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INFORMATIONAL ENCAPSULATION & SYNTACTIC PROCESSING

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A core issue in the psychology of language is the validity of the autonomy of syntax hypothesis for theories of sentence comprehension. In this paper I report the results of three experiments which lend support to the view that human syntactic processing (parsing) is informationally encapsulated in that it fails to make use of certain types of information, even when such information would be useful (Fodor 1983).

The debate whether sentence comprehension is modular (involving distinct, domain specific, processors) or interactive (allowing the interaction of syntactic, semantic, and non-linguistic information) is of longstanding in the experimental literature. A central focus of this research has been the attempt to confirm or disconfirm the temporal priority of syntactic information relative to the use of semantic or pragmatic information.

The present paper shifts the focus from temporal priority to informational encapsulation. That is, from the attempt to establish that semantic and pragmatic processing is a comparatively 'late' phenomenon, to an investigation of whether the operations of the syntactic processor are affected by the semantic or pragmatic context. As Merrill Garrett has noted, "The central empirical challenge to the modularity thesis for language processing has been the need to maintain plausible real-time models that are form driven, while at the same time providing for the very rapid and

powerful interpretive constraints on sentence processing" (Gorrell, in press).

1. The Autonomy of Syntax in Sentence Comprehension

As Chomsky (1974) has observed, the autonomy of syntax thesis does not imply that the interpretation of sentences is independent of non-syntactic knowledge. But rather that syntactic knowledge represents a distinct contribution to the perceptual process. As a starting point we can state the hypothesis as in (1).

- (1) In sentence comprehension, the computation of a syntactic structure is done without recourse to semantic or pragmatic knowledge.

Of course, there is no pre-theoretic division of information types. How we construe the distinction between syntax and semantics in the competence grammar will have important implications for theories of linguistic perception in general and, in particular, how we relate the grammar and the parser.

For example, suppose that a particular grammatical theory posits that information type X is syntactic information and that information type Y is semantic information. If the experimental evidence indicates that there is no computational distinction of information types X and Y, then the grammar/parser relation will be less transparent than if the grammatical theory regarded both X and Y as syntactic phenomena. An example will illustrate the point.

Consider sentence (2), given in Chomsky (1955) as an example of a cognitive distinction between form and meaning.

- (2) Colorless green ideas sleep furiously

In the grammar presented at the time, (2) was argued to be syntactically wellformed but semantically anomalous. But within the framework of Chomsky (1965), (2) was regarded as syntactically ill-formed. This is because lexical insertion was restricted by selectional restrictions incorporating information, such as animacy, that the earlier approach had treated as non-syntactic.

However, subsequent work (e.g. Jackendoff 1972) argued that the Aspects approach introduced serious problems

and redundancies into the theory of grammar. Consider, for example, the problematic status of the embedded clause in (3).

(3) John thinks that rocks talk

Here I will adopt the approach of Chomsky (1955), but however the issue is resolved in terms of syntactic theory, we would still need to address the question of whether the parser respects distinctions postulated for the competence grammar, and what is the most computationally efficient way for it to do so.

Before proceeding with a discussion of the autonomy thesis from the perspective of experimental psycholinguistics, I will briefly mention the relevant grammatical assumptions (in addition to the role of selectional restrictions) which motivate the experiments reported here.

The work of many researchers in linguistic theory suggests that syntactic categories are feature bundles reflecting properties of their heads, e.g. an NP is a projection of the head N, a VP a projection of the head V, etc. I assume as well that such feature bundles include specifications for number and case. This type of approach is evident in Generalized Phrase Structure Grammar (Gazdar, Klein, Pullum & Sag (1985)) as well as in recent work within Government-Binding Theory (e.g. Fukui & Speas (1986); Lamontagne & Travis (1987)).

From the perspective of a modular parser, the issue arises as to how articulated (in terms of features) a structure is computed by the syntactic processor. Given our grammatical assumptions, are features such as number and animacy distinguished by the parser? It is the purpose of the present experiments to begin to answer this type of question.

The autonomy hypothesis in (1) may be instantiated in many ways. One version of the Clausal Hypothesis (cf. Fodor, Bever & Garrett 1974), an early modular view, is given in (4).

(4) Semantic interpretation is delayed until the computation of a syntactic clause is complete.

According to this parsing model, lexical and syntactic information were used to compute a deep-structure clause (more than one if the input was ambiguous).

When a clause boundary was reached, the computed syntactic structure was shunted to interpretive processors. Thus, semantic and pragmatic processing did not begin until the end of a clause.

A number of interesting experiments were conducted to experimentally test this prediction of the model, most notably by Marslen-Wilson and Tyler. These experiments established that pragmatic effects were evident in advance of clause boundaries (see Tyler 1981 and Fodor 1983 for discussion).

Forster's (1979) model of language processing, sketched in (5), allowed the output of the syntactic processor to be "relayed piecemeal" to the next processor. This would permit semantic and pragmatic interpretation to begin before the completion of a clause.

(5) -> lexical --> syntactic --> semantic/prag.
 processing processing processing

Within the framework of this model, all processing must be independent of the output of subsequent processors. Thus, lexical processing is predicted to be independent of syntactic and discourse contexts (see Swinney 1979). But all lexically specified information is potentially available for syntactic and interpretive processing.

Fodor (1983) argues for a research program to investigate the claim that the operation of a processing unit, or module, will tend to exhibit the characteristics listed in (6), among others.

(6) A module's operations tend to be:

- a. domain specific
- b. automatic
- c. (comparatively) fast
- d. informationally encapsulated

Domain specificity indicates that a module's operation will only be triggered by certain types of stimuli. For example, it has been argued that speech perception is the domain of a special-purpose module within the auditory system (e.g. Mattingly and Liberman 1990).

A module's operation is automatic in that it is mandatory, or outside of conscious control. As Fodor observes, "You can't hear speech as noise even if you

would prefer to." Marslen-Wilson and Tyler (1981) make similar observations for lexical identification. In this sense, a module's operations are reflexive.

Fodor argues that the (comparative) speed of a module's operation may follow from its mandatory operation. There is no delay in a module's activity caused by the operations of (comparatively) slow central processors.

A module is informationally encapsulated in that it only has access to a restricted data base. This data base may itself be the output of other processors. In the case of a modular language comprehension model such as Forster's, the prediction is that syntactic processing cannot be affected by semantic information. In terms of our assumption that selectional restrictions are non-syntactic, the prediction is that such information will not affect syntactic processing.

It is important to note that this prediction does not necessarily follow from Fodor's view of the language processing model. For Fodor, all linguistically specified information may be available for use in the perception of sentences. What is disallowed is the use of non-linguistic 'background' information such as plausibility.

In addition to the grammatical assumptions described above, I will assume that the computation of a syntactic phrase marker is a necessary intermediate stage in sentence comprehension. Further, that the integration of incoming lexical items into the phrase marker is an automatic, reflexive, operation. I will refer to this operation as syntactic integration (Gorrell 1987, 1989). In anticipation of the appearance of lexical items belonging to obligatory syntactic categories (e.g. a noun, given the string 'John saw a...' or a locative phrase given the string 'John put the book...'), the parser precomputes structure relevant to those items. This capability of building structure in advance of predicted categories is characteristic of many distinct parsing models, e.g. Frazier & Fodor 1978 and Marcus 1980. We will use this capability as a window into the operation of the parser with respect to its use of different types of information.

In the next section I briefly describe the experimental methodology that was used in the

experiments reported below and discuss its applicability for testing the hypothesis that syntactic processing is informationally encapsulated.

2. The Lexical Decision Paradigm

Several recent studies (e.g. Lukatela, Kostic, Feldman, and Turvey, 1983; Wright and Garrett, 1984) have studied the effect of syntactic context on lexical decision times. Lukatela *et al* (1983) studied the effects of case marking on lexical decision in Serbo-Croatian. Serbo-Croatian is a richly inflected language in which nouns are normally preceded by prepositions which determine their case marking. Contrasting appropriate and inappropriate case marking, they found that lexical decision times were faster for nouns after prepositions if the noun's case marking was appropriate to the preposition. They concluded that this effect was strictly grammatical and not semantic.

Wright and Garrett conducted a series of experiments designed to articulate more clearly the precise nature of the syntactic context effect. Their first experiment was designed to determine if a reliable effect could be obtained using a full sentential context. They used quadruples such as that in (7).

- (7) a. If your bicycle is stolen, you must FORMULATE
 b. If your bicycle is stolen, you must BATTERIES
 c. For now, the happy family lives with FORMULATE
 d. For now, the happy family lives with BATTERIES

All targets were matched for frequency and were selected so that they were not predictable on semantic grounds. The targets in the (b) and (c) members of each quadruple were ungrammatical in context, while the targets in the (a) and (d) members were syntactically obligatory, i.e. a verb following a modal and a noun following a preposition. Note that the obligatory item need not be the next item in the string

Wright and Garrett reported that noun and verb targets were recognized significantly faster when they were appropriate continuations of the syntactic context than when they were not. As with the Lukatela *et al* study, the conclusion was that the effect was due to structural, and not semantic or pragmatic, factors.

Additional experiments were consistent with the

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view that the parser predicts the syntactic heads of phrases and that this prediction allowed for faster lexical decision times when the target functioned as the head of a predicted phrase. The noun and verb targets in the first experiment both functioned as heads of predicted phrases.

To test the hypothesis that only heads of phrases would produce faster lexical decision times, Wright and Garrett constructed contexts in which adjectives would function as heads of phrases and contrasted these with contexts in which they would not. The relevant contrast is shown in (8).

- (8) a. The interesting clock seems very TOLERABLE
 b. Your visiting friend should enjoy TOLERABLE

The prediction of the heads-of-phrases hypothesis is that RTs to targets in the (8a) context should be significantly faster than the targets in the (8b) context. In (8a), tolerable functions as the head of a predicted adjective phrase. In (8b) it would presumably function as the modifier in a noun phrase.

The prediction of the heads-of-phrases hypothesis was confirmed. Thus the general finding of the Wright and Garrett study was that faster RTs were observed only for predicted heads of phrases, whereas lexical items representing optional, but grammatical and acceptable, continuations produced a response pattern indistinguishable from items representing ungrammatical continuations. It must be noted, however, that Wright and Garrett's experiments do not allow us to determine whether the crucial variable is predictability or functioning as a head of a predicted phrase (Gorrell 1990b). The results of these experiments do show that the relevant distinction is not between targets which represent permissible or impermissible continuations of the context string, but between predicted and non-predicted targets.

One plausible account of these findings is as follows. The reason predicted items produced faster RTs may be due either to the parser adopting some strategy which seeks out predicted items in the input, as Wright and Garrett suggest, or to the fact that the parser may confidently construct, in advance, structure appropriate to the predicted item (Gorrell 1987, 1989).

Within the context of our assumptions concerning

syntactic integration, the lexical decision paradigm appears to reflect a point in the parse which follows syntactic integration of lexical items. Therefore, lexical decision times should be sensitive to the speed of syntactic integration. If this process is facilitated by the parser precomputing structure, then lexical decision times for targets belonging to predicted categories will be fast compared to targets for which syntactic integration either fails (i.e. ungrammatical items) or requires structure building in response to the appearance of the item (i.e. optional items).

Although Wright & Garrett found that only predicted items produced faster lexical decision times, with both optional and ungrammatical items producing comparatively long RTs, Gorrell (1990b) reports evidence of a tripartite division. That is, predicted items producing faster RTs than optional items which, in turn, produce faster RTs than ungrammatical items.

In addition, Gorrell (1990a) reports that lexical decision times for noun targets are significantly affected by contexts ending in either transitive or intransitive verbs. Lexical decision times for noun targets were elevated following intransitive verbs (as compared with transitive verb contexts).

Thus, we find in these experiments that lexical decision times are affected by manipulating syntactic category specifications, as in Wright & Garrett's work. We also find that RTs, if categorial appropriateness is maintained, are affected by manipulations of subcategory information and by case specification, but not by manipulations of plausibility.

The hypothesis to be tested is that the parser precomputes structure which is articulated only for syntactic features, and thus lexical decision times, so long as categorial appropriateness is maintained, will be affected by manipulations of other syntactic features, such as number, but not by manipulations of non-syntactic features such as animacy.

There is only as yet preliminary data for the first two experiments, but these results are promising and are consistent with the view that only syntactic information is encoded in the computed structure. The third experiment, which tested ambiguous stimuli, indicates that the parser fails to use non-syntactic

information even in contexts where it may be useful.

3. Experiment 1

This experiment was designed to assess whether or not the feature number affects RTs for lexical decision targets. A syntactic context effect which depends upon both category specification and number agreement is consistent with the view that the parser makes use of them in a similar fashion. If we do not find that category and number pattern together, we will have evidence for a computational distinction of information types. Twelve subjects were tested.

Twelve quadruples such as (9) were tested. Subjects were divided into four groups and stimulus lists were constructed such that each subject saw only one member of each quadruple. The entire stimulus set, including fillers, consisted of 106 sentences.

- (9) a. Mary tried to explain the fact that her hand and her foot HAS
 b. Mary tried to explain the fact that her hand and her foot HAVE
 c. Mary tried to explain the fact that one of her feet HAS
 d. Mary tried to explain the fact that one of her feet HAVE

The contexts end either with a coordinate NP (a plural phrase ending with a singular noun) or the phrase one of NP (a singular phrase ending with a plural noun). These structures insure that any context effects obtained are not the result of word-level relations between the lexical decision target and the context-final word.

The results, given below in (10), indicate that a target's congruence or incongruence for number does effect lexical decision times. Analyses of variance treating subjects and items as the random variable were performed. There was no main effect of either context or target. There was a significant context x target interaction for both the subjects analysis ($F_1(1, 11) = 37.41; p < .01$) and the items analysis ($F_2(1, 11) = 20.61; P < .01$). Planned t-tests reveal that both singular and plural verb targets produced faster RTs when they were congruent with the context.

(10)	CONTEXT	TARGET	RT (MSEC)
	Plural	Sing.	728
	Sing.	Sing.	645
	Plural	Plural	653
	Sing.	Plural	704

With context/target pairs where the target is categorially appropriate to the context, if number agreement is violated, lexical decision times are effected. This result is consistent with those reported by Lukatela *et al* (1983) for case in Serbo-Croatian.

4. Experiment 2

This experiment is quite similar in design to the first experiment, but here animacy is manipulated instead of number. (In fact, the manipulation of animacy is here confounded with abstractness, but the hypothesis is that these two features will produce similar effects, both being non-syntactic). Twelve subjects were tested.

Twelve triples such as (11) were created. In the (a) and (b) contexts, a verb represents a categorially appropriate target, but is inappropriate for the (c) contexts. For the contexts requiring a verb, half contained [+ animate] subjects and half contained [-animate] subjects. All verb targets prohibit a [+abstract] subject.

The context disallowing a verb target is important because it is difficult to rule out plausibility as a confounding factor with these materials. Thus, for both (11a) and (11c), admire is an implausible continuation, but it is syntactically appropriate in (11a). Half the (a) and (b) contexts in the stimulus set ended in modals, half did not. As with number specification, if we do not find that category and animacy pattern together, we will have evidence for a parsing distinction.

- (11) a. It is clear that sincerity will ADMIRE
 b. It is clear that people will ADMIRE
 c. It is clear that some very old ADMIRE

The results, given below in (12), indicate that, unlike number, animacy specification does not interrupt

the syntactic context effect. Note also that the response pattern in (12) cannot be due to a general effect of plausibility, as that would predict comparatively slow times for the contexts with [-animate] subjects. The observed pattern is in stark contrast to the results obtained for number in the first experiment and are consistent with the findings of Nicol (1988) for trace postulation in relative clause structures. There was no significant effect (nor a non-significant trend) for the presence or absence of modals.

(12)	CONTEXT	RT (MSEC)
	[- animate] subject	706
	[+ animate] subject	693
	adjective	737

Analyses of variance were significant for both the subjects analysis ($F_1(2,11) = 5.63; p < .03$) and the items analysis ($F_2(2,11) = 4.23; p < .04$). Planned *t*-tests reveal that there was no significant difference between RTs for verb targets following the 'subject' contexts, with each significantly faster than the 'adjective' context.

The results of these two experiments, in conjunction with earlier work, support the view that the parser respects the posited grammatical distinction of information types. While categorial appropriateness is maintained, manipulations of syntactic features such as case and number, as well as subcategory information, produce a significant effect on lexical decision times. But this is not true for the feature animacy tested in Experiment 2.

It is interesting to note that this distinction suggests a stronger view of modularity than either Forster's or Fodor's views would predict. That is, animacy information is presumably specified in the lexicon as part of the entry for each noun. Despite this, the experimental evidence reported here (although preliminary), indicates that the parser failed to make use of it as it does number and case.

5. Experiment 3

In contrast to the results of Experiment 2, Stowe

(1989) reports that by manipulating the animacy feature of subject NPs, subjects' preferences for the attachment of NPs following ambiguous verbs can be affected. For example, in (13b) Stowe found that the inanimate subject in the initial clause appears to decrease (or eliminate) the garden-path effect of attaching the NP the driver as the direct object of the ambiguous verb stop.

It is possible that even if the parser does not normally make use of non-syntactic features, in cases of syntactic ambiguity, such features are used to determine a unique analysis (cf. the concept of bottom-up priority in Marslen-Wilson & Tyler 1987).

- (13) a. Before the police stopped the driver became very nervous
 b. Before the truck stopped the driver became very nervous

The reasoning is that verbs such as stop (as in (13)) are associated with two possible argument structures: (i) [AGENT verb THEME], and (ii) [THEME verb] (Carlson & Tanenhaus 1988). Thus if the theme role is assigned to the subject (as is likely with an inanimate subject NP), there is no (or a reduced) expectation for an object.

Stowe used a self-paced word-by-word reading task and found a robust effect due to the animacy specification of the initial subject. Given the arguments presented here, we would not expect such a manipulation to interfere with the syntactic context effect. The Stowe effect may well be due to the nature of the self-paced reading task. Stowe used a subordinate grammaticality task so that subjects were required to make a judgment at each new word. It is quite possible that this judgment is affected by non-syntactic factors.

The present experiment adapted Stowe's materials for the lexical decision task. An example set is given in (14). The first member of each triple contains an unambiguous intransitive verb, the third member an unambiguous transitive verb, and the second ambiguous verbs from Stowe (1989).

(14) Animate Subjects:

- (i) He said that before the police struggled MEN

- (ii) He said that before the police stopped MEN
- (iii) He said that before the police took MEN

Inanimate Subjects:

- (i) He said that before the truck struggled MEN
- (ii) He said that before the truck stopped MEN
- (iii) He said that before the truck took MEN

If the parser uses the animacy of the subject NP to form expectations concerning the verbs argument structure (e.g. 'if the subject is inanimate, then it's the THEME and expect no object), then the ambiguous verbs should pattern with the intransitive verbs for the inanimate subjects, but with the transitive verbs for the animate subjects.

The results are given in (15) below. There is no indication that the animacy specification of the subject NP affected lexical decision times. However there is a significant main effect of verb type, with noun targets following intransitive verbs producing faster RTs than either the ambiguous or the transitive contexts. The ambiguous and transitive verbs patterned together, as has been shown in previous work with the lexical decision task.

(15) Mean RT as a Function of Subject Animacy and Verb Type (Noun Targets)

Verb Type	Subject Animacy		Difference
	Animate	Inanimate	
Intransitive	766	750	16
Ambiguous	710	713	3
Transitive	718	691	27

6. Conclusion

The results from the experiments reported here, as well as many previous studies, are consistent with the view that there is a module for syntactic processing which computes a structure based on syntactically-relevant lexical information and general syntactic information, but whose operations are unaffected by non-syntactic contexts.

There is much work still to be done. We are not in a position to explicitly reconcile the modularity thesis with (to quote Garrett once more) "the powerful interpretive constraints on sentence processing." But the present study does support the hypothesis that the structure-building module is informationally encapsulated along the lines suggested by Fodor (1983).

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