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Processing Complex Sentences: A Cross-linguistic Study

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The Competition Model is an interactive-activation framework for the study of sentence processing that is designed to handle quantitative as well as qualitative variations in performance across natural languages. Previous studies within this framework have shown that adult listeners base their interpretation of simple sentences on the most valid and reliable cues in their language (e.g. more use of word order in English and more use of subject–verb agreement in Italian). Critics have argued that such effects may reflect heuristics that are only applied to simple sentences. The present study shows that these cross-linguistic differences are maintained when participants are asked to interpret complex sentences with an embedded relative clause. A comparison of "off-line" (untimed) and "on-line" (timed) versions of the same experiments shows that these effects hold up under time pressure. The on-line versions also provide new information about cross-linguistic differences in timing and demands on processing. In particular, the processing costs associated with centre embedding and non-canonical order are greater in English, which may be the price that English listeners have to pay for heavy reliance on word order information.

INTRODUCTION

The Competition Model is an interactive-activation framework for the study of sentence processing that is designed to handle quantitative as well as qualitative variations in performance across natural languages

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(MacWhinney & Bates, 1989). The term "competition" reflects a central assumption of the model: That different sources of information (i.e. "cues") converge, compete and/or conspire to determine the outcome of sentence processing, with different outcomes depending on the relative strength of cues from one language to another. For example, the model is designed to capture the fact that two languages with the same basic word order (e.g. subject–verb–object, or SVO) can differ markedly in the extent to which listeners rely on word order information to assign semantic roles in sentence comprehension, compared with other sources of information like subject–verb agreement.

In a long series of sentence comprehension studies, researchers working within the Competition Model have shown that listeners rely on the most valid (i.e. frequent and reliable) sources of information in their language. MacWhinney and Bates (1989) refer to this effect as "cue validity", a term borrowed from Brunswik (1956). English is a language in which word order is high in cue validity: Constituent order is rigidly preserved across sentence types, and correlates highly with semantic roles (i.e. "who did what to whom"). Italian is in the same typological category (SVO, without case marking on nouns), but word order is low in cue validity; that is, because extensive variation of word order is permitted for pragmatic purposes, the correlation between word order and semantic roles is relatively low. Studies of sentence comprehension in these two languages have shown that English listeners rely primarily on word order to decide "who did the action", making little use of subject–verb agreement or semantic contrasts. Italian listeners are heavily influenced by subject–verb agreement and semantic contrasts, but they pay little attention to word order. The same paradigm has now been used in more than a dozen languages (English, Italian, Spanish, French, German, Dutch, Serbo-Croatian, Hungarian, Japanese, Chinese, Warlpiri, Hebrew, Arabic, Greek; for summaries, see Li, Bates, & MacWhinney, 1993; MacWhinney & Bates, 1989). It is clear from these studies that many different profiles or hierarchies of cue utilization are possible (e.g. word order > agreement > semantics in English; case > agreement > semantics > word order in Serbo-Croatian; passive marking > semantics > word order > topic marking in Chinese). For any given language, the most valid cues also tend to be the first ones used by children (Devescovi et al., 1998; Kail, 1989), the most prone to transfer during second-language learning (Hernandez, Bates, & Avila, 1994; Kilborn & Ito, 1989; Liu, Bates, & Li, 1992), and the most resistant to loss following focal brain injury (Bates, Wulfeck, & MacWhinney, 1991).

In most of these studies, listeners are asked to "choose the one who did the action" in response to simple sentences or sentence-like strings consisting of a transitive verb and two concrete animate or inanimate

nouns. These stimuli are constructed to represent orthogonal combinations of cue types, including word order, semantic reversibility, subject-verb agreement, case marking, contrastive stress and topic marking. Because factorial designs are used, the stimuli represent all possible competing and converging combinations of cues to sentence meaning. Hence it is possible to evaluate the relative strength of comparable linguistic forms from one language to another (Massaro, 1987). On the other hand, this factorial approach also means that listeners are sometimes faced with a combination of grammatical and semi-grammatical stimuli. Some typical examples from English would include the following:

1. The horse is kicking the cow. (NVN, Animate–Animate, neutral agreement)
2. The dog the cat is chasing. (NNV, Animate–Animate, neutral agreement)
3. Is kissing the boy the girl. (VNN, Animate–Animate, neutral agreement)
4. The ball is pushing the elephant. (NVN, Inanimate–Animate, neutral agreement)
5. The tiger are chasing the bears. (NVN, Animate–Animate, 2nd noun agrees)
6. The rocks is hitting the pig. (NVN, Inanimate–Animate, 2nd noun agrees)
7. Is hitting the rabbit the pencils. (VNN, Animate–Inanimate, 1st noun agrees)
8. The boy are pushing the blocks. (NVN, Animate–Inanimate, 2nd noun agrees)

To illustrate, consider the following findings for English and Italian on sentences like these and their Italian equivalents, replicated in several different experiments (Bates et al., 1982, 1984, 1987;; Devescovi et al., 1998; Hernandez et al., 1994; Liu et al., 1992; MacWhinney, Bates, & Kliegl, 1984).

Starting with sentence (1), any theory of sentence processing in English or Italian would necessarily predict a SVO interpretation, and that is exactly what we find. However, our studies have also shown that use of SVO is *quantitatively* greater in English than in Italian on semantically and morphologically reversible items of this kind (averaging 10% more choice of the first noun in English from one experiment to another). To explain this outcome, one needs to know something about the *relative* strength of cues like SVO in English versus Italian—a kind of information that is left out of many parsing and sentence interpretation theories.

Languages can also vary in the way that listeners respond to non-canonical word orders like the NNV and VNN structures in sentences (2) and (3). In our previous studies using stimuli of this kind, we have shown that English adults are much more likely to choose "the cat" in sentence (2) and "the girl" in sentence (3), which are OSV and VOS interpretations that do not correspond to any single grammatical structure in this language. However, this result for English can be explained if we assume that listeners make use of the *partial* overlap between semi-grammatical stimuli and well-formed phrase structure types that do exist in the language. For example, it is true that subjects are overwhelmingly more likely to precede the verb in canonical SVO sentences, in relative clause constructions like "The boy that the girl kicked", and in left-dislocated structures that are permitted in informal speech within some dialects (e.g. "Now this one I like!"). The conjoint effects of these models could explain the OSV bias in English. Similarly, it is also true that objects are overwhelmingly more likely to follow the verb in canonical SVO sentences, in imperative constructions (e.g. "Hit the ball, John!"), and in right-dislocated "afterthought" structures that are occasionally observed in informal discourse (e.g. "Makes a mean apple pie, old Gertrude does"). These structures could explain the VOS bias that English listeners use to interpret VNN stimuli. In contrast with the VOS and OSV patterns observed in English, Italian listeners are close to the random 50% baseline in their interpretations of sentences like (2) and (3), presumably because OSV, SOV, VOS and VSO are all permitted in informal Italian discourse under some pragmatic and/or morphological conditions (Benincà, 1993; Simone, 1993). Across several experiments, Italians tend to show a slight bias towards SOV and VOS, but these trends are not always reliable.

In sentences like (4), most English listeners choose "the ball" as the actor, which means that SVO word order dominates over semantic contrasts in this language. In addition, English listeners usually choose "the tiger" as the actor in sentence (5), which means that SVO word order also wins in a competition against subject–verb agreement. The use of word order is so strong in English that listeners usually choose "the rocks" in sentence (6), where SVO word order must compete against the combined forces of animacy and agreement. Indeed, English listeners even trust their non-canonical OSV and VOS strategies more than they trust semantic or morphological information, evidenced in the fact that "the pencils" is chosen more often as the actor in sentences like (7), where VOS must compete against animacy and agreement. In contrast, Italians show dramatically different patterns of sentence interpretation with equivalent stimuli. On sentences like (4), Italians typically choose "the elephant" as the actor, which means that animacy wins in a competition with SVO word order. This cross-linguistic difference is even more dramatic on items like

(5), where Italians are overwhelmingly more likely to choose "the bears" as the actor, suggesting that subject–verb agreement is far more important than SVO word order. Not surprisingly, the combined forces of animacy and agreement defeat word order handily in items like (6) and (7) for Italian listeners. Finally, on items like (8), where animacy and word order compete against agreement, English listeners continue to follow their SVO bias (choosing "the boy" as actor), but Italian listeners choose "the blocks" as actor, showing that subject–verb agreement is by far the most important cue within their language.

Although a large number of studies have used this method successfully, in many languages the method itself is still controversial (e.g. Caplan & Hildebrandt, 1988; Gibson, 1992). Criticisms have focused on three issues: (1) Because listeners are asked to make explicit interpretations of agent–patient roles (i.e. "who did what to whom"), the task encourages use of conscious strategies. (2) The presence of ungrammatical stimuli could have a deleterious or unnatural effect on the processes listeners use to interpret any or all of the sentence stimuli. (3) Results may reflect "short-cuts" or heuristics that listeners use to interpret simple transitive sentences; the same processes may not hold when listeners are forced to parse and interpret complex sentence stimuli. The first two criticisms have been addressed in several previous studies, with arguments that we will summarise briefly here. The third criticism will be addressed in the present study, where we examine the profiles of cue utilisation that English and Italian speakers use to interpret complex sentence stimuli.

The first criticism can be decomposed into two problems: "strategies" and "consciousness". Our answer to the first problem is that strategies or heuristics are not necessarily a bad thing if the strategies that we elicit in our design generalise to those that are used in everyday life (Kimball, 1973). In this regard, we are comforted by the fact that the performance profiles displayed by native speakers in our cross-linguistic experiments correlate highly with independent measures of cue validity, and with performance across different laboratory tasks, including grammaticality judgement (Devescovi et al., 1997; Liu et al., 1992; Wulfeck, Bates, & Capasso, 1991) and word monitoring (Kilborn, 1987). With regard to the supposed problem of consciousness, we note that perceptual psychophysics has made great strides through the use of methods that enlist the conscious cooperation of the perceiver. When we engage the subject's cooperation in deciding "who did the action" in our cross-linguistic studies, we are emloying a similar approach. Consciousness *per se* is not a problem; the real issue is whether the mix of conscious and unconscious processes tapped by a given technique generalises to real-time language use under natural conditions—which seems to be the case for the method that we have used.

The second major criticism revolves around the mix of grammatical and semi-grammatical stimuli that are used in many of our experiments. To address this problem, we have carried out several studies in languages in which all the stimuli produced by a factorial design are grammatically acceptable (e.g. studies of Serbo-Croatian by Smith & Mimica, 1984, and by Smith & Bates, 1987). In those studies, we have found the same effects of cue validity, competition and convergence that emerge in factorial designs that use a mixture of grammatical and ungrammatical forms. This point was made explicitly by MacWhinney and Pléh (1988), who conducted two studies of sentence interpretation in Hungarian in which word order and animacy were pitted against the presence or absence of nominative/accusative case marking. In one study, sentence stimuli without case marking were all ungrammatical; in another, the stimuli without case marking were all grammatical. The results were the same in both experiments. Findings like these have convinced us that our results and conclusions are valid, despite the presence of ungrammatical stimuli in a factorial design. Indeed, we believe that these stimuli can be just as revealing as the impossible figures and visual illusions that are so often used to study competing and converging principles in visual perception (Gregory, 1966).

The third criticism pertains to the limitations of a research program based entirely upon simple transitive sentences. Do the results that we have obtained for short sentence stimuli generalise to the parsing and interpretation of complex structures? Or are they "short-cuts" that are only used for simple sentence types (cf. Caplan & Hildebrandt, 1988)? This criticism has not been addressed systematically in any of our comparative studies, although MacWhinney and Pléh (1988) have conducted a related study of relative clause interpretation within a single language, Hungarian. In that study, MacWhinney and Pléh took advantage of the fact that Hungarian permits a wide range of word order variations at the level of the matrix clause (SOV, SVO, OVS, etc.). As a result, they were able to test a range of competing theories of relative clause interpretation that are necessarily confounded within English. For example, Sheldon (1974) has proposed the Parallel Function Hypothesis to explain the fact that object-relatives are more difficult to process than subject-relatives. Within a subject-relative (e.g. "The girl that pushed the boy opened the door"), the head noun "girl" plays the same role within both the matrix and the embedded clause; within an object-relative (e.g. "The girl that the boy pushed opened the door"), the head noun is the subject in the matrix clause but it takes the object role within the embedded clause. Because of the opportunities offered by Hungarian, MacWhinney and Pléh were able to show that some of the strategies for parsing relative clauses that have been proposed in the English language literature are the by-product of two

or more simple tendencies (e.g. ''Take the speaker's point of view'') that are confounded in English but separable in Hungarian.

The paper by MacWhinney and Pléh testifies to the value of cross-linguistic research to resolve issues that cannot be addressed within a single language (e.g. English). However, that within-language study does not provide a direct cross-language test of the cue validity hypothesis for complex sentence types. In the present study, we compare processing of transitive sentences with a relative clause in English and Italian, in order to determine whether the strong cross-linguistic contrasts that we have observed with simple sentence types are preserved when listeners have to parse more complex structures. We examine the strategies that are used to interpret the matrix clause when the first or second noun is modified by a relative; we also look at the strategies that English and Italian listeners use to interpret the relative clause itself.

In this regard, we need to underscore a paritcularly important and interesting characteristic of Italian: Word order can be varied for pragmatic purposes within *both* the matrix and the relative clause. Within the matrix clause, all possible orderings of subject, verb and object can be observed in Italian under some combination of pragmatic, semantic, morphological and/or prosodic conditions. These variations are more common in informal spoken language (Bazzanella, 1994; Duranti & Ochs, 1979; Simone, 1990), but all of them have been observed in written discourse as well (Devescovi, 1986). Word order variation is not unusual in richly marked languages, including case-marked languages like Hungarian as well as languages like Italian that have no case inflections but do employ a rich set of agreement markers (e.g. subject–verb agreement, and agreement between objects and clitic pronouns). However, unlike Italian, many languages that permit word order variation within the matrix clause do not permit the same degree of freedom inside an embedded clause. Consider the following examples:

9a.	The boy saw the woman that is hitting the man.	(NVN(VN))
9b.	Il ragazzo ha visto la donna che picchia l'uomo.	(NVN(VN))
10a.	The boy saw the woman that the man is hitting.	(NVN(NV))
10b.	Il ragazzo ha visto la donna che l'uomo picchia.	(NVN(NV))

In English, these sentences are absolutely unambiguous: (9a) contains a subject-relative, in which the woman is the one who does the hitting (NVN(VO)), while (10a) contains an object-relative, in which the woman is hit (NVN(SV)). As we shall see, these are also the preferred readings in Italian. However, they are not the only *possible* readings. For morphologically ambiguous sentences like (9b) and (10b), two different readings are possible in Italian: In both sentences, the woman may be the one who

does the hitting (so-called subject relatives, NVN(VO) or OV)) or the one who gets hit (so-called object relatives, NVN(VS or SV)). The existence of two alternative interpretations (albeit at different levels of probability) means that the reliability of word order information is low in Italian, in both the main clause and the relative clause. Under these conditions, the Competition Model predicts that Italians will prefer to make use of agreement information to interpret complex sentences, at every level of the sentence (i.e. main and/or subordinate clause). Conversely, we may expect English listeners to ignore agreement contrasts in favour of word information, in both the main clause and the relative clause. In other words, the same cross-linguistic differences that we have observed with simple sentence stimuli will replicate when subjects are required to interpret much more complex sentence types.

We will report results below for a series of studies in the visual modality. This is in contrast to most studies within the Competition Model, which have been carried out in the auditory modality. Hence, in addition to new explorations with complex sentences, we also need to build in a replication of our results for simple sentences. The decision to use visual stimuli was made to avoid any confounds that might result from known and unknown effects of sentence prosody on assignment of agent–patient roles (for examples, see MacWhinney et al., 1984). The first two studies were conducted "off-line", with subjects making their response to written stimuli in test booklets, at their leisure. The second two studies were conducted "on-line", with subjects instructed to make their decisions as quickly as possible to sentence stimuli presented one at a time on a computer terminal. The same sentence stimuli were used in both the off-line and on-line studies.

GENERAL METHODS

Studies of relative clause processing are notoriously difficult to interpret and even more difficult to follow, because so many factors are involved. The factors of interest here include word order variations and agreement variations, in simple sentences (to ensure that our previous findings replicate in the visual modality) and within both the main clause and the relative clause in complex sentences; in the latter case, we also want to know if these factors vary depending on the position of the relative clause (i.e. whether it modifies the first or the second noun in the main clause). These factors would, if fully crossed, yield a $3 \times 2 \times 2 \times 3 \times 3 \times 2$ design for the complex sentences (with 216 cells) and a 3×3 design for simple sentences (with 9 cells), resulting in a minimum of 1125 trials (assuming no fewer than five sentences per cell). To get around this combinatorial explosion, we broke the full design into two separate experiments, one

focusing on variations in word order in both the main and the relative clause (with agreement held constant), and another focusing on variations in agreement in both the main and the relative clause (with order in the main clause held constant, in its canonical form). Each of these experiments actually contains three sub-experiments that must be analysed separately: simple sentences (to replicate auditory effects in the visual modality), complex sentences in which participants must interpret the main clause, and complex sentences in which participants must interpret the relative clause. Hence the two larger experiments will require a total of six separate analyses of variance with language as a between-subjects factor. Because these experiments were conducted both off-line (untimed, in booklet form) and on-line (timed, with computer-controlled presentation), with separate subjects participating in the off-line and on-line versions, the study as a whole comprises 12 sub-experiments, which may result in a large number of effects. To reduce the likelihood of false-positives, we have set the study-wide alpha level at $P < 0.01$; the only effects discussed are those that reach this conservative level of significance. To reduce the reader's workload, statistical details for all significant main effects and interactions are reported in appendices.

Subjects. The subjects in all of our experiments are college students attending an urban university, and they are native speakers of English or Italian. The students who participated in Experiment 1 also participated in Experiment 2 (i.e. the off-line series), in counterbalanced order, in a single test session or in two separate sessions depending on their individual scheduling constraints. In contrast, Experiments 3 and 4 (i.e. the on-line series) each used a separate group of subjects.

Materials. To convert our usual "who did it?" task for use with complex sentences, we had to solve a methodological problem. If we want to ask our listeners to decide "who did it" in a complex sentence with three participants and two verbs, we have to decide which verb we want them to interpret on a given item, and we need an easy and straightforward way to convey that instruction. Our solution to this problem is called the "Who Dunnit?" task. All complex sentence stimuli involve two transitive events: one with a verb referring to a cruel or criminal act (e.g. "The waitress shoots the cowboy") and one with a verb of witness (e.g. "The secretary sees the waitress"). Our instructions to the subject are to "catch the bad guy" (i.e. to report which of the three characters in a given sentence committed the crime in question). Thus, subjects are tacitly required to interpret the main clause in sentences like "The waitress that the secretary sees shoots the cowboy", and they are tacitly required to interpret the

relative clause in sentences like "The secretary sees the waitress that shoots the cowboy". For simple sentences, only criminal verbs were used.

The nouns and verbs used in all the studies that follow are listed in Appendix 1 (for English and Italian), and sample sentences for each experiment are listed in Appendix 2 (for English only). For each study, lexical items were randomly assigned to sentence conditions. To ensure that item-specific lexical effects could not influence the results, five different versions were created for each experiment, each with a different random assignment of words to sentence types.

Scoring. Since the notion "number correct" is meaningless in a competition design of this sort, the dependent variable was defined by which noun the subjects chose as the actor. For sentences in which the criminal verb is in the main clause, a score of 1 was given if the subjects chose the first noun in that clause as the actor, and a score of 0 was given if they chose the second noun as the actor. If they failed to give any response at all, or if they chose the third noun (in this case, the internal noun in the relative clause), they were given a score of 0.5. A score of 100% would mean that the subject always chose the first noun as actor, a score of 0% would mean that they always chose the second noun, and a score of 50% would indicate chance performance. For sentences in which the criminal verb is in the relative clause, a score of 1 was given if the subjects chose the head (external) noun as the actor (e.g. "the waitress" in "the waitress that shoots the cowboy"); a score of 0 was given if they chose the embedded (internal) noun as the actor (e.g. "the cowboy") in "the waitress that shoots the cowboy"). If they failed to give a response on that item, or chose the third noun (in this case, the unmodified noun in the matrix clause), they were given a score of 0.5. For these analyses, a score of 100% means that the subjects always chose the head noun as actor, 0% means that they always chose the embedded noun, and 50% indicates chance performance.

EXPERIMENT 1: WORD ORDER VARIATIONS

Subjects. The subjects for this experiment were 25 American college students enrolled in undergraduate courses at the University of California, San Diego, and 25 Italian college students attending the University of Rome "La Sapienza". All participants were native speakers, with minimal bilingual experience (although most have been exposed to a second or third language in a classroom setting).

Materials and Procedure. The 135 sentence stimuli for Experiment 1 were printed in a test booklet, in randomised order. The subjects were

tested individually in a quiet room. They were told that each sentence contained three characters and a single "bad action", and that their job was to decide which individual committed the crime. They were asked to read each sentence carefully, and to indicate for each sentence "Which character did the bad action" by underlining or circling the relevant noun.

Results and Discussion (see Appendix 3 for statistical details)

Experiment 1a: Word Order in Simple Sentences. The main aim of this sub-experiment was to determine whether the cross-linguistic differences in interpretation of word order observed in previous studies within the auditory modality are preserved with the visual method adopted here. The 15 simple sentences with no relative clause were analysed in a 2 × 3 design, with language (English *vs* Italian) as a between-subjects variable and word order (NVN, VNN, NNV) as a within-subjects variable. All results were statistically reliable, including main effects of language and word order and a language × word order interaction (Appendix 3). The interaction is illustrated in Fig. 1, which shows that English subjects have a strong preference for SVO, OSV and VOS interpretations (for NVN, NNV and VNN, respectively), while Italian subjects show a somewhat weaker SVO

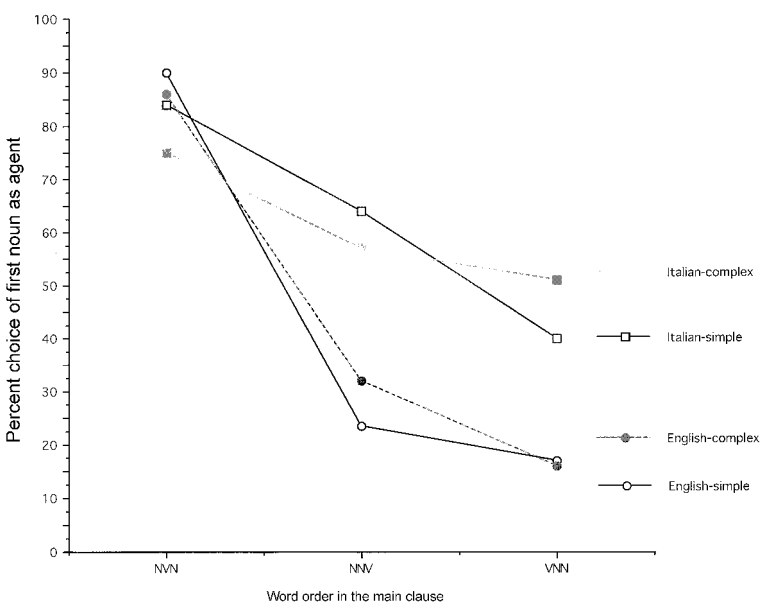


FIG. 1. Language × word order interaction for agent choice in simple *vs* complex sentences (Experiments 1a and 1b).

bias, and very small biases towards SOV and VOS. Separate analyses of variance for English and Italian showed that these main effects of word order are also reliable within each language (also in Appendix 3). These findings constitute a visual replication of many previous auditory studies, demonstrating once again that English speakers "trust" word order more than their Italian counterparts.

Experiment 1b: Interpretation of the Main Clause. The main aim of this sub-experiment was to determine whether the cross-linguistic differences in word order use observed in simple sentences are also observed when one of the nouns in the main clause is modified by a relative. This analysis covered the 60 complex sentences in which the criminal verb appears in the main clause, with a verb of witness in the relative clause. The data were subjected to a 2 (English *vs* Italian × 3 (word order within the main clause) × 2 (position of the relative clause, modifying the first or second noun) × 2 (order within the relative clause) mixed analysis of variance, with language serving as a between-subjects factor and the other variables as within-subjects factors.

A large number of significant main effects and interactions were found (see Appendix 3). Based on the cue validity principle of the Competition Model, the most important effect in Experiment 1b is the language × word order interaction, which tests the prediction that English and Italian subjects show the same language-specific word order strategies in complex sentences that they show in many studies using simple sentence stimuli. This does indeed appear to be the case. Figure 1 plots the data for simple and complex sentences together (Experiment 1a *vs* 1b) to facilitate comparison. With added complexity, English subjects continue to pursue a strong SVO strategy for NVN strings (86% first-noun choice *vs* 90% in simple sentences), a strong VOS strategy for VNN strings (16% first-noun choice *vs* 17% in simple sentences), with a somewhat weaker OSV bias on NNV strings (32% first-noun choice *vs* 23.5% on simple sentences), Italian subjects also show a bias towards SVO, although it is slightly flatter in complex sentences (75% first-noun choice on complex items *vs* 84% in simple sentences). They also show a slight flattening of their SOV bias on NNV (58% first-noun choice on complex items *vs* 64% on simple sentences). By contrast, their VOS bias is somewhat stronger on complex VNN strings compared with simpler items (33% and 42%, respectively).

Overall, these results are in line with our predictions: *When sentences are rendered more complex through the addition of a relative clause, English and Italian listeners continue to display the same language-specific word order strategies that we have observed in this and other experiments using simple transitive sentences.* The primary effect of complexity lies in a slight flattening of word order strategies for NVN and NNV strings, pushing

them in the direction of the 50% chance baseline. The most parsimonious explanation for these small differences is that processing is harder in complex sentence types, adding noise to the data.

On the other hand, the results in Fig. 1 also suggest that some word order types (especially NNV) appear to be more strongly affected by complexity than others. The reason for this became clear when we explored the significant three-way interaction of language, main clause order and position of the relative clause (i.e. modifiying the first *vs* the second noun). To unpack the three-way effect, separate analyses of variance were conducted for English and Italian. When the Italian data were analysed alone, the only reliable finding was a significant main effect of main clause order (as in Fig. 1). In contrast, the English-only analysis yielded a significant two-way interaction between main clause order and relative clause position, illustrated in Fig. 2. This figure shows that performance on NNV strings is essentially random (i.e. 48% first-noun choice) when the relative clause modifies the second noun. The reasons for this total parsing failure are clear when we consider a sample item from this set:

11. The waitress the cowboy that the baker hears kills. (NN(NV)V)

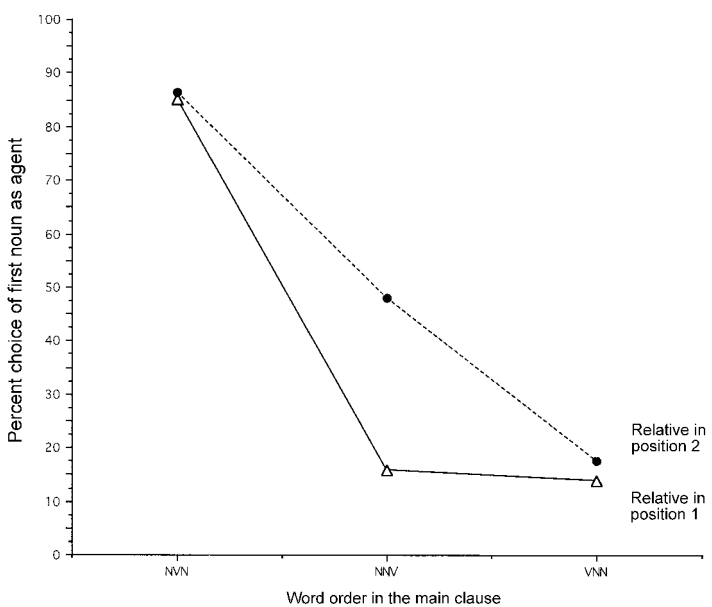


FIG. 2. Effects of main clause order and relative clause position on the interpretation of the main clause, for English only (Experiment 1b).

Of all the grammatical and ungrammatical stimuli in this complex design, this is by far the most difficult; that is, it is the hardest to parse (three nouns are stacked up before the subject encounters a single verb) and the most deviant (i.e. farthest from any well-informed sentence in the English language). It seems that we have found the outer limits, the point at which our English subjects' ability to assimilate semi-grammatical stimuli to well-formed options in the language finally breaks down.

Experiment 1c: Interpretation of the Relative Clause. The aim of this sub-experiment was to determine whether the cross-linguistic differences that we have observed for both simple and complex main clauses (i.e. English speakers rely more on word order than their Italian counterparts) are also observed within the relative clause itself. This analysis covers the 60 complex sentences in which the criminal verb is located within the embedded clause, with the verb of witness in the matrix clause. The design and the analysis of variance are identical to Experiment 1b. Multiple significant effects were found and are summarised in Appendix 3.

The most important effect from the point of view of the Competition Model is the two-way interaction between language and relative clause order, illustrated in Fig. 3. We pointed out earlier that Italian permits pragmatic word order variation within both the main and the relative clause. Hence relative clause ordering should be a relatively weak cue to agent–object relations for Italians. The results in Fig. 3 show that this prediction is confirmed. Word order biases are in the same direction in both languages; that is, VN items are interpreted as subject-relatives (e.g. "The waitress that shoots the cowboy") and NV items are interpreted as object-relatives (e.g. "The waitress that the cowboy shoots"). However, this effect is stronger in English. On VN items, English subjects choose the head noun as agent 85% of the time, compared with 73% in Italian. On NV items, English subjects choose the head noun only 15% of the time (i.e. 85% object-relative interpretations), compared with 35.5% for Italian (i.e. 64.5% object-relative interpretations). Hence, even in the absence of conflicting morphological or semantic information, Italian subjects rely less on word order to understand a relative clause.

The most complex effect in Experiment 1c was a three-way interaction of language, main clause order and relative clause order. To explore this interaction further, we conducted separate analyses for English and Italian. These analyses showed that word order is the *only* factor influencing relative clause interpretation in English (i.e. relative clause order was the only significant effect, in the predicted direction). In contrast, the Italian-only analysis yielded main effects of word order at both levels of the sentence (main clause and relative clause), together with a significant two-way interaction. Examination of cell means yielded a straightforward

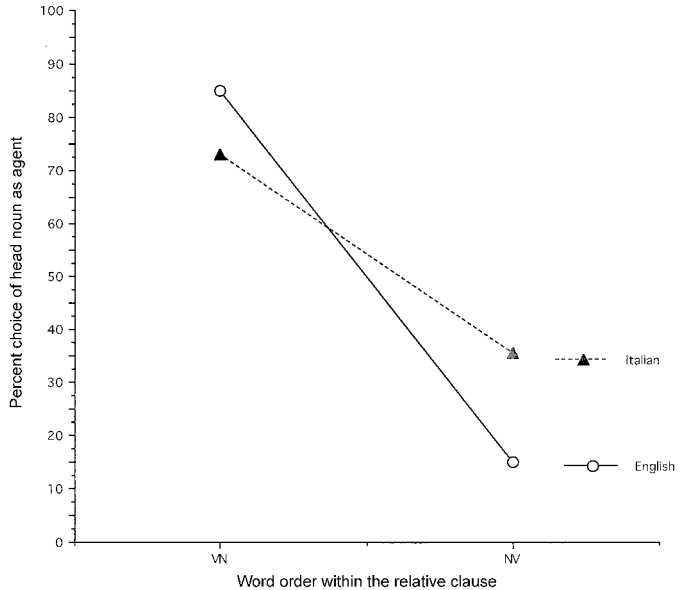


FIG. 3. Effect of relative clause order on the interpretation of the relative in English and Italian (Experiment 1c).

interpretation of these effects: *A canonical interpretation of the relative clause is less likely in Italian when a highly marked and difficult word order type is used in the main clause.* On VN items, Italians choose the preferred subject-relative (VO) interpretation 77% of the time if the matrix clause is a canonical NVN, compared with 71% for VNN and 72% for NNV. On NV items, Italians choose the preferred object-relative (SV) interpretation of NV clauses 71.5% of the time when the matrix clause is a canonical NVN, 70% when the matrix clause is VNN, versus a near-random 53% on NNV. These subtle but reliable effects testify further to the fragile and pragmatically conditioned nature of word order strategies in Italian, compared with the robust, context-independent word order effects that are observed in English.

Summary of Experiment 1

We have shown that language-specific word order strategies are observed not only in simple transitive sentences, but also in complex sentences in which one of those nouns is modified by a relative clause. English subjects show robust and consistent word order profiles in the main clause, for all three word order configurations: NVN is interpreted as SVO, NNV is interpreted as OSV and VNN is interpreted as VOS. They also display

strong word order biases within the relative clause itself, interpreting VN orders as VO (subject relatives, where the agent role is assigned to the head noun) and NV orders as SV (object relatives, where the agent role is assigned to the embedded noun). Italians display their own word order preferences within the main clause (NVN as SVO; NNV as SOV; VNN as VOS), with or without a relative, and they display reliable effects of word order within the relative clause, similar in direction to those observed in English. However, the use of word order is invariably weaker and less consistent in Italian than it is in English, at both levels of the sentence, in line with the cue validity principle of the Competition Model. When simple and complex sentences are compared, the effects of complexity are rather small, restricted primarily to a slight "flattening" of effects in the direction of the 50% random baseline. This is particularly true for English items in the order NNV, where a pile-up of nouns prior to the main verb seems to neutralise the OSV strategy that is usually employed for these sentence types.

EXPERIMENT 2: SUBJECT-VERB AGREEMENT VARIATIONS

In all of our previous experiments, Italian subjects made extensive use of subject–verb agreement to assign sentence roles, far more than their English counterparts. When sentences contain a competition between agreement and word order, agreement information "wins" in Italian and word order "wins" in English. Once again, however, we did not know if these cross-linguistic differences would hold up for complex sentence types. This was the main aim of Experiment 2. As described in the General Methods, the stimuli for Experiment 2 were designed to examine competing and converging effects of word order and agreement, within simple sentences (restricted to NVN order only), within the main clause in complex sentences (also restricted to NVN order only) and within the relative clause itself (both VN and NV).

Subjects. The subjects for this experiment were the same 25 American and 25 Italian college students who participated in Experiment 1. The order of presentation of the experiments was randomised, with approximately half of the subjects participating first in Experiment 1 and half participating first in Experiment 2.

Procedure. The 375 sentence stimuli for Experiment 2 were printed in a separate test booklet, in randomised order. The instructions and test procedures were identical to those used in Experiment 1.

Results and Discussion (see Appendix 3 for statistical details)

Experiment 2a: Agreement in Simple Sentences. The main aim of this sub-experiment was to provide a visual replication of the cross-linguistic differences in reliance on subject–verb agreement that we have observed in auditory studies. This part of the experiment contains 15 sentences, 5 in each of three cells (ambiguous agreement; agreement in number with the first noun; agreement in number with the second noun), analysed within a mixed 2 (language) × 3 (agreement conditions) analysis of variance. All three effects were reliable (language, agreement and the language × agreement interaction). The interaction is illustrated in Fig. 4, which shows that subject–verb agreement is a much stronger cue in Italian than it is in English. Recall that all the stimuli in Experiment 2 have the order NVN within the main clause. English subjects are overwhelmingly more likely to choose the first noun as agent on such stimuli: 100% on sentences with no morphological contrast, 100% on sentences in which SVO and agreement converge, and 92% on items in which SVO and agreement are in competition. A separate one-way analysis of variance for English subjects alone showed that the effect of agreement does not even reach significance

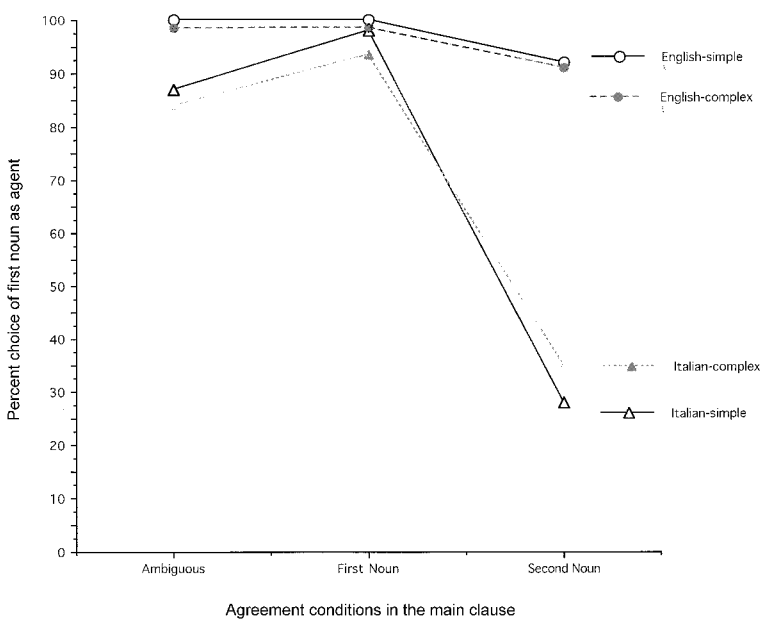


FIG. 4. Effects of language and main clause agreement on the interpretation of the main clause in simple *vs* complex sentences (Experiments 2a and 2b).

in this language. By comparison, Italians choose the first noun only 87% of the time on morphologically ambiguous sentences, compared with 98% on items in which SVO and agreement converge, and 28% on items in which SVO and agreement point in other directions (i.e. agreement wins the competition). A separate one-way analysis of variance for Italian alone yielded a robust main effect of agreement. In short, this experiment in the visual modality replicates our previous findings for English versus Italian using auditory stimuli: (1) canonical word order "wins" in English, while subject–verb agreement "wins" in Italian; and (2) canonical word order is weaker in Italian even when there is no competition from other sources.

Experiment 2b: Interpretation of the Main Clause. The main aim of this sub-experiment was to determine whether the cross-linguistic differences in agreement that we have observed in simple sentences are also seen in the main clause of complex sentences. The design involved a total of 180 sentences, analysed within a 2 (language) × 3 (levels of agreement in the main clause) × 3 (levels of agreement in the relative clause) × 2 (order within the relative clause) × 2 (placement of the relative after the first or the second noun) design, with language serving as a between-subjects factor and all other variables as within-subjects factors. A large number of significant main effects and interactions were found (see Appendix 3), including a four-way interaction of language, main clause agreement, relative clause agreement and order in the relative clause.

The largest effect and the most important for our purposes here is the interaction between language and subject–verb agreement in the main clause, illustrated in Fig. 4 (where it is plotted against the analogous effect for simple sentences from Experiment 2a in order to facilitate comparison). As Fig. 4 shows, our predictions were confirmed: The same cross-linguistic differences are observed in simple and complex sentence types; that is, SVO word order "wins" in English and subject–verb agreement "wins" in Italian. The only difference between Experiment 2a and Experiment 2b appears to be a slight flattening of results on complex items. In other words, complexity does exact a small toll, but the overall pattern is preserved. This is the most important effect in Experiment 2b, but the minor effects deserve exploration. To simplify the task of interpreting a four-way interaction, we again conducted separate analyses of variance for English and Italian.

In the English analysis, two effects reached significance: a main effect of order within the relative clause, and an interaction between relative clause order and position of the relative within the main clause. Cell means for this interaction break down as follows. When the relative clause modifies the first noun, English subjects choose that noun as the actor in the main clause 93% of the time with a VN relative versus 97.5% with a NV relative.

When the relative clause modifies the second noun, that noun is chosen as the object of action 98% of the time with a VN relative versus 97% with a NV relative. The outliers here (at 93%) are sentences of the form S(VO)VO. To be sure, this is a very small effect, but it runs directly counter to predictions based on the Parallel Function Hypothesis (Sheldon, 1974), according to which the "subjecthood" of the first noun in a NVN sentence should be enhanced if that noun also plays the subject role within the relative clause. Why should this be? We suspect that our English subjects are occasionally seduced into a parsing error on sentences of this type. Consider the following item:

(12a.) The ballerina that sees the policeman shoots the cook. (N(VN)VN)

This item may be accidentally parsed as (12b) or (12c):

(12b.) The policeman shoots the cook. (NVN)
(12c.) The ballerina sees the policeman that shoots the cook. (NVN(VN))

Whether or not this is the correct explanation, we should bear in mind that the difference is relatively small (i.e. 93 *vs* 98% first-noun choice), a minor perturbation of an overwhelming tendency for English subjects to apply SVO interpretations within the main clause.

In the separate analysis of variance for Italian, two effects reached significance: a large effect of main clause agreement (see Fig. 4) and a small three-way interaction of main clause agreement, relative clause agreement and relative clause order. Examination of the cell means for this three-way interaction suggests that it is entirely due to sentences that are morphologically ambiguous in the main clause, where Italians do not have their favourite cue available (see Table 1). In the absence of their favourite cue, they are forced to rely primarily on SVO word order. However, in contrast to their English counterparts, they do not "trust" SVO very much, and can be thrown off by other combinations of information. In fact, the smallest effect of SVO (i.e. 73.5% choice of the first noun) occurs in morphologically ambiguous main clauses that contain a competition within the relative clause: The relative is in the non-canonical order NV (favouring an object-relative interpretation), but the head noun agrees with the embedded verb (favouring a subject-relative interpretation). Bearing in mind that subjects are supposed to interpret the main clause in this part of the experiment, in principle it should be possible to ignore the relative clause altogether. Indeed, the corresponding sentences do not bother English subjects at all, but they do bother Italians. This may occur

TABLE 1
Effects of Main Clause Agreement, Relative Clause Agreement and Relative Clause Order on Interpretation of the Main Clause, for Italians Only (Experiment 2b)

Main Clause Agreement	*Relative Clause Agreement (%)*		
	Ambiguous	*Head Noun*	*Embedded Noun*
Ambiguous			
VN	88.0	88.0	82.0
NV	80.0	73.5	92.5
First noun agrees			
VN	97.0	95.5	91.0
NV	93.0	92.5	92.0
Second noun agrees			
VN	33.0	36.0	38.5
NV	37.0	35.0	34.5

for two reasons (which are not mutually exclusive), either because processing load has become so heavy that response moves towards the random baseline (i.e. a noise overload), or because the highly marked nature of the relative clause persuades Italians to be suspicious of canonical interpretations at every level. Evidence in favour of the latter interpretation comes from our previous studies of simple sentences in Italian, which showed that Italians are likely to reject an SVO interpretation in favour of OVS when contrastive stress is used on either noun (MacWhinney et al., 1984), or when the sentence contains a morphologically ambiguous clitic pronoun (Devescovi, 1992). The story is complex, but the basic intuition is a simple one: Italians do not trust canonical SVO word order, and they are willing to suspend default SVO interpretations under heavily marked or unusual morphological, semantic, pragmatic and/or prosodic conditions.

Experiment 2c: Interpretation of the Relative Clause. The aim of this sub-experiment was to determine whether the cross-linguistic differences in agreement that we have observed in main clauses (simple or complex) are also observed when participants have to interpret the relative clause. Hence the criminal verb is located in the relative clause, and the verb of witness in the main clause. Otherwise, the design is identical to that of Experiment 2b, involving a total of 180 sentences, analysed within a 2 (language) × 3 (levels of agreement in the main clause) × 3 (levels of agreement in the relative clause) × 2 (order within the relative clause) × 2

(placement of the relative after the first or the second noun) design, with language serving as a between-subjects factor and all other variables as within-subjects factors. The analysis of variance yielded a large number of significant effects and these are summarised in Appendix 3.

The most important effect for our purposes here is the three-way interaction of language, relative clause agreement (which should be strong in Italian and weak in English) and relative clause order (which should be strong in English and weak in Italian). This interaction is illustrated in Fig. 5, which shows that all of our predictions are roundly confirmed. In interpreting the relative clause, English speakers rely overwhelmingly on word order: items in the VN order are interpreted as subject-relatives, and items in the NV order are interpreted as object-relatives. Competing information from agreement within the clause has virtually no effect in English (see below). In contrast, Italians rely overwhelmingly on agreement information: If the head noun agrees with the embedded verb, a subject-relative interpretation is assigned; if the embedded noun agrees with the embedded verb, an object interpretation is far more likely. Italians do have the same word order biases as their English counterparts (VN as subject-relative; NV as object-relative), but they are relatively weak, showing up primarily on morphologically ambiguous items. To

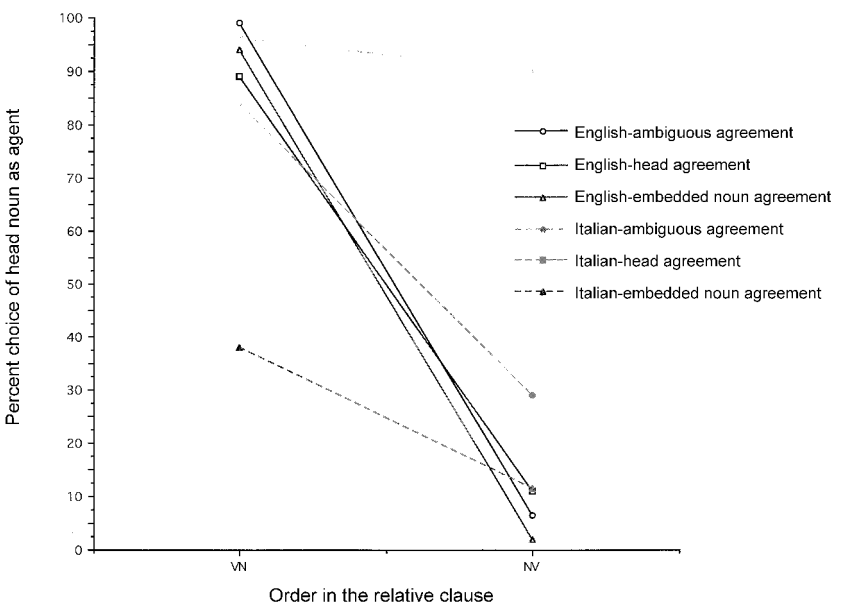


FIG. 5. Effects of relative clause order and relative clause agreement on the interpretation of the relative in English *vs* Italian (Experiment 2c).

explore these effects and the other complex interactions in this data set in more detail, separate analysis of variance were again conducted for English and Italian (Appendix 3).

The results for the English analysis are crystal-clear: The only effect to reach significance at the $P < 0.01$ level was the robust main effect of order within the relative clause. Nothing else even approached significance. This means, of course, that all of the complex interactions listed in Appendix 3 are coming from Italian.

Turning to the Italian effects, the largest and most imortant of the two-way interactions in Italian involves the relationship between order and agreement within the relative clause, illustrated in Fig. 5. This interaction shows that agreement wins out over default word order across the board in Italian, but competition between factors does exact a small toll. On VN items, Italians choose the head noun as subject 84% of the time if there is no competition from morphology (the default subject-relative interpretation), 96% when morphology and word order lead to the same interpretation (a convergence between agreement and the default interpretation), but only 38% of the time when morphology and word order are in competition (corresponding to 62% object-relatives, the opposite of English interpretations on the corresponding items). On NV items, Italians choose the head noun as subject 29% of the time on morphologically ambiguous items (corresponding to 71% default object-relative interpretations), 11% when morphology and word order lead to the same answer (89% object-relatives, reflecting the convergence of agreement and default order), and 90% when agreement and word order are in competition (overwhelming preference for a subject-relative assignment, the exact opposite of performance by English subjects on analogous items).

The two remaining interactions can be summarised as follows. Regardless of agreement conditions within the matrix clause, the huge effect of relative clause agreement in Italian always runs in the same direction. However, this effect is slightly flatter on non-canonical items in which the second noun in the main clause agrees with its verb (i.e. items that are likely to receive an OVS interpretation). This may be one more example of when markedness (in the main clause) adds to overall complexity, pushing performance (in the relative clause) slightly closer to the chance baseline. The effect of relative clause agreement is also slightly smaller (by a few percentage points) when the relative clause is in the second position. The reason for this latter finding is not at all obvious. However, a look through all the cells in this complex interaction revealed an interesting oddity: the flattest agreement effect was observed on items like the following (from Appendix 2):

(13.) The secretary see the cooks that shoot the doctors.

These are items in which the verb of witness in the main clause agrees with the second noun (which should force an OVS interpretation), and where the relative clause modifies the second noun, in the VN order, with agreement on the embedded noun (which should force a VS interpretation). In addition to the fact that these items involve a high degree of competition and non-canonical form, they have another peculiar characteristic: If Italians use morphology at all levels to make their assignments (which is usually the case), they arrive at an interpretation in which the crime victim is busy watching somebody else while he himself is getting murdered! By reinterpreting these sentences, Italians can restore a more pragmatically felicitous situation in which it is the criminal who is watching out for other individuals who might be on the scene. Note, however, that such pragmatic biases are small, and play their greatest role in highly marked sentences that are particularly difficult to interpret (even though they are grammatically correct in the Italian language).

Summary of Experiment 2

The largest effects by far in this experiment are the ones predicted by the Competition Model: English listeners rely exclusively on word order to interpret the relative clause, whereas Italians rely overwhelmingly on agreement information, a bias that only breaks down when processing is maximally overloaded. These results complement our findings in Experiment 1, where English word order biases only break down under the worst possible processing conditions. We did find some minor effects in both experiments that are not predicted by the model, which we attribute to a breakdown or "softening" of sentence processing due to combinations of complexity, markedness and pragmatic felicity. These effects are interesting, and may be worthy of further investigation, but they are very small compared with the large cross-linguistic findings predicted by the model.

In view of previous complaints about the use of ungrammatical sentences in previous studies testing the Competition Model, we want to remind readers that all of the sentence types in Experiments 1 and 2 are grammatical in Italian, although some items are so pragmatically marked that they stretch the definition of grammaticality. Many of the sentence types in Experiments 1 and 2 are frankly ungrammatical in English, but it is clear that English subjects know exactly what to do with them in all but a few cases. Despite the difficult and often very odd nature of these materials, English and Italian subjects respond with consistent and language-specific interpretations that are predicted by cue validity in their respective languages.

These results suggest to us that the strategies used by English and Italian subjects in our experiments bear a consistent relationship to the strategies

used in everyday conversation. However, this conclusion would be strengthened if we could show that the same cross-linguistic effects hold up in an "on-line" (timed) paradigm. First, if similar profiles of agent assignment are obtained when subjects are tested under time pressure, with relatively fast reaction times, then we may conclude with greater confidence that our findings are related to sentence interpreation strategies that listeners use in everyday life. Second, we should find cross-linguistic differences in reaction time profiles, reflecting convergence and/or competition between cues that differ in strength in English and Italian. We would, for example, expect word order to create larger effects in English; conversely, we would expect to find more effects of agreement in Italian. This brings us to Experiments 3 and 4, on-line versions of the two complex experiments that we have just described. In addition to providing a further test of the Competition Model, these on-line studies may yield new insights into the processing demands associated with complex sentences, illuminating the interplay between universal and language-specific factors in sentence processing.

EXPERIMENT 3: WORD ORDER VARIATIONS ON-LINE

Subjects. The subjects for this experiment were 25 American college students enrolled in undergraduate courses at the University of California, San Diego, and 25 Italian college students attending the University of Rome "La Sapienza". All participants were native speakers, with minimal bilingual experience (although most have been exposed to a second or third language in a classroom setting). None had participated in Experiments 1 and 2.

Materials and Procedure. In this on-line version, the same 135 sentence stimuli used in Experiment 1 were presented one at a time on a computer screen, at a MacIntosh SI workstation controlled by the Carnegie Mellon Experimental Control Shell (ECS), a predecessor of the PsyScope System (Cohen, MacWhinney, Flatt, & Provost, 1993). (For eight subjects in this experiment and six in Experiment 4, administration was switched from ECS to the updated PsyScope system. Preliminary analyses indicated that the two systems did not yield significant differences in performance; data are pooled across ECS and PsyScope in all subsequent analyses.) Subjects were tested individually in a quiet room. The instructions were identical to Experiments 1 and 2, except that subjects were asked to press a button on the Carnegie Mellon button box as soon as they knew which actor had carried out the "bad action". After each button press, they were asked to say the name of the chosen agent aloud; this response was recorded

manually by the experimenter. If subjects failed to respond within a 5-sec time window, the test sentence disappeared from the screen and the next trial began.

Scoring. Scoring of the manually recorded agent assignments (i.e. "who did it?") was identical to the scoring used for the test booklets in Experiments 1 and 2, with one exception: Trials in which the subject failed to respond within the 5-sec time window were eliminated prior to analysis of either the decision or the reaction time data, and scores for that cell were averaged to reflect performance on the remaining items. Such non-responses comprised 1.37% of all responses for English subjects and 1.30% of all responses for Italian subjects in Experiment 3.

Results and Discussion (see Appendices 4 and 5 for statistical details)

Before exploring the reaction time results obtained in this experiment, we began by examining results for agent choice, to determine whether the results obtained off-line in Experiment 1 replicate when subjects are placed under time pressure. All of these analyses described for Experiment 1 were repeated using experiment (1 *vs* 3) as a between-subjects factor. Appendix 4 reports only those main effects and interactions that involved the factor "experiment". Despite the complexity of these analyses, the results were strikingly similar in the off-line and on-line versions. There were a few small but significant effects involving experiment as a factor. In general, these discrepancies involved a sharpening of word order effects in the on-line version, a tendency that was most evident in English. However, all of these between-experiment findings were relatively small, and none of them reflected a change in the direction of results compared with Experiment 1. Therefore, in the interests of parsimony, we will restrict our discussion to reaction time findings.

Experiment 3a: Word Order Variations in Simple Sentences. The aim of this sub-experiment was to determine whether cross-linguistic differences in reliance on word order are reflected in reaction time. A 2 (English *vs* Italian) $\times$ 3 (word order in the main clause) analysis of variance yielded a significant main effect of word order and a significant interaction between language and word order (see Appendix 5 for statistical details). The main effect of language was not reliable, indicating that English and Italian subjects take approximately the same amount of time to read these sentences (i.e. a mean of 2439 msec, less then 2.5 sec from stimulus onset). These relatively fast reaction times (less then 600 msec per word) suggest to us that subjects are applying familiar strategies borrowed from those

that are used in everyday life. The interaction between language and word order is illustrated in Fig. 6, which shows that English subjects responded faster than Italians on NVN (1895 *vs* 2092 msec) and VNN ((2310 *vs* 2661 msec), and slower on NNV (3024 *vs* 2664 msec). Hence we may conclude that word order has a larger effect on the processing of simple sentences in English than Italian, an effect that is compatible with cross-linguistic differences in agent choice.

Experiment 3b: Interpretation of the Main Clause. The main aim of this sub-experiment was to determine whether cross-linguistic differences in reliance on word order are reflected in reaction times, for complex as well as simple sentences. In addition, we hoped that this analysis would yield new information about the specific processing costs associated with sentence embedding, in canonical versus non-canonical word order types. The materials and design were identical to those of Experiment 1b. Significant findings (listed in Appendix 5) included main effects of all variables, a three-way interaction of language, main clause and relative clause order, and a three-way interaction of language, main clause order and relative clause position. Although this is an intricate nest of findings,

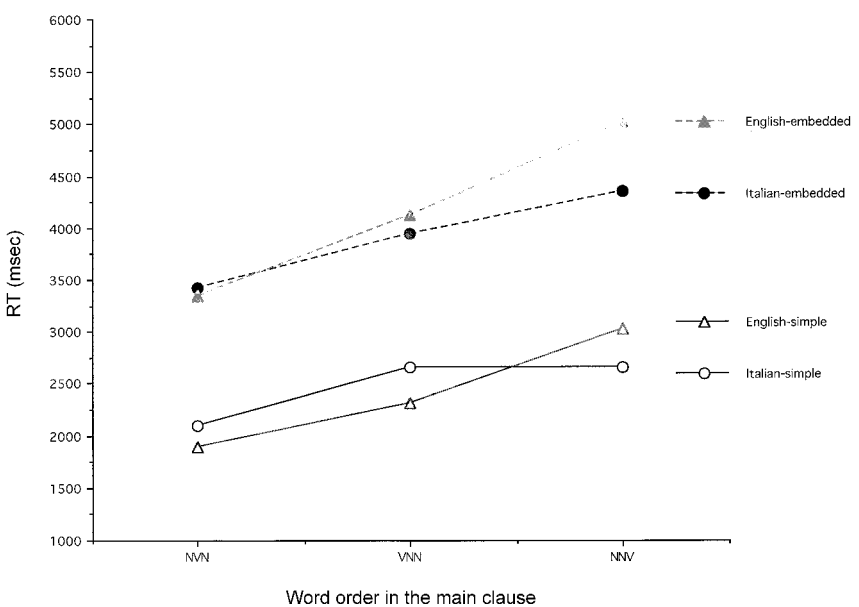


FIG. 6. Reaction times for the interpretation of the main clause in English and Italian, in simple *vs* embedded sentences (Experiments 3a and 3b).

all of them are quite sensible, reflecting variations in processing load that follow from the strategies used in each language.

First, the main effect of order and its intereaction with language are similar to the results that we have already encountered for simple sentences: Canonical NVN is the fastest order in both languages (averaging 3341 msec in English and 3423 msec in Italian), followed by VNN (4172 msec in English and 3950 msec in Italian), with the slowest RTs observed on NNV items (5018 msec in English and 4358 msec in Italian). Of course, these reaction times are considerably slower than the averages obtained with simple sentences, reflecting the additional time required to read and interpret sentences with an embedded clause. The very sharp increase in RTs for NNV reflects the fact that these items suffer the most from centre embedding (i.e. N(rel)NV and NN(rel)V are both centre-embedded items). This situation weights most heavily on English subjects, who are struggling to apply their non-canonical OSV strategy to the main clause in these difficult embedded structures. It has less of an effect on Italian subjects, who have very weak biases on both VNN and NNV, and treat the two indifferently with or without an embedded clause. The language × main clause order interaction for Experiment 3b is also presented in Fig. 6, to facilitate comparison of performance in simple versus complex sentences.

Second, the effect of relative clause order on interpretation of main clauses reflects the additional processing load that arises with the presence of a non-canonical relative (even though subjects do not have to interpret the relative in this section of the experiment). Collapsed over language and other sentence effects, reaction times to interpret the main clause averaged 3898 msec when the relative clause was a canonical VN, compared with 4190 msec when the relative as a non-canonical NV. The interaction between language and relative clause order shows us that this effect of canonicity is much worse for English subjects. In fact, separate analyses of variance within each language showed that the clause order effect was highly reliable for English, but not for Italian. The three-way interaction of language, main clause order and relative clause order is illustrated in Fig. 7, which shows that English subjects find it especially difficult to interpret items in which the main clause is in the order NNV *and* the embedded clause in the order NV, a situation of maximal embedding with non-canonical word order at both levels of the sentence (e.g. "The secretary the cowboy that the policeman shoots sees"). These conditions are apparently far less taxing for Italians, who come to the task with less pronounced word order biases at either level.

Finally, the position effects also reflect the problem posed by centre embedding (i.e. interruption of the main clause). This problem is particularly serious for English subjects, who are trying hard to use their

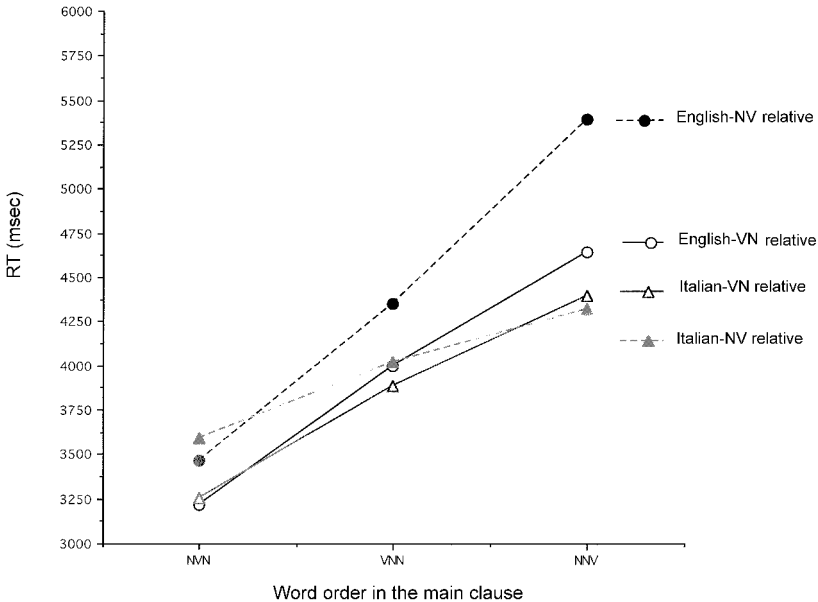


FIG. 7. Reaction times for the interpretation of the main clause as a function of language, order in the main clause and order in the relative (Experiment 3b).

word order strategies in every case. Overall, the main effect of relative clause position reflects slower RTs when the relative modifies the first noun in the main clause (mean = 4140 msec) and faster RTs when the main clause modifies the second noun (mean = 3946 msec). However, this position effect is accounted for entirely by VNN and NVN strings, where early placement of the clause results in a centre embedding, whereas late placement does not. On NNV strings where centre embedding occurs regardless of relative noun position, faster results are obtained with early placement. In fact, NNV items present the most severe problems of centre embedding overall, a situation that is apparently exacerbated when the relative modifies the second noun (giving sentences of the form NN(rel)V). This is true for both languages, but it is especially true for English, as we can see from the three-way interaction of language, main clause order and relative clause position illustrated in Fig. 8.

To summarise the findings for this section, we again find significant cross-linguistic differences in the direction and magnitude of word order effects in the main clause, similar to the effects we have observed in many studies using simple transitive sentences with no embedding. Reaction times reflect larger effects of word order for native speakers of English,

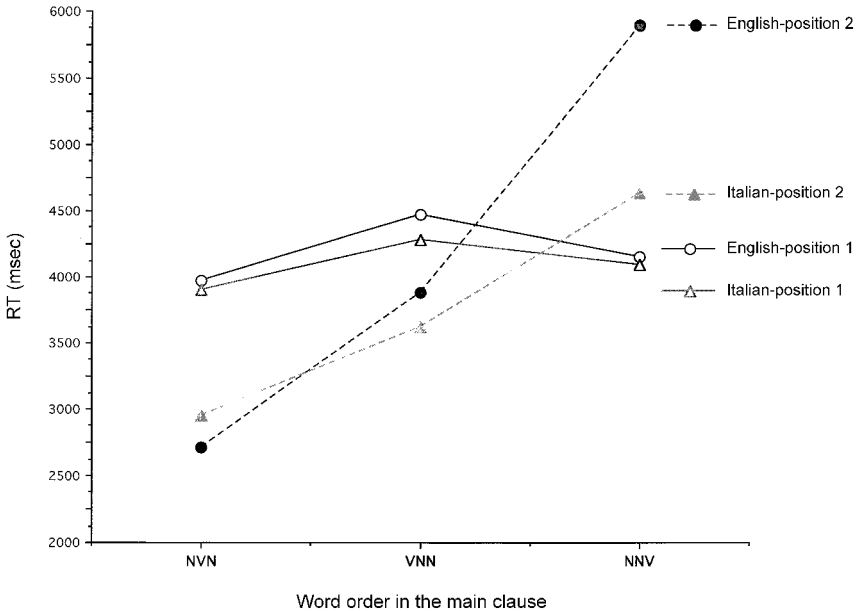


FIG. 8. Reaction times for the interpretation of the main clause as a function of main clause order and relative clause position in English *vs* Italian (Experiment 3b).

who also pay a greater price than Italians do for centre embedding and non-canonical order.

Experiment 3c: Interpretation of the Relative Clause. The main aim of this sub-experiment was to determine whether the cross-linguistic differences in RT to word order variations reported for simple and complex sentences are also observed within the relative clause itself. The materials and design are identical to those of Experiment 1c, covering the 60 complex sentences in which the criminal verb is located within the embedded clause, with the verb of witness in the matrix clause. The analysis of variance yielded a large number of significant effects, which are summarised in Appendix 5.

Again, although this is an intricate set of statistical findings, their interpretation is relatively straightforward. Most of the effects in this analysis are in the same directions for English and Italian, and most of them reflect three general factors: processing is slower in the presence of non-canonical word orders at either level (relative or main clause), processing is slower with heavily embedded items, and interpretations of the relative clause tend to be faster when that clause occurs early in the sentence (modifying the first noun). As we shall see, the second factor (a

disadvantage for centre embedding) and the third factor (an advantage of early placement of the relative clause within the sentence; i.e. an "early bird" effect) work against each other in some sentence types.

First, the effect of main clause order (significant in both languages) means that subjects find it easier to interpret the relative clause when the matrix clause is a canonical NVN (mean RT = 3516 msec for NVN, 4123 msec for VNN and 4134 msec for NNV). This is a straightforward effect of processing load. Similarly, the effect of relative clause order (also significant in both languages) means that interpretation of the relative clause is faster when that clause is a canonical VN (mean = 3742 msec) and slower when it is a non-canonical NV (mean = 4107 msec). This can also be interpreted as an effect of processing load and/or an effect of frequency of clause types (VN is more frequent than NV in both languages). The interaction between main clause and relative clause order is illustrated in Fig. 9, which shows that the fastest reaction times are observed when both levels of the sentence are canonical (NVN sentences with VN relatives). In separate analyses, this interaction only reached significance in English (Appendix 5).

The effects involving relative clause position are a bit more subtle, but they derive primarily from the conflict between availability (an advantage

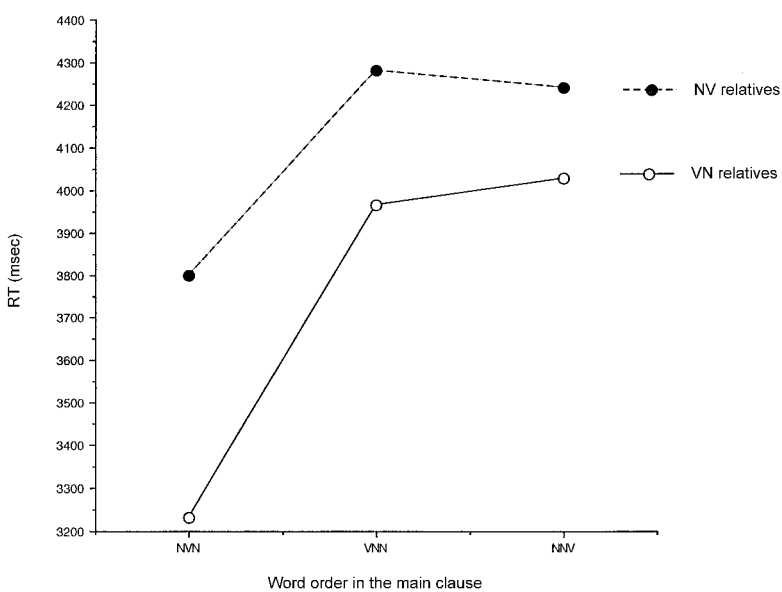


FIG. 9. Reaction times for the interpretation of the relative clause as a function of word order in both the main and relative clause (Experiment 3c).

for early placement) and structural difficulty (especially degree of embeddedness). Overall, a relative clause that occurs early in the sentence (modifying the first noun, mean = 3796 msec) can be interpreted sooner than a relative clause that occurs relatively late (modifying the second noun, mean = 4053 msec). However, in some sentence types, the "early bird" also produces a more thickly embedded sentence, a fact which cancels out any advantages that early placement might otherwise afford. This is evident in Fig. 10, which displays the only effect involving language in this analysis, a complex three-way interaction of language, main clause order and relative clause position. On NVN items, which are easy to process, early placement of the relative provides a substantial advantage in English, despite the fact that early placement also results in centre embedding (i.e. N(rel)VN is easier than NVN(rel)). On VNN items, which are more difficult to process, early placement slows things down in both languages (but more so in English), presumably because early placement results in embedding (VN(rel)N) but late placement does not (VNN(rel)). On NNV items, which are by far the hardest to interpret, early placement offers a substantial advantage (especially in English), and late placement offers a substantial disadvantage (again, especially in English). Presumably, this is the case because embedding occurs in NNV no matter where

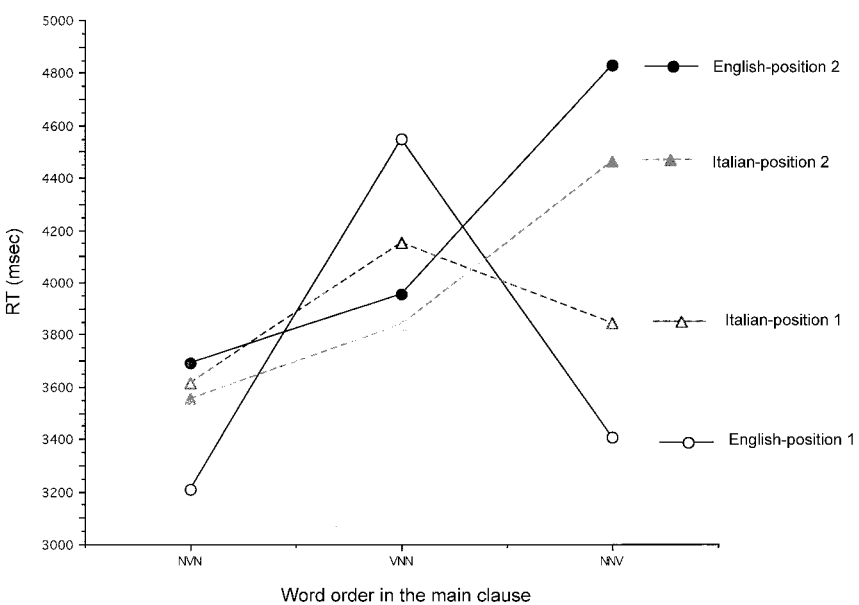


FIG. 10. Effects of main clause order and relative clause position on time to interpret the relative clause in English *vs* Italian (Experiment 3c).

we place the relative (N(rel)NV and NN(rel)V are both centre-embedded structures), leaving the advantage of early placement to operate on its own. Both these factors have a larger effect in English.

Finally, the three-way interaction of main clause order, relative clause order and relative clause placement is illustrated in Fig. 11. This result (which does not interact with language) also reflects the interaction between early availability (a good thing) and embeddedness (a bad thing), as they relate to canonicity (i.e. VN relatives are easier than NV relatives).

To illustrate this last point, note that the easiest relative clauses among the 12 conditions illustrated in Fig. 11 are canonical VN forms that occur in a canonical NVN (in either position), and canonical VN forms that occur very early, right after the first noun in an NNV (resulting in sentences like "The secretary that shot the cowboy the policeman saw"). Although this last structure is non-canonical and heavily embedded at the level of the main clause, it may be easy when subjects have to interpret the relative, because they can stop paying attention to the rest of the sentence after they have processed a well-formed opening fragment (i.e. "The secretary that shot the cowboy . . .").

In the same vein, the hardest relative clauses among the 12 conditions in Fig. 11 are those that involve lethal combinations of non-canonical relative

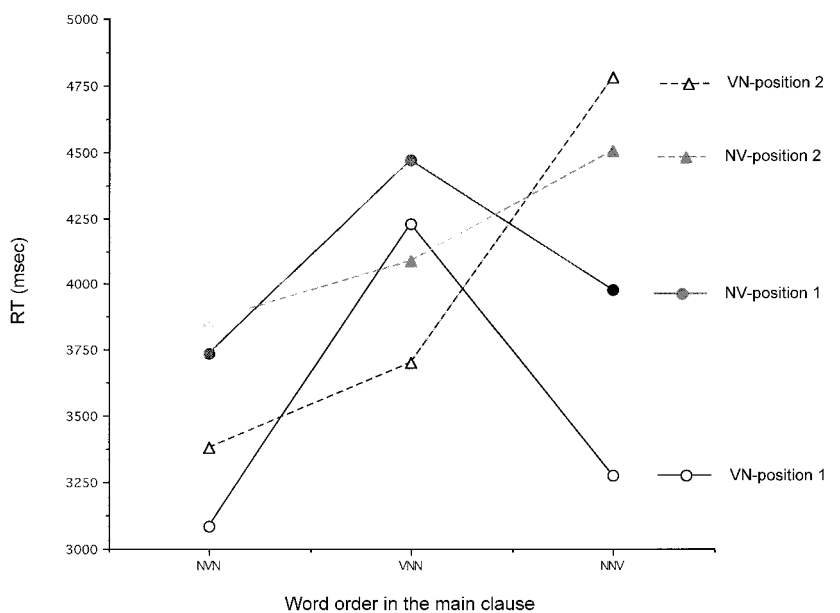


FIG. 11. Reaction times for the interpretation of the relative clause as a function of main clause order, relative clause order and relative clause position (Experiment 3c).

clause order (NV) in a non-canonical matrix (NNV or VNN), with thick centre embedding (e.g. the three worst are NN(VN)V, NN(NV)V and VN(NV)V, in that order). In other words, horrible sentences take a long time to interpret, in both languages, although the price appears to be more severe in English.

Summary of Experiment 3

Reaction time findings in Experiment 3 are intricate, but they boil down to the interaction of some relatively straightforward principles: (1) reaction times are faster for canonical word order types, in both the main clause and the relative clause; (2) centre embeddings take longer to interpret; and (3) interpretation of the relative clause is faster (all other things being equal) when that clause is encountered early in the sentence. These factors operate in both languages, but they exact a great reaction time cost in English, leading to the speculation that embedding costs may be higher in a language that relies heavily on word order information (see Hawkins, 1994, for an extensive discussion of processing costs and linguistic typology).

This brings us to our final comparison, an on-line version of Experiment 2, investigating the effects of variations in subject–verb agreement at both levels of the sentence, in relation to relative clause order and relative clause placement. In this experiment (as in Experiment 2), order in the main clause is held constant, in the canonical NVN. Again, we expect to find larger effects of agreement in Italian, and larger effects of relative clause order and relative clause placement in English, in both agent assignment (noun choice) and reaction times.

EXPERIMENT 4: SUBJECT–VERB AGREEMENT VARIATIONS

Subjects. The subjects for this experiment were 23 American and 23 Italian college students, meeting all the criteria outlined earlier. None of these subjects had participated in Experiments 1, 2 or 3. For analyses comparing Experiments 2 and 4, the last two of the 25 subjects in Experiment 2 were dropped, to equalise sample size.

Procedure. The stimuli were identical to those used in Experiment 2. The instructions, test procedures and scoring criteria were identical to those used in Experiment 3.

Scoring. Trials on which subjects failed to respond within the 5-sec time window were removed from the analysis, with mean agent assignment scores and mean reaction times based on the remaining trials within each

cell. A total of 0.27% of all trials for English subjects and 0.64% of all trials for Italian subjects were removed owing to non-response.

Results and Discussion (see Appendices 4 and 5 for statistical details)

Before exploring the reaction time results obtained in this experiment, we began by examining the results for agent choice, to determine whether the results obtained off-line in Experiment 2 replicate when subjects are placed under time pressure. All of the analyses described for Experiment 2 were repeated using experiment (2 *vs* 4) as a between-subjects factor (see Appendix 4). The results were identical for Experiments 2a and 4a, and for Experiments 2b and 4b (i.e. there were no main effects of interactions involving the factor "experiment"). Results for the third part of the experiment (interpretation of the relative clause, Experiment 2c *vs* Experiment 4c) were also similar in direction and magnitude, although there were a few small effects involving experiment as a factor. All of these effects were significant in Italian, but not in English. Examination of cell means led us to the culprit: The worst cell occurs in the Italian on-line condition, where an NV clause (non-canonical) occupies first position (maximal embedding), with ambiguous relative clause agreement (so that Italians cannot rely on their favourite cue). Italians are driven to random performance in this cell (50.4% object-relative interpretations, compared with 75% object-relative interpretations in the equivalent cell off-line). Interestingly, English subjects reach an object-relative interpretation 93.5% of the time in the same on-line cell. Hence the processing costs experienced by English and Italian speakers diverge in this particular condition, suggesting that English listeners are resistant (because they are not trying to use agreement information) while Italians are vulnerable (because they are trying very hard to use agreement information under the worst possible conditions). In all other respects, the off-line and on-line versions yield comparable results for agent choice. Therefore, in the interests of parsimony, we will restrict our discussion of Experiment 4 to reaction time findings.

Experiment 4a: Agreement in Simple Sentences. The main aim of this sub-experiment was to determine whether cross-linguistic differences in the use of subject–verb agreement are also reflected in reaction times, for simple sentences in the visual modality. Reaction times for the 15 sentences in this sub-experiment were analysed in a 2 × 3 design, with language treated as a between-subjects factor and agreement as a within-subjects factor (see Appendix 5 for details). The main effect of language was large and reliable, reflecting much faster RTs in English (mean =

1416 msec) than Italian (mean = 2170 msec). Note also that the overall mean RTs in this experiment (1793 msec) are 761 msec faster than the mean RTs observed for simple sentences under the word order variations manipulated in Experiment 3a (2440 msec). Both these findings are due to the fact that all sentences in this section are in the canonical NVN order, a situation that leads to substantially faster reaction times overall, but especially in English. The main effect of agreement did not reach significance by the $P < 0.01$ standard, nor did we find the expected interaction between language and agreement. This contrasts with other experiments in our laboratories, in which Italians were faster than English subjects with converging agreement (i.e. agreement with the first noun on NVN) and slower with competing agreement (i.e. agreement with the second noun on NVN). As we shall see below, the predicted interaction does appear in main clauses modified by a relative (Experiment 4b).

To summarise the results for simple sentences, Italians show much stronger effects of agreement variation than their English counterparts in off-line and on-line agent choice. Contrary to our expectations, this interaction does not show up in reaction times. However, the RT data do show that English listeners are much faster overall to interpret these canonical NVN strings.

Experiment 4b: Interpretation of the Main Clause. The main aim of this sub-experiment was to uncover cross-linguistic differences in the RT profiles associated with differential use of subject–verb agreement within the main clause in complex sentences. The materials and design were identical to those in Experiment 2b with 180 complex items in which the criminal verb is located in the main clause. This RT analysis yielded a large number of significant effects (see Appendix 5), including a significant four-way interaction of language with agreement, order and position within the relative clause.

The main effect of language reflects much faster reaction times in English (mean = 2444 msec) than Italian (mean = 3433 msec). Bearing in mind that all the main clauses in Experiment 4b are in the canonical NVN order, this result reflects the basic findings for agent choice described earlier. That is, English listeners apply their SVO strategies across the board, despite the various manipulations that we have imposed, while Italians vacillate between SVO and OVS in interaction with other factors. As a result, English listeners are much more efficient in this part of the study, while Italians pay a price for their willingness to accept OVS interpretations.

The interaction between language and main clause agreement confirms our prediction that Italians are influenced more by a competition between main clause order and main clause agreement. For Italians, reaction times

averaged 3157 msec with first-noun agreement, 3087 msec for ambiguous items and 4056 msec for competition items (which are usually interpreted as a non-canonical OVS). For Americans, reaction times averaged 2361 msec with first-noun agreement, 2394 msec for ambiguous items and 2576 msec for competition items (which are interpreted as a canonical SVO). The competition effect proved to be reliable in both languages when the data were analysed separately, so this language difference is simply a matter of degree.

All of the remaining main effects and interactions can be understood in terms of variations in processing load. Factors that slow down interpretation of the matrix clause include non-canonical agreement (with the second noun in the main clause; with the embedded noun in the relative clause), non-canonical word order (NV in the relative) and centre embedding (when the relative modifies the first noun in these NVN strings). These factors apply to some extent in both language groups. However, our findings for agent assignment clearly indicate that English speakers "trust" word order and Italian speakers "trust" agreement at both levels of the sentence. Hence, in this sub-experiment, we should expect bigger effects of relative clause order and embedding on reaction times in English, and bigger effects of main and relative clause agreement on reaction times in Italian. The results are largely in line with these predictions.

First, the main effect of relative clause order reflects faster RTs in the presence of a canonical VN relative (mean = 2849 msec) and slower RTs when the main clause is modified by a non-canonical NV relative (mean = 3028 msec). This variable does not interact with language, which means that both language groups slow down in the presence of an NV relative (note that the main effect of relative clause order just misses significance, $P < 0.012$, when English is analysed separately; see Appendix 5).

Second, the main effect of relative clause position reflects faster RTs when the relative modifies the second noun (no centre embedding, mean = 2384 msec) and slower RTs when the relative modifies the first noun (with centre embedding, mean = 3492 msec). This embedding effect also holds in both languages, but the significant language × position interaction tells us that the cost of centre embedding is greater in English (mean RT in position 1 = 3179 msec *vs* 1710 msec in position 2) than Italian (mean RT in position 1 = 3807 msec *vs* 3059 msec in position 2).

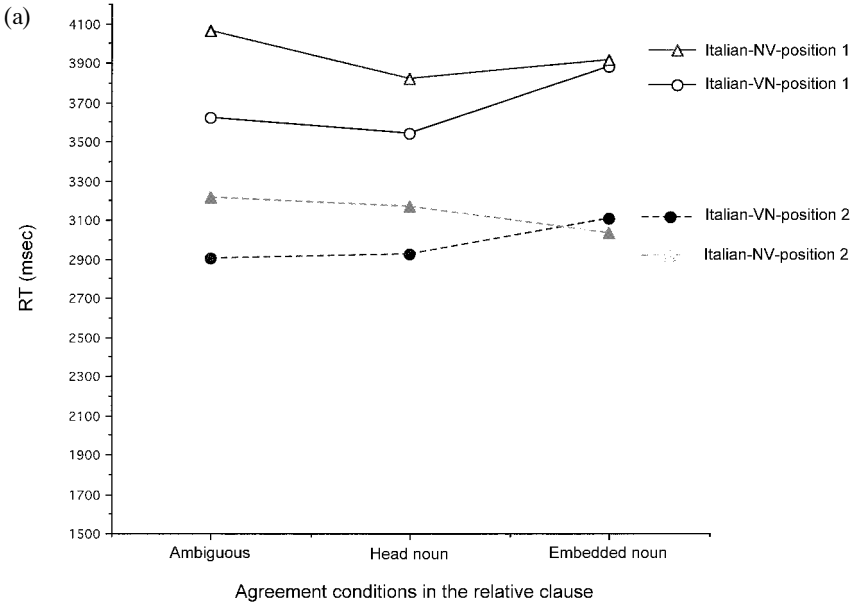
Finally, there was no significant main effect for relative clause agreement, but this variable did interact with a number of other factors, including language. For the sake of economy, we will restrict our discussion to the four-way interaction, because this higher-order interaction subsumes most of the other effects. As before, we began our exploration of this complex interaction by conducting separate analyses in English and Italian.

Figure 12a illustrates the relationships among relative clause agreement, order and position in Italian. This three-way interaction was not reliable for Italians alone. Hence the pattern for Italians in Fig. 12a actually reflects three separate results: (1) a main effect of relative clause order (with slower RTs in the presence of an NV relative), (2) a large main effect of position (with slower RTs with the RT in position 1), and (3) a two-way interaction of relative clause agreement and relative clause order. The interaction (see Fig. 12a) shows that the advantage of canonical order (VN) within the relative clause is wiped out in Italian when agreement runs in the opposite direction.

The corresponding results for English are illustrated in Fig. 12b. A separate analysis of the English data shows that the full three-way interaction is statistically reliable. The most obvious feature in Fig. 12b is the massive effect of embedding, with RTs in centre-embedded sentences that are more than 1000 msec longer than RTs on sentences that end in a relative clause. It is also clear from Fig. 12b that the RT difference between "easy" VN and "hard" NV relatives is relatively small, which means that the distracting effect of a non-canonical relative is not as troublesome for the English group in this part of the experiment. For our English subjects, the most troublesome cell in the design contains items with the relative clause in the first position (embedded sentences), in NV order (a non-canonical form), where the verb inside the relative clause agrees with the head noun (in direct competition with an NV interpretation). Hence English listeners are not entirely immune to the distracting effects of relative clause agreement, but such effects are only observed under the worst possible conditions of embedding and non-canonicity.

To summarise the results for interpretation of the main clause, there are larger effects of word order and embedding in English, and larger effects of agreement in Italian, in accord with the predictions of the Competition Model. However, processing costs are in the same general direction for both groups (i.e. slower RTs with centre embedding, and in the presence of a non-canonical relative clause).

Experiment 4c: Interpretation of the Relative Clause. The main aim of this final sub-experiment was to assess cross-linguistic differences in the processing costs associated with variations in agreement inside the relative clause. In particular, we predicted that agreement effects within the relative would be greater for Italians. The materials and design were identical to those in Experiment 2c. Once again, there were a large number of significant effects (see Appendix 5), including a four-way interaction of language with all three relative clause factors (agreement and order within the clause, and position of the clause within the sentence).



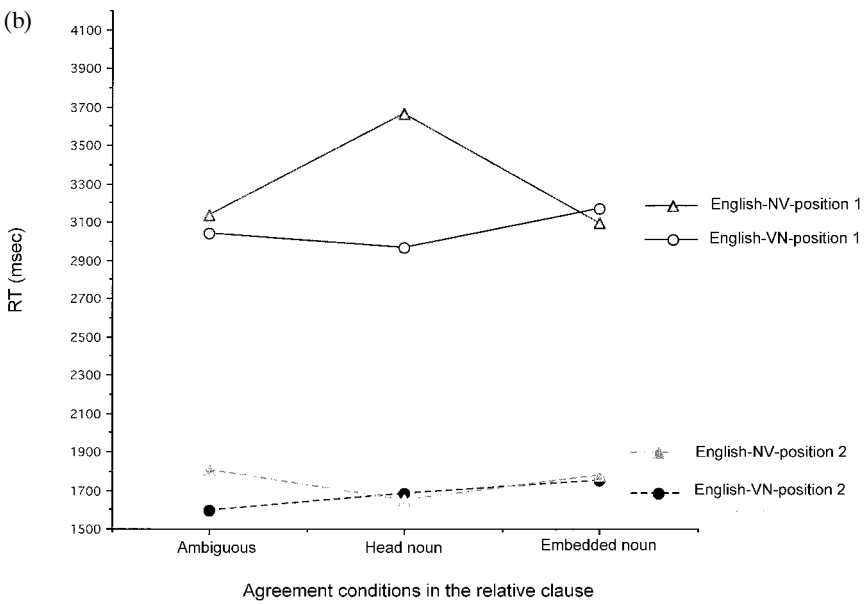


FIG.12. (a) Effects of relative clause agreement, order and position on time to interpret the main clause, in Italian only (Experiment 4b). (b) Effects of relative clause agreement, order and position on time to interpret the main clause, in English only (Experiment 4b).

All of these effects reflect a combination of cross-linguistic differences (i.e. relative clause agreement is more important in Italian; relative clause order and position are more important in English) and variations in processing load that apply in both languages. The processing facts (which may be universal) are the same ones described earlier: (1) reaction times are slower in the presence of non-canonical forms (when the verb in the main clause agrees with the second noun; when either word order or agreement in the relative clause favour an object-relative interpretation), and (2) reaction times are slower in the presence of embedding, although (3) early placement of the relative can provide an RT advantage (an "early bird" strategy).

First, the main effect of agreement within the main clause was in line with our predictions, reflecting slower performance with agreement on the second noun (a competition between default SVO and agreement-induced OVS). As expected, separate analyses for each language showed that this effect only reached significance in Italian. In other words, because English speakers do not care very much about agreement, a violation of agreement in the main clause does not delay their interpretations of the relative. In contrast, the same effect increases processing load for Italians, and slows them down across the board.

Second, the main effect of agreement within the relative clause reflects slower performance when agreement supports an object-relative interpretation (mean = 3289 msec), compared with roughly similar RTs for morphologically ambiguous relatives (mean = 3051 msec) and for items in which agreement fosters a subject-relative interpretation (mean = 3079 msec). In accord with our predictions, separate analyses within each language showed that this agreement manipulation does not reach significance in English but is highly reliable in Italian. Hence it is the Italian group that is most affected by agreement manipulations, at both levels of the sentence.

Third, the main effect of relative clause order reflects faster performance on canonical VN clauses (mean = 2940 msec) and slower performance on non-canonical NV clauses (mean = 3339 msec). In this case, there was no two-way interaction with language, indicating that relative clause order is important for both groups However, there was a reliable three-way interaction of language with relative clause agreement and relative clause order, illustrated in Fig. 13. Several aspects of our results are evident in Fig. 13, including the much greater reaction time advantage for English subjects, who rely faithfully on word order and pay little attention to agreement. It is also clear from Fig. 13 that the three-way interaction is coming from Italian, where there is a crossover interaction between order and agreement within the relative clause: Italians are slower on NV clauses when agreement is ambiguous or when agreement and NV order are in

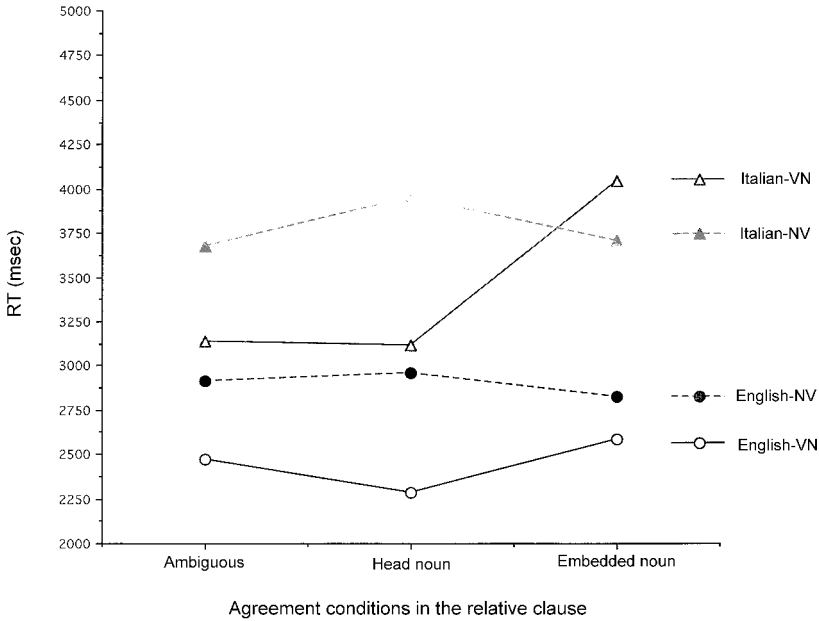


FIG. 13. Effects of order and agreement within the relative clause on time to interpret the relative clause (Experiment 4c).

competition, but they are faster on NV clauses when agreement and order converge. These reaction time results mirror our findings for agent choice, both on-line and off-line, and they are also similar to the subtle three-way interactions observed for interpretation of the main clause in Experiment 4b.

The remaining effects all involve relative clause position, and it is here that we begin to see some language-specific processing costs in English. The main effect of position is the same in both languages, an "early bird" effect with faster RTs for early relatives (mean = 2974 msec) and slower RTs for later relatives (mean = 3305 msec). However, the advantages of early placement may be counteracted in some cases by the costs associated with centre embedding. In fact, separate analyses of English and Italian reveal that all interactions of relative clause position with the other factors are coming from the English group. This includes the interaction between relative clause order and position, and the three-way interaction of position, order and agreement within the relative clause. The three-way interaction for English alone is presented in Fig. 14, which illustrates several interesting facts. First, there is no difference between canonical VN and non-canonical NV when these clauses occur late in the sentence (i.e.

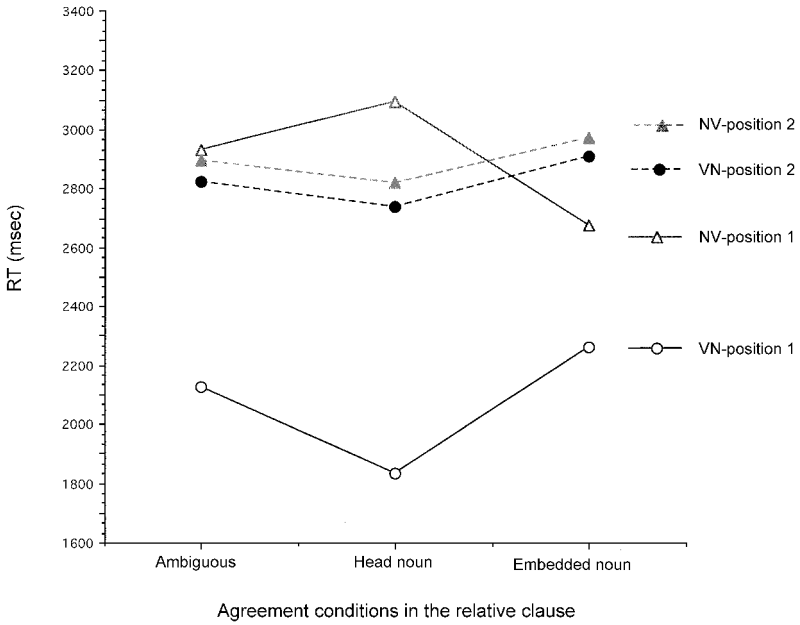


FIG. 14. Effects of order, agreement and position of the relative clause on time to interpret the relative clause, for English only (Experiment 4c).

with no centre embedding), nor can we find any evidence that relative clause agreement makes a difference when the clause occurs in sentence-final position, outside of the matrix sentence. Second, English speakers respond very quickly and efficiently to "early bird" relatives that modify the first noun, but only if the relative is a canonical VN. In this case, we also find some facilitation from converging agreement. These findings make sense if we remember that these items lend themselves to early interpretation, with processing interrupted half way through the sentence (e.g. "The secretary that shoots the cowboys . . ."). This is less true for NV clauses in first position, particularly when there is competition between order and agreement (e.g. "The secretaries that the cowboy shoot . . ."). In these cases, the advantage of early placement is apparently overcome by the disadvantages of embedding and non-canonical form.

In general, the results for this section support the view that word order is the major factor influencing interpretation of the relative clause in English, although English reaction times are also affected by degree of embedding and the presence of non-canonical forms. Subject–verb agreement is the major determinant of relative clause interpretation in Italian, although non-canonical word order does exact a cost.

Summary of Experiment 4

We have uncovered some extraordinarily complex effects in this experiment, but the major findings are in the directions predicted by the Competition Model. English subjects show a marked RT advantage overall (due to the canonical order of the matrix clause), but they also display greater effects of centre embedding, interacting with canonical form in the relative clause. Italian subjects show pronounced effects of subject–verb agreement at both levels of the sentence, evidenced in large delays when canonical word order and subject-verb agreement are in competition, in either the main clause or the relative clause. At the same time, Italians show relatively few effects of embedding in their reaction time data. Hence our results suggest that the costs associated with centre embedding are greater in languages that rely heavily on word order, and lighter (although still present) in languages that rely more on morphological information. We may speculate that the costs of centre embedding are lower in a richly inflected language because listeners can sometimes rely on "local" solutions to agent interpretation, while English listeners have to keep the topology of the sentence in mind in order to reach an interpretation.

CONCLUSIONS

The main aim in this study was to determine whether (and to what extent) the cross-linguistic differences in sentence interpretation that we have observed with simple sentences also generalise to complex sentences with an embedded clause. After this long journey, we can say with some confidence that the answer is "yes". Native speakers of English rely primarily on word order information, in simple sentences, in the main clause of sentences with a relative clause, and inside the relative clause itself. This tendency is evident in their sentence interpretations both on-line and off-line, and in the speed with which solutions are reached in the on-line versions of each experiment. Native speakers of Italian rely primarily on subject–verb agreement, in both the main clause and the relative clause, despite variations in word order, canonicity and degree of centre embedding. This tendency is also evident on-line and off-line, in agent choice and in reaction times.

In both languages, these tendencies do break down under some structural conditions. For example, English speakers fall towards chance when they have to interpret horrific centre embeddings like "The secretary the cowboy that the policeman shoots sees". Italian speakers also fall towards chance when they are forced to interpret non-canonical centre-embedded structures with no morphological contrasts. Hence there are

clear limits on processing strategies that characterise and differentiate performance in these languages.

Between the two extremes of language-specific performance and random behaviour, the reaction time results of Experiments 3 and 4 provide some insights into universal processing costs and their language-specific instantiations. For both language groups, processing is more difficult (and reaction times are slowed accordingly) in the presence of non-canonical structures, at either level of the sentence. This includes non-canonical word orders (NNV and VNN in the main clause; NV in the relative) and forms of agreement that compete with canonical word order (agreement on the second noun in an NVN main clause; agreement with the embedded noun in a VN relative or with the head noun in an NV relative). In both languages, centre embedding can slow the interpretation of a main clause, although the magnitude of this embedding cost depends on other factors. Early placement can hasten the interpretation of a relative clause (i.e. the "early bird" effect), but this factor also interacts with other structural facts (especially the interplay between early placement and centre embedding).

Although these processing costs are observed in both languages (and might be put forward as candidates for "processing universals"), there are also robust cross-linguistic differences in the price that must be paid. English listeners pay a larger price for centre embedding, leading us to speculate that resistance to centre embedding may be a natural by-product of heavy reliance on word order (i.e. the "dark side" of a word order language). Italians are less affected by centre embedding, at least within the variations that we have attempted here, a fact that may result from the application of "local" solutions in a language that relies heavily on agreement morphology. However, Italians do pay a significant cost in processing time when agreement must compete with a strong (albeit non-deterministic) word order bias. Agreement does "win" in such situations, but only after a measurable delay. We must assume that such dilemmas rarely come up in everyday life for Italian speakers, due to the convergence of lexical, prosodic and contextual information that usually applies when non-canonical word orders are used. But when competition does occur, and other favourite sources of information are not around to settle the fight, Italians pay a greater cost than English speakers (who really don't care very much about any source of information other than word order).

Of course, more research is needed to achieve a more complete understanding of cross-linguistic similarities and differences in the time course of language processing. However, the cross-language differences that we have uncovered here regarding preferred interpretations of complex sentences and their associated processing costs have interesting

implications not only for future psycholinguistic research, but for typological and diachronic linguistics. Theorists like Hawkins (1994) and Givón (1995) have speculated about the role of processing constraints on historical language change, and on the class of languages that can be processed in real time. Although these hypotheses are well grounded in linguistic data, and appear to have considerable face validity (based on introspection about what is "hard" or "easy" in one's native language), cross-linguistic studies of on-line sentence processing may provide a more solid grounding to speculations about the factors that force historical language change. The results presented here suggest that the costs associated with centre embedding and the costs involved in processing of non-canonical word order types are both greater in a language that relies heavily on word order. Conversely, the costs associated with pockets of morphological ambiguity and real or illusive morphological competition may be greater in a language that permits extensive word order variation. Hence we may find that different languages have different "breaking points" when the communicative process is placed under pressure, in the lifetime of an individual and perhaps in the lifetime of the language itself.

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APPENDIX 1

Italian/English relative clause experiment: Nouns and verbs used

Italian	*English*	*Italian*	*English*
N1S (animals)	**N1S (animals)**	**N1P (animals)**	**N1P (animals)**
il cane	the dog	i cani	the dogs
la puzzola	the skunk	le puzzole	the skunks
la talpa	the mole	le talpe	the moles
il cavallo	the horse	i cavalli	the horses
il canguro	the kangaroo	i canguri	the kangaroos
il gatto	the cat	i gatti	the cats
l'elefante	the elephant	gli elefanti	the elephants
il leone	the lion	i leoni	the lions
la tigre	the tiger	le tigri	the tigers
la mucca	the cow	le mucche	the cows
la foca	the seal	le foche	the seals
la giraffa	the giraffe	le giraffe	the giraffes
N2S (humans)	**N2S (humans)**	**N2P (humans)**	**N2P (humans)**
il falegname	the carpenter	i falegnami	the carpenters
la maestra	the teacher	le maestre	the teachers
la segretaria	the secretary	le segretarie	the secretaries
il dottore	the doctor	i dottori	the doctors
il parrucchiere	the hairdresser	i parrucchieri	the hairdressers
il professore	the professor	i professori	the professors
la cameriera	the waitress	le cameriere	the waitresses
il cuoco	the cook	i cuochi	the cooks
il contadino	the farmer	i contadini	the farmers
la ballerina	the ballerina	le ballerine	the ballerinas

Italian/English relative clause experiment: Nouns and verbs used

Italian	*English*	*Italian*	*English*
il soldato	the soldier	i soldati	the soldiers
il pagliaccio	the clown	i pagliacci	the clowns
il dentista	the dentist	i dentisti	the dentists
V1S	**V1S**	**V1P**	**V1P**
picchia	strikes	picchiano	strike
morde	bites	mordono	bite
tira	shoots	tirano	shoot
colpisce	hits	colpiscono	hit
rompe	breaks	rompono	break
graffia	scratches	graffiano	scratch
uccide	murders	uccidino	murder
pizzica	pinches	pizzicano	pinch
brucia	burns	bruciano	burn
suffoca	suffocates	soffocano	suffocate
spinge	pushes	spingono	push
strozza	strangles	strozzano	strangle
distrugge	destroys	distruggono	destroy
ammazza	kills	ammazzano	kill
bastona	beats	bastonano	beat
V2S	**V2S**	**V2P**	**V2P**
vede	sees	vedono	see
aspetta	expects	aspettano	expect
sente	hears	sentono	hear
ascolta	listens to	ascoltano	listen to
guarda	watches	guardano	watch
chiama	calls	chiamano	call
cerca	seeks	cercano	seek
segue	follows	seguono	follow
osserva	observes	osservano	observe

APPENDIX 2

Sample English Sentences for Experiments 1–4[a, b]

Experiments 1 and 3: Word order variations

1a/3a: Simple sentences only

NVN: The secretary shoots the cook
NNV: The secretary the cook shoots
VNN: Shoots the secretary the cook

1b/3b: Main clause interpretation

NVN: The secretary that sees the doctor shoots the cook (rel. pos. 1, VN)
The secretary that the doctor sees shoots the cook (rel. pos. 1, NV)

	The secretary shoots the cook that sees the doctor	(rel. pos. 2, NV)
	The secretary shoots the cook that the doctor sees	(rel. pos. 1, VN)
NNV:	The secretary that sees the doctor the cook shoots	(rel. pos. 1, VN)
	The secretary that the doctor sees the cook shoots	(rel. pos. 1, NV)
	The secretary the cook that sees the doctor shoots	(rel. pos. 2, VN)
	The secretary the cook that the doctor sees shoots	(rel. pos. 2, NV)
VNN:	Shoots the secretary that sees the doctor the cook	(rel. pos. 1, VN)
	Shoots the secretary that the doctor sees the cook	(rel. pos. 1, NV)
	Shoots the secretary the doctor that sees the cook	(rel. pos. 2, VN)
	Shoots the secretary the doctor that the cook sees	(rel. pos. 1, NV)

1c/3c: Relative clause interpretation

NVN:	The secretary that shoots the doctor sees the cook	(rel. pos. 1, VN)
	The secretary that the doctor shoots sees the cook	(rel. pos. 1, NV)
	The secretary sees the cook that shoots the doctor	(rel. pos. 2, VN)
	The secretary sees the cook that the doctor shoots	(rel. pos. 2, NV)
NNV:	The secretary that shoots the doctor the cook sees	(rel. pos. 1, VN)
	The secretary that the doctor shoots the cook sees	(rel. pos. 1, NV)
	The secretary the cook that shoots the doctor sees	(rel. pos. 2, VN)
	The secretary the cook that the doctor shoots sees	(rel. pos. 2, NV)
VNN:	Sees the secretary that shoots the doctor the cook	(rel. pos. 1, VN)
	Sees the secretary that the doctor shoots the cook	(rel. pos. 1, NV)
	Sees the secretary the doctor that shoots the cook	(rel. pos. 2, VN)
	Sees the secretary the doctor that the cook shoots	(rel. pos. 2, NV)

Experiments 2 & 4: Agreement Variations[3]

2a/4a: Simple sentences only

Ag0:	The secretary shoots the doctor
Ag1:	The secretary shoots the doctors
Ag3:	The secretary shoot the doctors

2b/4b: Main clause interpretation

Ag0:	The secretary that sees the doctor shoots the cook	(rel. pos. 1, VN, Ag0 rel)
main	The secretary that the doctor sees shoots the cook	(rel. pos. 1, NV, Ag0 rel)
	The secretary that sees the doctors shoots the cook	(rel. pos. 1, VN, Ag1 rel)
	The secretary that the doctors sees shoots the cook	(rel. pos. 1, NV, Ag1 rel)
	The secretary that see the doctors shoots the cook	(rel. pos. 1, VN, Ag2 rel)
	The secretary that the doctors see shoots the cook	(rel. pos. 1, NV, Ag2 rel)
	The secretary shoots the cook that sees the doctor	(rel. pos. 2, VN, Ag0 rel)
	The secretary shoots the cook that the doctor sees	(rel. pos. 2, NV, Ag0 rel)
	The secretary shoots the cook that sees the doctors	(rel. pos. 2, VN, Ag1 rel)
	The secretary shoots the cook that the doctors sees	(rel. pos. 2, NV, Ag1 rel)
	The secretary shoots the cook that see the doctors	(rel. pos. 2, VN, Ag2 rel)
	The secretary shoots the cook that the doctors sees	(rel. pos. 2, NV, Ag2 rel)
Ag1:	The secretary that sees the doctor shoots the cooks	(rel. pos. 1, VN, Ag0 rel)
main	The secretary that the doctor sees shoots the cook	(rel. pos. 1, NV, Ag0 rel)
	The secretary that sees the doctors shoots the cooks	(rel. pos. 1, VN, Ag1 rel)

	The secretary that the doctors sees shoots the cooks	(rel. pos. 1, NV, Ag1 rel)
	The secretary that see the doctors shoots the cooks	(rel. pos. 1, VN, Ag2 rel)
	The secretary that the doctors see shoots the cooks	(rel. pos. 1, NV, Ag2 rel)
	The secretary shoots the cooks that sees the doctor	(rel. pos. 2, VN, Ag0 rel)
	The secretary shoots the cooks that the doctor sees	(rel. pos. 2, NV, Ag0 rel)
	The secretary shoots the cooks that sees the doctors	(rel. pos. 2, VN, Ag1 rel)
	The secretary shoots the cooks that the doctors sees	(rel. pos. 2, NV, Ag1 rel)
	The secretary shoots the cooks that see the doctors	(rel. pos. 2, VN, Ag2 rel)
	The secretary shoots the cooks that the doctors see	(rel. pos. 2, NV, Ag2 rel)
Ag2:	The secretary that sees the doctor shoot the cooks	(rel. pos. 1, VN, Ag0 rel)
main	The secretary that the doctor sees shoot the cooks	(rel. pos. 1, NV, Ag0 rel)
	The secretary that sees the doctors shoot the cooks	(rel. pos. 1, VN, Ag1 rel)
	The secretary that the doctors sees shoot the cooks	(rel. pos. 1, NV, Ag1 rel)
	The secretary that see the doctors shoot the cooks	(rel. pos. 1, VN, Ag2 rel)
	The secretary that the doctors see shoot the cooks	(rel. pos. 1, NV, Ag2 rel)
	The secretary shoot the cooks that sees the doctor	(rel. pos. 2, VN, Ag0 rel)
	The secretary shoot the cooks that the doctor sees	(rel. pos. 2, NV, Ag0 rel)
	The secretary shoot the cooks that sees the doctors	(rel. pos. 2, VN, Ag1 rel)
	The secretary shoot the cooks that the doctors sees	(rel. pos. 2, NV, Ag1 rel)
	The secretary shoot the cooks that see the doctors	(rel. pos. 2, VN, Ag2 rel)
	The secretary shoot the cooks that the doctors see	(rel. pos. 2, NV, Ag2 rel)

2c/4c: Relative clause interpretation

Ag0:	The secretary that shoots the doctor sees the cook	(rel. pos. 1, VN, Ag0 rel)
main	The secretary that the doctor shoots sees the cook	(rel. pos. 1, NV, Ag0 rel)
	The secretary that shoots the doctors sees the cook	(rel. pos. 1, VN, Ag1 rel)
	The secretary that the doctors shoots sees the cook	(rel. pos. 1, NV, Ag1 rel)
	The secretary that shoot the doctors sees the cook	(rel. pos. 1, VN, Ag2 rel)
	The secretary that the doctors shoot sees the cook	(rel. pos. 1, NV, Ag2 rel)
	The secretary sees the cook that shoots the doctor	(rel. pos. 2, VN, Ag0 rel)
	The secretary sees the cook that the doctor shoots	(rel. pos. 2, NV, Ag0 rel)
	The secretary sees the cook that shoots the doctors	(rel. pos. 2, VN, Ag1 rel)
	The secretary sees the cook that the doctors shoots	(rel. pos. 2, NV, Ag1 rel)
	The secretary sees the cook that shoot the doctors	(rel. pos. 2, VN, Ag2 rel)
	The secretary sees the cook that the doctors shoot	(rel. pos. 2, NV, Ag2 rel)
Ag1:	The secretary that shoots the doctor sees the cooks	(rel. pos. 1, VN, Ag0 rel)
main	The secretary that the doctor shoots sees the cooks	(rel. pos. 1, NV, Ag0 rel)
	The secretary that shoots the doctors sees the cooks	(rel. pos. 1, VN, Ag1 rel)
	The secretary that the doctors shoots sees the cooks	(rel. pos. 1, NV, Ag1 rel)
	The secretary that shoot the doctors sees the cooks	(rel. pos. 1, VN, Ag2 rel)
	The secretary that the doctors shoot sees the cooks	(rel. pos. 1, NV, Ag2 rel)
	The secretary sees the cooks that shoots the doctor	(rel. pos. 2, VN, Ag0 rel)
	The secretary sees the cooks that the doctor shoots	(rel. pos. 2, NV, Ag0 rel)
	The secretary sees the cooks that shoots the doctors	(rel. pos. 2, VN, Ag1 rel)
	The secretary sees the cooks that the doctors shoots	(rel. pos. 2, NV, Ag1 rel)
	The secretary sees the cooks that shoot the doctors	(rel. pos. 2, VN, Ag2 rel)
	The secretary sees the cooks that the doctors shoots	(rel. pos. 2, NV, Ag2 rel)

Ag2:	The secretary that shoots the doctor see the cooks	(rel. pos. 1, VN, Ag0 rel)
main	The secretary that the doctor shoots see the cooks	(rel. pos. 1, NV, Ag0 rel)
	The secretary that shoots the doctors see the cooks	(rel. pos. 1, VN, Ag1 rel)
	The secretary that the doctors shoots see the cooks	(rel. pos. 1, NV, Ag1 rel)
	The secretary that shoot the doctors see the cooks	(rel. pos. 1, VN, Ag2 rel)
	The secretary that the doctors shoot see the cooks	(rel. pos. 1, NV, Ag2 rel)
	The secretary see the cooks that shoots the doctor	(rel. pos. 2, VN, Ag0 rel)
	The secretary see the cooks that the doctor shoots	(rel. pos. 2, NV, Ag0 rel)
	The secretary see the cooks that shoots the doctors	(rel. pos. 2, VN, Ag1 rel)
	The secretary see the cooks that the doctors shoots	(rel. pos. 2, NV, Ag1 rel)
	The secretary see the cooks that shoot the doctors	(rel. pos. 2, VN, Ag2 rel)
	The secretary see the cooks that the doctors shoot	(rel. pos. 2, NV, Ag2 rel)

[a]For the sake of economy, only English examples are listed; Italian items are direct translations, with verbs in the present indicative (e.g. "shoots" = *spara*; "shoot" = *sparano*).

[b]The same lexical items are used in all examples to facilitate comparison; actual stimuli contain five different randomised assignments of lexical items to conditions (see Table 1).

[c]These examples are restricted to cases in which the first noun is singular and the second noun is plural on all items with an agreement contrast; in the full set of stimuli, plural *vs* singular nouns and verbs are counterbalanced across all agreement conditions.

Abbreviation: rel. pos. = relative position.

APPENDIX 3

Off-line choice ANOVA: Significant results[a]

		Overall			*English only*			*Italian only*		
Experiment	*Source*	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
1a: simple sentences	language	1,48	16.14	0.0001						
	word order	2,96	71.73	0.0001	2,48	71.36	0.0001	2,48	13.81	0.0001
	language × word order	2,96	11.21	0.0001						
1b: main clause	language	1,48	26.85	0.0001						
	main clause order (MCO)	2,96	60.99	0.0001	2,48	66.03	0.0001	2,48	8.16	0.001
	relative clause position (RCP)	1,48	9.68	0.003	1,24	15.96	0.001			
	language × MCO	2,96	14.58	0.0001						
	MCO × RCP	2,96	8.26	0.001	2,48	20.28	0.0001			
	language × MCO × RCP	2,96	7.13	0.001						
1c: relative clause	main clause order (MCO)	2,96	6.64	0.002				2,48	5.32	0.008
	relative clause order (RCO)	1,48	98.72	0.0001	1,24	61.05	0.0001	1,24	8.16	0.0001
	language × RCO	1,48	8.74	0.005						
	MCO × RCO	2,96	9.9	0.003				2,48	10.37	0.0001
	language × MCO × RCO	2,96	6.31	0.003						
2a: simple sentences	language	1,48	44.16	0.0001						
	agreement	2,96	41.26	0.0001				2,48	42.98	0.0001
	language × agreement	2,96	25.36	0.0001						

APPENDIX 3 (cont)

Off-line choice ANOVA: Significant results[a]

		Overall			*English only*			*Italian only*		
Experiment	*Source*	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
2b: main clause	language	1,48	47.48	0.0001						
	main clause agreement (MCA)	2,96	52.62	0.0001				2,48	53.43	0.0001
	relative clause order (RCO)				1,24	11.81	0.002			
	language × MCA	2,96	30.39	0.0001						
	language × RCO	1,48	8.31	0.006						
	RCO × relative clause position (RCP)				1,24	12.51	0.002			
	relative clause agreement (RCA) × RCO	2,96	5.92	0.004						
	MCA × RCA × RCO	4,192	3.58	0.004				4,96	4.162	0.004
	language × MCA × RCA × RCO	4,192	3.963	0.004						
2c: relative clause	language	1,48	7.23	0.01						
	main clause agreement (MCA)	2,96	7.28	0.001				2,48	6.63	0.003
	relative clause agreement (RCA)	2,96	100.55	0.0001				2,48	135.27	0.0001
	relative clause order (RCO)	1,96	535.13	0.0001	1,24	498.77	0.0001	1,24	82.24	0.0001
	relative clause position (RCP)							1,24	9.05	0.006
	language × RCA	2,96	65.06	0.0001						
	language × RCO	1,96	142.48	0.0001						
	language × RCP	1,48	10.43	0.002						
	MCA × RCA	4,192	4.12	0.003				4,96	5.78	0.0001
	RCA × RCO	2,96	28.23	0.0001				2,48	28.44	0.0001
	RCA × RCP	2,96	5.94	0.004				2,48	5.85	0.005
	language × MCA × RCO	4,192	5.59	0.0001						
	language × RCA × RCO	2,96	20.29	0.0001						

[a] Experiment-wide alpha level set at $P < 0.01$.

APPENDIX 4

Off-line versus on-line choice ANOVA: Significant results involving the factor "experiment"

		Overall			*English only*			*Italian only*		
Experiment	*Source*	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
3a: simple sentences	experiment	1,96	7.20	0.01	1,48	8.23	0.01			
	experiment × word order				2,96	11.22	0.0001			
	language × experiment × word order	2,192	4.72	0.01						
3b: main clause	experiment × main clause order	2,192	6.87	0.001						
	experiment × main clause order × position				2,96	6.45	0.002			
3c: relative clause	experiment	1,96	12.41	0.001				1,48	10.96	0.002
	language × experiment	1,96	8.53	0.004						
	experiment × relative clause order				1,48	7.49	0.009			
4a: simple sentences										
4b: main clause										
4c: relative clause	experiment × relative clause position							1,46	14.75	0.001
	experiment × relative clause agreement × relative clause position							1,46	10.14	0.003
	experiment × relative clause agreement × relative clause order × relative clause position							2,92	6.192	0.003

[a] Experiment-wide alpha level set at $P < 0.01$.

APPENDIX 5

On-line reaction time ANOVA: Significant results

		Overall			*English only*			*Italian only*		
Experiment	*Source*	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
3a: simple sentences	word order	2,96	38.47	0.0001						
	language × word order	2,96	7.70	0.01						
3b: main clause	main clause order (MCO)	2,96	82.26	0.0001	2,48	60.91	0.0001	2,48	23.87	0.0001
	relative clause position (RCP)	1,48	7.43	0.009				1,24	15.80	0.001
	relative clause order (RCO)	1,48	30.98	0.0001	1,24	40.19	0.0001			
	language × MCO	2,96	6.73	0.002						
	language × RCO	1,48	9.11	0.004						
	language × MCO × RCO	2,96	4.97	0.009						
	MCO × RCP	2,96	8.26	0.001	2,48	90.46	0.001	2,48	22.26	0.001
	language × MCO × RCP	2,96	11.25	0.0001						
3c: relative clause	main clause order (MCO)	2,96	48.50	0.0001	2,48	43.07	0.0001	2,48	14.27	0.0001
	relative clause order (RCO)	1,48	30.33	0.0001	1,24	17.70	0.0001	1,24	15.69	0.001
	MCO × RCO	2,96	7.48	0.001	2,48	8.41	0.001			
	relative clause position (RCP)	1,48	14.68	0.0001	2,48	18.17	0.0001			
	MCO × RCP	2,96	42.65	0.0001	2,48	48.66	0.0001	2,48	7.70	0.001
	language × MCO × RCP	2,96	6.24	0.003						
	RCO × RCP	1,48	8.75	0.005	1,24	10.18	0.004			
	MCO × RCO × RCP	2,96	11.75	0.0001	2,48	5.49	0.007	2,48	6.51	0.003
4a: simple sentences	language	1,44	18.87	0.0001						

APPENDIX 5 (cont)

On-line reaction time ANOVA: Significant results

		Overall			*English only*			*Italian only*		
Experiment	*Source*	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
4b: main clause	language	1,44	14.65	0.0001						
	main clause agreement (MCA)	2,88	58.58	0.0001	2,44	7.68	0.001	2,44	52.56	0.0001
	relative clause order (RCO)	1,44	22.43	0.0001				1,22	16.20	0.0001
	language × MCA	2,88	24.99	0.001						
	MCA × relative clause agreement (RCA)	4,164	5.00	0.001	4,88	4.55	0.002			
	RCA × RCO	2,88	12.92	0.0001	2,44	9.7	0.0001	2,44	6.64	0.003
	relative clause position (RCP)	1,44	200.65	0.0001	1,22	224.21	0.0001	1,22	37.62	0.0001
	language × RCP	1,44	21.22	0.0001						
	RCA × RCO × RCP				2,44	15.71	0.0001			
	language × RCA × RCP	2,88	6.305	0.003						
	language × RCA × RCO × RCP	2,88	7.152	0.001						
4c: relative clause	language	1,44	9.93	0.003						
	main clause agreement (MCA)	2,88	6.89	0.002				2,44	9.36	0.0001
	relative clause agreement (RCA)	2,88	9.30	0.002				2,44	9.54	0.0001
	relative clause order (RCO)	1,44	35.90	0.0001	1,22	16.27	0.001	1,22	22.76	0.0001
	relative clause position (RCP)	1,44	36.492	0.0001	1,22	28.14	0.0001	1,22	11.81	0.0002
	language × RCA	2,88	6.54	0.002						
	RCA × RCO	2,88	39.27	0.0001	2,44	12.57	0.0001	2,44	28.19	0.0001
	language × RCA × RCO	2,88	9.23	0.0001						
	RCO × RCP	1,44	24.22	0.0001	1,22	33.45	0.0001			
	RCO × RCA × RCP				2,88	8.78	0.0001			
	language × RCO × RCP	1,44	24.22	0.0001						
	language × RCO × RCA × RCP	2,88	5.34	0.006						

Experiment-wide alpha level set at $P < 0.01$.