 and had participated to Experiment 1. They received credits for their participation.

Materials. Experimental items consisted of the 32 sentence preambles used in the clitic condition of Experiment 3 reported in our previous study (Franck et al., 2006). To form the preambles for the condition with the object in situ, clitic pronouns were replaced by a full object noun phrase situated in post-verbal position. Two variables were manipulated: (1) Structure (Object in situ vs. Clitic object) and (2) Number (Match vs. Mismatch). Number was only manipulated on the interfering element; all subject head nouns were singular. Hence, each item appeared in four different versions: object in situ SS, object in situ SP, clitic object SS, clitic object SP. Each preamble was associated with an infinitive verb. In the object in situ condition, the expected position of the verb in the preamble was indicated by an underscore. Examples of sentence preambles in the different experimental conditions are provided in Table 3 and the list of items is in Appendix 2.

A total of 72 filler items were built, mostly in order to balance the number of plural and singular verbs produced in the experiment. Of the 72 fillers, 48 contained plural heads and 24 contained singular ones, such that of the total of 104 verbs produced by each participant, half were

Table 2

Mean percentages (Standard Deviations in parentheses) of agreement errors in the four experimental conditions of Experiment 1, calculated over the total number of responses.

	Agreement errors		
	Complement clause	Relative clause	Total
Match	.5 (.07)	2.8 (.16)	1.6 (.13)
Mismatch	2.8 (.16)	11.1 (.31)	6.9 (.25)
Total	1.6 (.13)	6.9 (.25)	4.3 (.20)

Table 3
Examples of items in the different experimental conditions of Experiment 2.

Type of structure	Number	Preamble	Verb
Object in situ	Match	La vache_le chien	SUIVRE
		The cow_the dog	TO FOLLOW
	Mismatch	La vache_les chiens	SUIVRE
		The cow_the dogs	TO FOLLOW
Clitic object	Match	La vache_le	SUIVRE
		The cow it	TO FOLLOW
	Mismatch	La vache les	SUIVRE
		The cow them	TO FOLLOW

singular and half plural. Five different structures were used (complement clause, relative clause, clitic object, post-verbal object, subject modifiers). Number on the head noun and interfering noun was equally balanced across these five structures.

Each list contained eight experimental items per experimental condition.

Procedure, scoring and data analysis. Identical to Experiment 1.

Results

A total of 1152 sentences were produced: 32 (2.8%) contained an agreement error and 32 (2.8%) contained a miscellaneous response. The distribution of errors in the different experimental conditions is presented in Table 4.

Agreement errors. The ANOVA conducted on the data indicate a significant effect of structure with more agreement errors in the clitic condition than in the condition with the object in situ ($F(1,135) = 15.4, p < .001$; $F(1,131) = 10.1, p < .005$). A significant effect of number was also found ($F(1,135) = 25.7, p < .001$; $F(1,131) = 22.7, p < .001$), showing a higher error rate in the number mismatch (SP) condition than in the condition of number match (SS). Finally, a significant interaction between the two variables indicates that the effect of number is stronger in the clitic condition than in the condition with the object in situ ($F(1,135) = 14.9, p < .05$; $F(1,131) = 10.8, p < .01$).

Miscellaneous responses. There were not significantly more miscellaneous responses in the clitic condition (19 errors) than in the full object condition (13 errors) ($F(1,135) = 1.4, p = .3$; $F(1,131) = 1.4, p = .2$). Number mismatch did not generate more errors (15) than number match (17) and there was no interaction between structure and number match ($F_s < 1$).

Table 4
Mean percentages (Standard Deviations in parentheses) of agreement errors in the four experimental conditions of Experiment 2, calculated over the total number of responses.

	Agreement errors		
	Object in situ	Clitic object	Total
Match	.4 (.05)	.7 (.08)	.5 (.07)
Mismatch	1.4 (.12)	8.7 (.28)	5.0 (.21)
Total	.9 (.09)	4.7 (.21)	2.8 (.16)

Discussion

The object did not interfere with subject–verb agreement when situated in its canonical post-verbal position; the low error rate is similar to that observed in complement clauses in Experiment 1. In contrast, the clitic object generated significant interference, similar to that observed in the relative clause condition of Experiment 1. Hence, the data show that being part of the argument structure is not a sufficient condition for object interference. Whereas the object does not move and therefore fails to intervene on the agreement relation in both the object in situ and the complement clause, the object is assumed to intervene on AGREE when situated in its intermediate position AgrO, after leaving its initial, thematic position. Hence, structural intervention resulting from object movement appears to be a necessary condition for interference. This does not mean that being part of the argument structure plays no role. It may not be a sufficient condition while still being a necessary condition; Experiment 5 tests this possibility.

Now that we have established that objects interfere with agreement only when they move from the thematic position, the question arises whether interference is due to object movement and its intervening trace on AGREE, or to the fact that the pre-verbal object triggers participial agreement. As mentioned in the section on agreement in linguistic theory, the moved pre-verbal direct object triggers agreement on the past participle in French, so the intermediate position through which it passes is an agreement position (AgrO; Kayne, 1989). Hence, the moved object differs from the object in situ in two respects: it undergoes movement and it triggers participial agreement. One could therefore hypothesize that the critical factor in object interference is not the intervention of the trace of the moved object, but the fact that an intervening agreement position, AgrO, is activated. If the latter case turns out to be correct, one would expect that interference occurs as the result of some more general attentional bias due to the fact that the language processor, in order to compute participle agreement, has to keep the object's feature activated when it is in pre-verbal position. In order to test this possibility, Experiment 3 examined interference in a structural configuration in which a moved object never triggers participle agreement.

Experiment 3: is AgrO a necessary condition for object interference?

Experiment 3 tests whether interference is found for any intermediate trace of a displaced object or only for traces in a position that triggers agreement. In French, the indirect object (dative) can also move and intervene on AGREE but without triggering participial agreement, that is, the past participle takes the default masculine, singular form independently of the number and gender features of the dative clitic (e.g., Les filles à qui elle a écrit, The girls-F,P to whom she-F,S has-S written-M,S). Under the current assumptions on locality (e.g., phase theory (Chomsky, 2001), but also the theory of barriers, etc.), the indirect object is assumed to transit via an intermediate position at the immediate periphery of the VP (more precisely, via the Spec of the vP in Chomsky, op. cit.), a

position distinct from AgrO. This experiment compares interference with dative clitics (11) to interference with accusative clitics (10). An additional condition involving a prepositional phrase subject modifier was introduced for the sake of comparison since, as will be argued in the Discussion, modifiers share structural similarities with dative clitics that were interesting to explore (12).

- (10) Le costume *les* A TRANSFORMES
The costume *them* HAS TRANSFORMED (The costume has transformed them)
- (11) Le costume *leur* A PLU
The costume *to them* HAS PLEASED (The costume has pleased them)
- (12) Le costume des *danseuses* A CHANGE
The costume of the *dancers* HAS CHANGED

Under the strong hypothesis that interference from the moved object (whether a full NP, as in relative clauses and object clefts, or a clitic) is entirely due to participial agreement, i.e., that AgrO is a necessary condition, dative clitics should not trigger interference.³

Method

Participants. Fifty two students from the University of Geneva aged between 20 and 40 participated to the experiment. They were all native French speakers and received credits for participating.

Materials. Forty-eight experimental sentence preambles were divided into six conditions crossing two experimental variables: (1) Structure (Dative vs. Accusative vs. Modifier) and (2) Number (Match vs. Mismatch). All head nouns were singular; only the number of the interfering element was manipulated. Each item appeared in six different versions: Dative SS, Dative SP, Accusative SS, Accusative SP, Modifier SS, Modifier SP. In contrast to Experiments 1 and 2, no verb was associated to the preambles. Examples of sentence preambles in the different experimental conditions are provided in Table 5 and the full list is in Appendix 3.

Forty filler items were built that involved sentences with the same three experimental structures but with plural head nouns. Half had singular interfering elements; the other half had plural ones. Six experimental lists were created such that each variant of an experimental item only appeared once. Each list contained eight experimental items per experimental condition.

Procedure. A slightly modified version of the procedure in previous experiments was used in that no verb was presented here. Participants were asked to produce past participles with the auxiliary 'avoir' (to have). The use of the auxiliary was imposed in order to ensure that number was audible on the verb. Participants were given with example items so that they were familiarized with the cli-

tic use of the forms *le/les* and *lui/leur* (since *le*, *les* and *leur* are homonymous with determiners).

Scoring and data analysis. Identical to Experiment 1.

Results

A total of 2496 observations were collected. Amongst them, 105 (4.2%) agreement errors were produced as well as 130 (5.2%) miscellaneous responses. The distribution of agreement errors is presented in Table 6.

Agreement errors. The analysis of variance shows an overall effect of structure ($F(2,51) = 9.9$, $p < .001$; $F(2,46) = 2.9$, $p < .05$), a significant effect of number with more errors in the condition of number mismatch ($F(1,51) = 59.2$, $p < .001$; $F(2,147) = 73.5$, $p < .001$) and, crucially, a significant interaction between structure and number ($F(2,51) = 3.9$, $p < .05$; $F(2,46) = 8.2$, $p < .001$) attesting to different interference effects across structures. Paired *t*-tests comparing interference across structures two by two show that the indirect clitic patterns like the modifier ($t(51) = -0.9$, $p = .34$), while the direct object clitic generates significantly more interference than the indirect clitic ($t(51) = 2.3$, $p < .05$) and the modifier ($t(51) = 2.0$, $p < .05$).

Miscellaneous responses. Analyses revealed a significant effect of structure ($F(2,51) = 9.3$, $p < .005$; $F(2,47) = 7.3$, $p < .01$). Paired *t*-tests confirmed that participants produced fewer errors in the dative condition (25 errors) than in the accusative (46 errors) and modifier (59 errors) conditions (respectively $t(51) = 2.6$, $p = .01$ and $t(51) = -3.7$, $p < .001$). The latter two conditions did not differ from one another. However, and critically, no effect of number was found ($F_s < 1$), and there was no interaction between structure and number ($F(2,51) = 1.7$, $p = .2$; $F(2,47) = 2.6$, $p = .08$).

Discussion

In contrast to the results expected if AgrO were a necessary condition for interference, dative clitics were found to interfere significantly with agreement in French. Interestingly, datives appear to interfere similarly to subject modifiers, both interfering significantly less than accusative clitics. The smaller interference effect with modifiers than with accusative clitics is in line with previous reports (Franck et al., 2006). But why do datives behave like modifiers? We see two possible explanatory hypotheses for this difference. The first, most obvious hypothesis, is that even if non-agreeing positions intervening on AGREE have the potential to trigger interference, this potential is reduced in comparison to AgrO. That is, filling an agreement position (AgrO) would not be a necessary condition but would nevertheless contribute to increase the risk that interference occurs.

The second hypothesis appeals to the linguistic analysis of object movement and the structural configuration of intervention on AGREE. The reasoning involves three successive steps which we summarize here before describing them in more details: (1) the critical intervention responsible for interference is the intermediate trace intervening on AGREE, not that of the clitic in its final position intervening on Spec-Head; (2) the intermediate trace is assumed to be the full object noun phrase, not yet

³ Object clitics intervene at the level of AGREE, when in their intermediate position, but also at the level of Spec-Head, when in their final position. Arguments are presented in the Discussion that suggest that interference is entirely due to the intervention on AGREE; so we will assume that in the present reasoning.

Table 5
Examples of items in the different experimental conditions of Experiment 3.

Type of structure	Number	Preamble
Accusative clitic	Match	L'avocat le The lawyer him
	Mismatch	L'avocat les The lawyer them
Dative clitic	Match	L'avocat lui The lawyer to him
	Mismatch	L'avocat leur The lawyer to them
Modifier	Match	L'avocat de l'immigré The lawyer of the immigrant
	Mismatch	L'avocat des immigrants The lawyer of the immigrants

Table 6
Mean percentages (Standard Deviations in parentheses) of agreement errors in the six experimental conditions of Experiment 3, calculated over the total number of responses.

	Agreement errors			
	Accusative clitic	Dative clitic	Modifier	Total
Match	1.2 (.11)	0 (0)	.7 (.08)	.6 (.08)
Mismatch	11.3 (.32)	5.0 (.22)	7.0 (.25)	7.8 (.27)
Total	6.3 (.24)	2.5 (.16)	3.9 (.19)	4.2 (.20)

cliticized; (3) the preposition introducing the indirect object raises with the NP, so that the intermediate trace of the indirect object is a PP (Preposition + NP) which intervenes in terms of precedence on agreement (on AGREE), exactly like the prepositional phrase modifier. In contrast, the displaced direct object NP intervenes in terms of c-command on agreement, a configuration which has previously been shown to create stronger interference than precedence. The three steps are now described in details.

The first step in the demonstration consists in showing that interference arises from the intervention on AGREE of the intermediate trace of the moved object and not from the intervention on Spec-Head of the clitic itself. Moved object clitics indeed intervene on subject–verb agreement at two moments in the derivation: on AGREE, when in their intermediate position, and on Spec-Head, when in their final position. Which of these two intervention configurations is responsible for the interference observed? Evidence for the critical role of the intervention on AGREE comes from the repeated finding, in our previous data as well as in the current data, that object clitics do not trigger more interference than full object NPs moved pre-verbally (in relative clauses or in object cleft structures). Similarly, in Dutch no difference was found between interference with pronominal and phrasal objects (Hartsuiker et al., 2001). That is, the clitic, which intervenes twice on the agreement relation (on AGREE and on Spec-Head) does not cause stronger interference than the moved object NP which only intervenes on AGREE (since, when it ends up in its surface position, it is higher up than the subject in the hierarchy). Hence, clitic intervention on Spec-Head does not appear to create any additional interference effect.

But intervention in a Spec-Head configuration does trigger interference, as shown by the well attested report of interference with prepositional phrase subject modifiers

(which only intervene on Spec-Head, and not on AGREE). So why do clitics fail to interfere at that level as well? Clitics differ from prepositional phrase modifiers in that they are not full phrasal NPs but just nominal heads, hence they are not elements of the same structural kind (phrasal) as the target of agreement, the subject NP. The possibility that clitics per se do not interfere with agreement is actually in line with the principle of Relativized Minimality (Rizzi, 1990) according to which only elements of the same structural type get involved in interference effects. That is, only NP elements of the same type as the NP subject would trigger interference (see the literature on NP-type effects for similar observations as to the role of similarity in interference in sentence comprehension, e.g., Gordon, Hendrick, & Johnson, 2001; Warren & Gibson, 2005).

The second step in our argument consists in showing that the displaced object, when intervening on AGREE, is still a phrasal entity. Straightforward support comes from the phenomena of quantifier floating (Sportiche, 1988). Take sentence (13) with the direct object in situ and sentences (14) and (15) in which the direct object has been cliticized.

- (13) J'ai rencontré **tous les acteurs**
I have met all the actors
(14) Je **les** ai rencontrés **tous**
I **them** have met **all**
(15) Je **les** ai **tous** rencontrés
I **them** have **all** met

What appears is that while the object moves, the quantifier 'tous' is stranded either in the initial position of the object (14) or, critically, in the intermediate position AgrO (15). This suggests that the object has moved as a full NP including the quantifier to the Spec of AgrO; from this intermediate position, the head of the NP, the clitic, undergoes a final movement step, head movement in this case, which cliticizes it to the inflected verb (on this mixed two-step movement derivation for clitics, first as phrasal movement and then as head movement, see Belletti, 1999).

Finally, what remains to be shown to account for the observation that datives interfere like modifiers but less than accusatives, is that datives intervene under a similar configuration to that of modifiers, but different from accusatives. The indirect object contrasts with the direct object in that it is introduced by a preposition when in its canonical position (16). This preposition is absent in the final, clitic position (17).

- (16) J'ai parlé **aux acteurs**
I have talked **to the actors**
(17) Je **leur** ai parlé
I (to) **them** have talked

What about the intermediate position: is the preposition still there? In the presence of a floating quantifier (18), the preposition is stranded with the quantifier, either in the base, post-verbal position (19) or in the intermediate position (20) (Sportiche, 1988).

- (18) J'ai parlé à tous les acteurs
I have talked to all the actors

- (19) Je **leur** ai parlé **à tous**
I **them** have talked **to all**
- (20) Je **leur** ai **à tous** parlé
I **them** have **to all** talked

Hence, these data suggest that the indirect object is still introduced by the preposition in its intermediate position: in fact, the preposition is spelled out when the quantifier is stranded as in (20). If this is correct, the structure of (20) is (21).

- (21) Je leur ai [à [tous < NP>]] parlé < à tous NP>(<> represents traces)

This preposition creates an additional layer in the hierarchy so that the indirect object NP, being embedded within a PP, intervenes on AGREE in terms of precedence and not in terms of c-command. The finding that datives behave like prepositional phrase modifiers in agreement performance finds a natural explanation in this framework: they both intervene in terms of precedence on AGREE, in contrast to accusatives which intervene in terms of c-command, a difference which has already been found to play a critical role in interference (Franck et al., 2006).

We thus have two hypotheses with respect to the enhanced intervention effect with the direct object: (1) it is due to the AgrO layer and (2) it is due to intervention in terms of command rather than precedence. Experiment 4 provides a test case that teases apart these two hypotheses.

Experiment 4: does AgrO play any role in interference?

The structures contrasted in the two conditions of Experiment 3 diverge in (at least) two respects: accusatives trigger participial agreement whereas datives do not, and accusatives intervene in terms of c-command on AGREE, whereas datives intervene in terms of precedence (under the assumptions we have made). Hence, the higher interference rate found with accusative clitics can be accounted for by at least two hypotheses. The first hypothesis is that although AgrO is not a necessary condition to interference, it would nevertheless contribute to enhance the effect. Under the second hypothesis, the critical factor at play is configurational: the dative is still phrasal at the level of its intervention on AGREE, and it is still introduced by the preposition which reduces its interference effect by creating a precedence configuration of intervention rather than the c-command configuration characterizing accusatives.

In order to tease apart these two hypotheses, we contrasted direct objects that trigger object agreement (22) to direct objects that do not trigger object agreement (i.e., not involving AgrO) (23). The test case involving direct objects that do not trigger participial agreement is provided by causative structures: the lack of AgrO in causatives is manifest in sentences involving past participles (23) in which the participle takes the default masculine, singular form, which contrasts to the feminine, plural form agreeing with the object in the accusative structure (22) (see Kayne (1989) for an analysis of the incompatibility of the causative 'faire' with agreement).

- (22) Les fautes, le professeur les a faites souvent
The mistakes-F,P, the teacher them has made-F,P often (the teacher has often made them)
- (23) Les filles, le professeur les a fait partir
The girls, the teacher them has made-M,S go (the teacher has made them go)

In the present experiment, agreement was tested on the main verb in sentences like (24) and (25). Hence, the two test conditions involve NPs that are not introduced by a preposition (in contrast to the dative construction in Experiment 3), and the only factor manipulated is whether the intermediate position is an agreement node (AgrO) or not.

- (24) Le professeur *les* FAIT souvent
The teacher *them* MAKES often (the teacher often makes them)
- (25) Le professeur *les* FAIT partir
The teacher *them* MAKES go (the teacher makes them go)

In contrast to datives, the intervening object in causatives is not introduced by a preposition and therefore intervenes in terms of c-command in AGREE, like the object in the accusative structure. Hence, if AgrO is the reason why accusatives interfered more than datives in Experiment 3 (first hypothesis), more interference is expected in the accusative than in the causative condition since AgrO only intervenes in the former.⁴ If the reason why accusatives trigger more interference than datives is the existence of an additional prepositional layer in datives (second hypothesis), similar interference is expected in accusative and causative structures since neither is introduced by a preposition and therefore both involve c-command intervention on AGREE.

Method

Participants. Fifty students from the University of Geneva aged between 20 and 40 participated to the experiment. They were all native French speakers and received credits for participating.

Materials. Experimental materials consisted of 32 sentence preambles in which two variables were crossed: (1) Structure (Causative vs. Accusative) and (2) Number (Match vs. Mismatch). Number was only manipulated on the clitic; all subject head nouns were singular. Only animate head nouns were used. Each preamble was accompanied by a verb, which was always 'faire' (to make) in the experimental items. The causative construction, being a subordinate structure, takes the infinitive verb as a complement of the main verb. In order to have the verb followed by a word in the accusative condition as well, an adverb was included in the preamble. Like in the post-verbal object condition of

⁴ We are assuming here that an AgrO node is present irrespective of the morphological realization of agreement on the past participle (Chomsky, 1995). The reason for this is that in the theoretical framework adopted to account for the data presented, all case features (accusative here) must be checked for the semantic interpretation to hold. Since accusative case is assumed to be checked at the level of AgrO, AgrO must be active even in structures with simple verbal forms, as were used in Experiment 4.

Experiment 2, the position of the verb within the sentence was indicated in the preamble by an underscore. Examples of experimental items are provided in Table 7 and the list of items is in Appendix 4.

A series of 128 filler items were built: (a) 32 were identical to the experimental items except that they had plural subject heads (with either matching or mismatching clitics), in order to counterbalance the singular head experimental items; (b) 32 had a structure similar to that of the causative (i.e., not triggering AgrO) but involved a variety of verbs, in order to introduce some variability on the verb (number was systematically manipulated on the head and the clitic); (c) 32 involved a structure similar to the accusative (i.e., triggering AgrO) but with a variety of verbs (number was systematically manipulated on the head and the clitic); (d) 32 involved a full NP as interfering element: 16 consisting of a subject modifier and 16 of an object in situ (number was systematically manipulated on the head and the interfering element).

A total of four 160-item lists (32 experimental items + 128 fillers) were created such that experimental items never appeared more than once for each participant. Each list contained eight experimental items per experimental condition.

Procedure, scoring, design and data analysis. Same as Experiment 3.

Results

A total of 1600 observations were collected involving 94 (5.9%) agreement errors and 169 (10.5%) miscellaneous responses. The distribution of agreement errors in the different experimental conditions is presented in Table 8.

Agreement errors. The analysis of variance shows a significant effect of number attesting a higher error rate in the condition of number mismatch than in the condition of number match ($F(1,149) = 42.7$, $p < .001$; $F(2,131) = 66.3$, $p < .001$). No effect of structure ($F_s < 1$) and no interaction between structure and number ($F_s < 1$) were found.

Miscellaneous responses. None of the tests reached significance level ($F_s < 1$).

Discussion. Similar interference was found in causative and in simple accusative structures. The finding that interference is the same whether the structure involves an intervening AgrO layer (as in simple transitives) or not (as in

Table 7

Examples of items in the different experimental conditions of Experiment 4.

Type of structure	Number	Preamble	Verb
Causative	Match	Le directeur le_acheter The director him_buy	FAIRE TO MAKE
	Mismatch	Le directeur les_acheter The director them_buy	FAIRE TO MAKE
Accusative	Match	Le directeur le_brutalement The director it_brutally	FAIRE TO MAKE
	Mismatch	Le directeur les_brutalement The director them_brutally	FAIRE TO MAKE

Table 8

Mean percentages (Standard Deviations in parentheses) of agreement errors in the four experimental conditions of Experiment 4, calculated over the total number of responses.

	Agreement errors		
	Causative	Accusative	Total
Match	2.5 (.16)	1.8 (.13)	2.1 (.14)
Mismatch	9.5 (.29)	9.8 (.29)	9.6 (.29)
Total	6.0 (.24)	5.8 (.23)	5.9 (.24)

causatives) suggests that AgrO plays no role in interference. Hence, the hypothesis that AgrO enhances interference with the accusative clitic as compared to the dative cannot explain the report of Experiment 3 that accusative clitics trigger more interference than datives. In contrast, the finding that two elements intervening in exactly the same configuration, here that of c-command, trigger exactly the same interference effect strongly supports the second hypothesis we proposed, namely that the critical factor distinguishing between accusatives and datives is the structural configuration of intervention of their intermediate position on AGREE. This hypothesis is based on the theoretically motivated assumption that the dative clitic is still a full PP at the level of its intermediate position, i.e., a NP introduced by a preposition, therefore intervening in terms of precedence on AGREE. In contrast, the accusative intervenes in terms of c-command on AGREE given the absence of a preposition introducing the accusative NP at the level of its intermediate trace.

Experiment 5: is argumenthood a necessary condition for object interference?

All effects of object interference reported until now (in the present paper, in Franck et al. (2006) and in Hartsuiker and colleagues (2001)) have involved elements that were part of the argument structure of the target verb.⁵ The only condition that involved an element external to the argument structure is the complement clause in Experiment 1, and it failed to show interference. Experiment 2 allowed us to conclude that being part of the argument structure is not a sufficient condition to trigger object interference: structural intervention resulting from object movement is necessary. This does not mean that being part of the argument structure plays no role at all; one could hypothesize that to trigger interference, the intervening element has to be part of the argument structure of the verb. That is, argument structure could be a non-sufficient but nevertheless necessary condition for interference.

Experiment 5 tests this possibility. As we already mentioned it, it is currently assumed that all elements that are moved out from the verb phrase pass through and leave a trace in the periphery of the phrase (in fact, according to

⁵ This is the case if one adopts the analysis of the French causative construction proposed in Rouveret and Vergnaud (1980), according to which the object in the causative is part of the argument structure of the causative verbal complex 'faire + V'. If Rouveret and Vergnaud's (1980) analysis is not adopted, the causative construction would be another case of object interference, on top of the one to be addressed in the following experiment.

Chomsky (2001), in the Spec of the vP, a category which defines a “phase”). Hence, in a structure from which an element is extracted, the moved element must transit through an intermediate position intervening between the subject and the AgrS specification of the relative clause. We contrasted two conditions illustrated in (26) and (27).

- (26) Voilà les *patientes* que le médecin ADMET que tu soignes t
Here are the *patients* that the doctor ADMITS that you cure t
- (27) Voilà les *patientes* que le médecin ENDORT t dans son cabinet
Here are the *patients* that the doctor ANAESTHETIZES t in his office

In (26) the moved element is the object of the subordinate verb, not of the target verb, and is therefore not part of the argument structure of the agreeing verb, in contrast to (27). Hence, past participle agreement cannot occur on the verb selecting the clausal complement from which extraction takes place (e.g., Voilà les patients que le médecin a admis(*-es) que tu soignes). Nevertheless, according to models with strict locality constraints such as the Phase Impenetrability Condition (Chomsky, 2001; Nissenbaum, 2000), the object is moved to its final destination through successive steps: first to the periphery of the VP headed by *soignes*, then to the embedded complementizer system, then to the periphery of the VP headed by *admet*. We are now testing for the existence of interference effects induced by the latter position. Note that this condition critically differs from the complement clause condition manipulated in Experiment 1 in that here, the object has moved and therefore intervenes on AGREE while no such intervention occurred in Experiment 1. It also differs from the causative construction manipulated in Experiment 4 in that here, the object is not part of the argument structure of the verb while it can be argued to be part of the complex argument structure of ‘faire + V’ in the causative construction (Rouveret & Vergnaud, 1980).

If being part of the argument structure is a necessary condition for interference, no interference should occur in the complement clause condition.

Method

Participants. Forty native French speakers between 20 and 40 took part in the experiment, all of them being students at the University of Geneva. All of them received course credits.

Materials. Experimental materials consisted 32 sentence preambles, each of which varied along four variants determined by the two variables manipulated: (1) Structure (Clausal complement vs. Relative clause)⁶ and (2) Number (Match vs. Mismatch). As in previous experiments, only sin-

gular head nouns were used so number was only manipulated on the potentially interfering element. In order to maximize the surface similarity between the two experimental structures, target verbs in the relative clause condition were followed with an adjunct of time or manner. Given the difficulty in finding verbs taking a clausal complement and suitable for the demands of the experiment, each of the two structure conditions contained 16 verbs repeated twice. As in Experiments 2 and 4 in which sentences did not end by the verb, the position of the verb in the preamble was indicated by an underscore. Examples of experimental items are provided in Table 9 and the full list is in Appendix 5.

A total of 112 fillers were created that displayed different structures: (a) 32 items structurally similar to the experimental items (with different verbs) but with a plural head noun (with balanced singular and plural objects); (b) 16 sentences in which an adjunct introduced by ‘où’ (where) is relativised; (c) 16 indirect questions; (d) 16 PP modified subject sentences; (e) 16 additional subject relative clauses observing the number condition well-established distribution; and (f) 16 SVO constructions. Number was systematically manipulated on the head noun and the interfering element in conditions (b–f). Four 144-item lists (32 experimental items + 112 fillers) were created in which only one variant of each experimental appeared. Each list contained eight experimental items per experimental condition.

Procedure, scoring and data analysis. Same as Experiments 3 and 4.

Results

A total of 1280 observations were collected involving 59 (4.6%) agreement errors and 203 (15.8%) miscellaneous responses. The distribution of agreement errors is presented in Table 10.

Agreement errors. Analyses of variance showed a significant effect of number with more errors in the condition of number mismatch ($F(1,39) = 34.7, p < .001$; $F(1,31) = 16.8, p < .001$) but no effect of structure ($F(1,39) = 2.9, p = .10$; $F(1,31) = 1.9, p = .17$) and no interaction between structure and number ($F_s < 1$).

Miscellaneous responses. None of the variables showed a significant effect on miscellaneous responses ($F_s < 1$).

Discussion

Objects from clausal complements were found to generate interference similar to objects from relative clauses. In these two structures, the object intervenes on the AGREE relation when in its intermediate position, but it does not intervene on the Spec-Head relation when in its final, surface position. However, intervention differs in two respects: (1) the object intervenes in AgrO in relative clauses but not in the case of extraction from an embedded complement clause and (2) the object is part of the argument structure of the target verb in relative clauses but not in clausal complement structures. We know from Experiment 4 that AgrO does not play any role in interference; and we can therefore conclude from the present

⁶ Note that both conditions involve a relative clause, however, for simplicity, “Clausal complement” is used to refer to the condition where the relative pronoun is extracted from a clausal complement embedded within the relative clause, while “Relative clause” refers to the condition where the object of the relative clause is moved.

Table 9

Examples of items in the different experimental conditions of Experiment 5.

Type of structure	Number	Preamble	Verb
Clausal complement	Match	Voici l'otage que le journaliste_qu'on a blessé Here is the hostage that the journalist_that has been injured	APPRENDRE TO HEAR
	Mismatch	Voici les otages que le journaliste_qu'on a blessé Here are the hostages that the journalist_that has been injured	APPRENDRE TO HEAR
Relative clause	Match	Voici l'otage que le journaliste_de sa voiture Here is the hostage that the journalist_from his car	APERCEVOIR TO SEE
	Mismatch	Voici les otages que le journaliste_de sa voiture Here are the hostages that the journalist_from his car	APERCEVOIR TO SEE

Table 10

Mean percentages (Standard Deviations in parentheses) of agreement errors in the four experimental conditions of Experiment 5, calculated over the total number of responses.

	Agreement errors		
	Clausal complement	Relative clause	Total
Match	2.5 (.16)	1.2 (.11)	1.9 (.14)
Mismatch	8.8 (.28)	5.9 (.24)	7.3 (.26)
Total	5.6 (.23)	3.6 (.19)	4.6 (.21)

results that being part of the verb's argument structure is irrelevant too. Hence, object movement, and more particularly the intervention, on AGREE, of the intermediate trace of the moved object appears as a plausible cause of interference.

General discussion

We have argued that under the assumption of a tight connection between grammar and the language processor, the different derivational steps assumed in formal syntax should be traceable in linguistic performance, and for our concerns here, in the way speakers err when producing agreement. Five experiments were reported that support this claim and more particularly here validate the relevance of a model of language production that assumes movement and intermediate traces. An overall summary of the results is presented in Table 11.

Of particular interest is the relevance of the abstract intermediate structure assumed to mediate between the

initial, thematic structure, and the final, surface structure. The argument goes as follows: (1) object interference is found in OSV structures even though the subject and the verb are contiguous in the surface structure; (2) interference only occurs with moved objects, in OSV (relative clauses in Experiment 1 and 5, object clefts in Franck et al. (2006)) or SOV (clitics in Experiments 2–4, Franck et al. (2006)); it does not occur with unmoved objects (complement clauses in Experiment 1, objects in situ in Experiment 2); (3) object interference occurs independently of whether the object is part of the argument structure of the verb or not (clausal complements, Experiment 5); and (4) object interference occurs independently of whether the object triggers participial agreement or not (datives in Experiment 3, causatives in Experiment 4 and extracted objects from a complement clause in Experiment 5).

Thus object interference occurs if and only if the object has moved, and crucially it cannot be accounted for by the object in its *final position*, which does not generate interference (complement clause in Experiment 1), nor by the object in its *thematic position*, which does not generate interference either (object in situ in Experiment 2). Hence, interference with the object seems to occur at a position that is neither the final nor the initial position, and that meets the previously identified condition for interference: intervention on the AGREE relation.

The existence of such an intermediate position has been proposed by models of formal syntax to account for completely independent linguistic facts and therefore provides an a priori explanatory framework for our data (see “Object

Table 11

Summary of the net percentage errors (Mismatch–Match) in Experiments 1–5.

Purpose and outcome	Experimental contrast	Example	Net % errors
Exp. 1: does the object interfere in relative clauses?	Complement clause (no movement)	Jean dit aux <i>patientes</i> que le médicament V	2.3
	Relative clause (movement)	Jean parle aux <i>patientes</i> que le médicament V t	8.3
Exp. 2: is argumenthood a sufficient condition?	Object in situ (post-verbal)	Le sénateur V les <i>députés</i>	1
Exp. 3: is AgrO a necessary condition?	Clitic object (pre-verbal)	Le sénateur <i>les</i> V	8
	Subject modifier	Le costume des danseuses AUX + V	6.3
	Dative clitic (no AgrO)	Le costume leur AUX + V	5
Exp. 4: does AgrO play any role?	Accusative clitic (AgrO)	Le costume les AUX + V	10.1
	Causative (no AgrO)	Le directeur les V acheter (V = faire)	7
Exp. 5: is argumenthood a necessary condition?	Accusative (AgrO)	Le directeur les V brutalement (V = faire)	8
	Clausal complement (Object argument of V)	Voici les otages que le journaliste V qu'on a blessé	6.3
	Relative clause (Object = argument of V)	Voici les otages que le journaliste V de sa voiture	4.7

movement: theoretical assumptions and empirical challenges”). Nevertheless, it is important to note that not all syntactic models require, or even permit, such an intermediate step. For instance, approaches to movement based on a somewhat weaker principle like classical Subjacency (Chomsky, 1973; Rizzi, 1982) do not require such a clause-internal step; other models do not envisage intermediate steps at all in A' dependencies (e.g., Bresnan, 1982; Gazdar, Klein, Pullum, & Sag, 1985). Our results can thus be construed as being optimally consistent with syntactic models which, through strict locality principles, predict an intermediate step in object movement to the left periphery of the clause (like more recently models of Phase Impenetrability, see Chomsky, 2001; Nissenbaum, 2000): the object first targets a position in the immediate periphery of the VP, where it is liable to trigger interference on subject–verb agreement, and then continues to move to the complementizer system.

To gain further support for an explanation in terms of the intervention of the intermediate trace on AGREE, two alternative hypotheses were considered. The first hypothesis was that interference occurs in relative clauses because any element from the argument structure could potentially interfere with agreement. The report that the object in situ (Experiment 2) does not interfere with agreement allowed us to conclude that being part of the argument structure of the target verb is not a sufficient condition: object movement is necessary. Moreover, the finding that the moved object interferes exactly in the same way whether it is part of the argument structure of the verb or not (as is the case for the object in the clausal complement tested in Experiment 5) indicates that being part of the argument structure of the target verb is not even a necessary condition. In sum, whereas movement appears as a necessary condition without which no interference occurs, argument structure does not appear to play a role in interference.

The second hypothesis we envisaged was that interference with the moved object was due to the fact that moved objects trigger participial agreement in French. Being an agreement controller, the moved object would be particularly disruptive for subject–verb agreement. That is, it is not movement and configurational intervention that are responsible for interference, but the fact that the language processor has to pay particular attention to this feature in order to compute participle agreement. The finding that dative clitics, which do not trigger participial agreement in French, do interfere with agreement (Experiment 3) allowed us to discard the hypothesis that participial agreement is a necessary condition: interference occurs even if the object is not an agreement controller. The additional finding that direct objects that do not trigger participial agreement, but intervene on AGREE in exactly the same conditions as direct objects that do trigger participial agreement (as is the case in causative structures, Experiment 4), generate interference like the latter further allowed us to conclude that interference is actually totally independent of whether the element is an agreement controller or not.

The report that dative clitics interfere with agreement to a lesser extent than accusatives, but in a similar way to prepositional phrase modifiers, allowed us to further

examine the role of the intervention configuration. After having argued, on empirical and theoretical grounds, that clitics do not interfere when in their final position, we provided arguments that clitics are still full NPs at the level of their intermediate position. Importantly, the hypothesis that at that level, dative NPs are PPs, introduced by a preposition, accounts for the higher interference rate observed with accusatives as compared to datives. Whereas accusatives intervene in terms of c-command on AGREE, datives only intervene in terms of precedence given the presence of the preposition. The similar interference rate observed for datives and prepositional phrase modifiers adds further support for the hypothesis that the critical factor at play here is the configuration of intervention; precedence in both cases. The finding that precedence intervention interferes less than c-command intervention is in line with our previous observations (Franck et al., 2006).⁷

There is yet a third hypothesis that we did not consider in our experimental work. As an anonymous reviewer suggested, one could claim that moved objects remain ‘active’ in the structural stretch between the position in which they are pronounced and the gap; so it could be that agreement is susceptible to interference from preceding plural nouns that are ‘active’, in the sense just mentioned, when the verb is produced. This statement appears to capture our main finding that moved objects interfere with agreement while unmoved objects fail to interfere. Although this account may seem attractively simple because it does not involve the complex machinery assumed by formal syntax, it appears to be at odds with previous experimental reports from the sentence processing literature. First, cross-modal priming experiments have shown that moved constituents are specifically reactivated at gap sites and not at other positions arbitrarily occurring between the antecedent and the gap (e.g., Nicol & Swinney, 1989). Hence, one cannot consider a moved element to remain active in an unqualified way throughout the whole structural stretch. Second, the experimental results by Gibson and Warren (2004) showing a facilitating effect of intermediate traces

⁷ Hartsuiker and colleagues (2001) found weaker interference from the object (whether phrasal or pronominal) than from the prepositional phrase modifier in Dutch embedded SOV structures. This result is consistent with our approach under standard assumptions on Dutch word order. If Dutch is an SOV language (Koster, 1978), an order which is directly manifested in embedded clauses, the relevant structure when AGREE applies is (i): (i) ...[... [VP Subj[Obj V]]... AgrS]. An AGREE relation is established between AgrS and Subj, and Subj is ultimately moved to the Spec of AgrS. So, when AGREE is established in Dutch, the object in its base position intervenes in this relationship between the subject in the VP and AgrS, but crucially this intervention is linear since the object follows the subject and fills a position lower than AgrS in (i). This configuration of intervention from the object differs from French in which the intermediate position of the displaced object (in clitic and clefted constructions) c-commands the subject in the VP, which explains why stronger object interference effects are found in French. The finding that, in Dutch, the object interferes even less than the prepositional phrase modifier, even though both intervene linearly on AGREE, is similar to the finding by Franck and colleagues (2002) that subject modifiers interfere less when they are more deeply embedded in the syntactic hierarchy (e.g., The helicopter for the flight over the canyons) than when they are situated higher up (e.g., The helicopter for the flights over the canyon). Hence, the Dutch data bring further evidence that the depth of embedding plays a role besides that of the configuration of intervention.

in sentence processing would not be expected under a generic notion of activation all the way through the stretch between the antecedent and the gap. In addition to that, some of the evidence provided in this paper also bears on the issue. The alternative account we are now considering fails to explain the report in Experiment 3 that accusative clitics trigger more interference than datives, while this difference follows from independently motivated assumptions on the nature of the intervening traces in our account (c-command vs. pure precedence of the intervening nominal). As a final remark, we would like to stress that the formal machinery that our approach appeals to receives strong independent motivation from the fact that it explains a wide range of linguistic phenomena described earlier in the Discussion.

How does our hypothesis fit with psycholinguistic models of sentence production? Although the model of syntactic structure used to account for our data deals with representational/configurational aspects of sentence structure, it is entirely compatible with feature-based psycholinguistic models of sentence formulation according to which features are copied from the agreement source to the target (e.g., Marking and Morphing model, Eberhard et al., 2005; Franck, Vigliocco, Antón-Méndez, Collina, & Frauenfelder, 2008). Our data and analyses further constrain these models by proposing a finer description of the hierarchical structure over which copying takes place. Nevertheless, the finding that object clitics interfere with agreement (Experiment 3, see also Fayol et al., 1994; Franck et al., 2006) may, at first glance, appear as incompatible with other processing models assuming that interference results of the incorrect identification of the subject (like the Working Memory Retrieval model, Badecker & Kuminiak, 2007; Badecker & Lewis, 2007). Indeed, the clitics manipulated share none of the cues that are deployed to retrieve the subject: they are unambiguously marked for non-nominative case (either accusative or dative), they do not belong to the category NP and they do not occupy the specifier position to the tensed verb. One way to adjust this model to be able to account for our data would be to integrate the notion of traces. In our framework, clitics interfere with agreement at the level of their intervention on AGREE, as they transit via an intermediate position in Spec of AgrO, on their way to their final, surface position. We provided arguments that at this level, clitics are full noun phrases situated in the Spec position of AgrO. At this level, clitics being full NPs deploy relevant subject-like features that may therefore lead to the incorrect identification of the agreement source, as is assumed in the Working Memory Retrieval model.

Finally, we would like to emphasize that our hypothesis about syntactic representations is entirely compatible with the on-line constraints of language production models, in particular incrementality in syntactic planning. Incrementality imposes that once an element (the object here) has been encoded grammatically, it is passed on for phonological encoding and articulation while the rest of the sentence is still being planned. Our hypothesis entails that even though the object has been encoded and passed on for articulation, it is kept active in some temporary memory buffer and regularly reactivated until its base position

(or gap site) has been reached. Importantly, our assumption is that this reactivation is not blind to syntactic structure; rather, it operates under fine structural guidance such that the moved element is reactivated at specific sites corresponding to the intermediate traces identified by syntactic theory. In this view, intermediate traces are conceived of as processing devices responding to memory limitations, allowing the grammatical encoder to keep track of displaced elements in structurally complex sentences.

Conclusion

In conclusion, the research presented here concretely illustrates the relevance of having experimental psycholinguists and linguists work together on the same questions. The detailed analyses of formal syntactic structures raise new questions, different from those that typically guide research in psycholinguistics, and offer new potential answers. This is possible thanks to the fine description of the syntactic hierarchy and the operations that underlie sentence derivation, issues that are not commonly dealt with in psycholinguistics. In turn, psycholinguistics can test specific hypotheses with controlled experiments, thus considerably enriching the types of evidence normally used in theoretical syntax. Although our explanation bears on the configurational constraints at play in sentence production, it is compatible with some of the dynamic models of agreement production, and it contributes to the long-standing enterprise of building models that integrate both structural constraints and dynamical, real-time constraints in language processing. We hope that our work will contribute to consolidate the link between our two disciplines, much in the spirit of the collaborative research which gave rise to modern psycholinguistics in the early years of generative grammar.

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A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.jml.2009.11.001](https://doi.org/10.1016/j.jml.2009.11.001).

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