Graded Effects of Verb Subcategory Preferences on Parsing: Support for Constraint-satisfaction Models

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This study examined whether the preferences of verbs for appearing in particular subcategory structures can have an influence on parsing, and whether this influence is graded according to the strength of the preferences. We measured naming latencies for transitive and complement clause continuations of sentences which contained verbs which subcategorise for these two structures. Naming latency was taken to be an on-line indication of parsing difficulty. Faster latencies were found when the sentence continuation accorded with a verb’s preferred subcategory structure, than when it accorded with its non-preferred structure. This suggests that verb subcategory preferences do influence the parse. The stronger the preference of the verb for one subcategory structure over the other, the larger the advantage in naming latency found for the preferred over the non-preferred continuation. This suggests that the verb subcategory preferences do produce a graded influence on the parse, according to their strength. The findings support the predictions of constraint-satisfaction models of parsing.

INTRODUCTION

As we listen to spoken language, a complex set of processes operate upon various types of stored linguistic knowledge to produce a meaningful representation of what is being heard. Over the years, there has been a healthy debate as to the nature of these different types of stored linguistic knowledge and their relationship to each other during processing. The debate has primarily centred around the issues of whether syntax and semantics correspond to distinct and separate types of knowledge...
representation, and how they relate to each other during the process of interpreting a sentence. Participants in this debate fall into two broad camps. First, there are the modularity theorists who claim that the language system can be characterised as a set of independent components (such as syntax, semantics, pragmatics and prosody), each of which corresponds to a distinct type of linguistic knowledge which operates independently in the course of comprehending an utterance. The most forcefully articulated model of this type has been developed by Frazier and colleagues (Frazier, 1987; Frazier & Rayner, 1982; Rayner, Carlson, & Frazier, 1983).

Second, there is the view that syntactic and semantic knowledge interact during sentence comprehension (Marslen-Wilson & Tyler, 1980). There have been many versions of the interactionist view (e.g. Ades & Steedman, 1982; Altmann & Steedman, 1988; Marslen-Wilson & Tyler, 1980); its most recent incarnation is in the lexicalist accounts of language comprehension (McDonald, Pearlmutter, & Seidenberg, 1994a, 1994b; Trueswell & Tanenhaus, 1994; Tyler, 1989). According to the lexicalist view, syntactic and semantic knowledge are not represented in distinct modules, but are jointly part of the specification of each word. In its strongest form—currently known as the constraint-satisfaction view—there is no module corresponding to the syntactic rules which typically comprise the parser in modularity theories. Constraints, which give rise to behaviour that looks as if it is rule-governed, are actually embodied within the lexical specifications of a word. These constraints function in a graded manner, according to their strength and frequency.

This claim—for the graded nature of constraints—is a fundamental aspect of the constraint-satisfaction view. In this paper, we report a cross-modal naming study which allowed us to test this claim directly.

This study focuses on whether verb subcategory preferences exert an effect on syntactic processing, which is graded according to the strength of the preferences. Many words, particularly verbs, can be classified into different subtypes, which affect the syntactic structures in which they can appear. For example, ditransitive verbs (e.g. give) appear in structures where the verb has both a direct and an indirect object, whereas transitive verbs (e.g. see) only take one object and intransitive verbs (e.g. pause) take no objects. The syntactic subclassification of words is referred to as subcategorisation (Chomsky, 1965). As well as words being restricted in the structures in which they can appear, due to their subcategorisation, they can also exhibit preferences for appearing more frequently in one permissible structure than another (Ford, Bresnan, & Kaplan, 1982). For example, the verb claimed can be used both transitively (1) and with a complement clause structure (2), but appears more frequently in the latter structure (Trueswell, Tanenhaus, & Kello, 1993):
1. The man claimed the prize.
2. The man claimed the prize was big.

The constraint-satisfaction model predicts that subcategory preferences exert a graded effect on parsing. According to the lexically based constraint-satisfaction model, the lexical entry for a word would consist of a series of “frames”, corresponding to each subcategory structure which the word can appear in. These frames structure the incoming sentence by attaching the input into appropriate argument slots in the frames. Parsing difficulty will arise if the input does not accord with any of the possible subcategory structures, because input cannot be integrated into any of the available frames (Marslen-Wilson, Brown, & Tyler, 1988). Subcategory preferences can be embodied in this model by positing that the frames have graded activation levels, according to the frequency of occurrence of the different structures for a word. If a word is used frequently in a particular subcategory structure, the frame for this structure will be highly activated. Frames corresponding to structures which occur less frequently will be less highly activated. Parsing will be easier the higher the activation of the frame into which the input fits.

According to the constraint-satisfaction model, a reduced complement sentence containing a verb which prefers to appear in a complement clause subcategory structure (2), should be parsed more easily than one which contains a verb which prefers an alternative (e.g. transitive) structure. With a complement clause preference verb, the activation of the correct complement clause frame would be high, and the input would be integrated into this frame easily. Whereas with a transitive preference verb, activation of the correct complement clause frame would be low, and integration would be proportionally more difficult. To support the constraint-satisfaction model, this pattern of graded subcategory preference effects needs to be clearly demonstrated.

Research carried out to look for effects of verb subcategory preferences in sentence types such as (1) and (2), has produced mixed results. While some studies have suggested that the subcategory preferences of transitive and complement clause verbs can have an effect on parsing (e.g. Boland, 1993; Trueswell et al., 1993), others have suggested they do not (e.g. Ferreira & Henderson, 1990).

Ferreira and Henderson (1990) failed to find effects of verb subcategory preferences when they compared reduced complement sentences containing transitive preference verbs (3) and complement clause preference verbs (4):

3. She suspected Jack owns credit cards.
4. She pretended Jack owns credit cards.
The disambiguating word *owns* was found to be parsed with equal difficulty in both sentence types. The transitive verb preference in (3) had not hindered the parsing of the complement clause structure. However, as noted by Trueswell et al. (1993), many of the noun phrases following the verbs were implausible direct objects for the transitive preference verbs, thereby providing evidence against an incorrect transitive interpretation before the disambiguating region was reached.

An experiment by Kennedy, Murray, Jennings and Reid (1989), with reduced complement sentences and transitive and complement clause preference verbs, also failed to find effects of the subcategory preferences on parsing. However, the experiment used verb preferences calculated using an Australian subject group (Holmes, 1987), which may not have been appropriate for the British subjects used in the experiment. When the same verb preference data were used in a similar experiment using Australian subjects (Holmes, Stowe, & Cupples, 1989), parsing difficulty of the reduced complement sentences was found to be influenced by the verb subcategory preferences.

Some recent research by Trueswell et al. (1993, experiment 1; see also Boland, 1993), using a cross-modal naming paradigm, does provide some support for the constraint-satisfaction view. They found that a visually presented complement clause sentence continuation (*he*) was named (non-significantly) faster following an auditory sentence fragment containing a verb which preferred to take a complement clause structure (5), than following a verb which preferred to take a transitive structure (6). The verbs which preferred to take a transitive structure could take the complement clause structure, but the complement clause structure was less preferred.

5. The old man realised *he*
6. The young boy observed *he*

Although the effect of subcategory preference was numerically in the right direction, it was not statistically significant. Trueswell et al. (1993) suggested that this was due to the omission of an overt complementiser in the reduced complement sentence structures. They found that processing difficulty of the complement clause preference verbs in the reduced complement sentences (as measured against their difficulty in unreduced versions of the same sentences) correlated with the percentage of complement clause completions using *that* in their verb preference pre-tests. The more usual it was for a verb to take an overt complementiser, the higher the processing difficulty in the reduced complement sentence structures. This could have masked effects due to verb subcategory preference. Trueswell et al. selected verbs with extremely strong preferences for each subcategory structure, and did not look at verbs lying along the whole
dimension of subcategory preference strength. Therefore, the issue of whether subcategory preferences exert a graded effect in proportion to their strength was not examined in this study.

Trueswell et al. (1993) did find that a transitive sentence continuation \((\text{him})\) was named significantly faster following the transitive preference verbs than following the complement clause preference verbs. However, this did not provide evidence for an effect of subcategory preferences. Not all the complement clause preference verbs could take a direct object; \(\text{him}\) would have been parsed with difficulty not because it was structurally less preferred, but because it could not be integrated. Where the complement clause preference verbs could take a direct object, the direct object could not be animate. In this case, \(\text{him}\) could prove difficult to parse, again not because it was less preferred, but because it could not fit semantically as a direct object.

In summary, the evidence in support of the effect of a verb’s subcategory preferences on parsing is mixed, with some studies suggesting that preferences do have an effect and others suggesting that they do not. Moreover, there is no direct evidence as to whether subcategory preferences have a graded effect, as the constraint-satisfaction model predicts. In the experiment reported here, we test, once again, for the effects of subcategory constraints on processing. However, we extend previous studies by testing one of the important predictions of the constraint-satisfaction model, that the effect of the verb subcategory preferences will be graded; that is, it will be proportional to the strength of the preferences.

We address these questions using a cross-modal naming paradigm, which allows us to probe for effects immediately after the verb (Boland, 1993; Marslen-Wilson, Tyler, & Koster, 1993; Trueswell et al., 1993; Tyler & Marslen-Wilson, 1977). The experiment uses verbs which can take both a transitive and a complement clause structure, but which exhibit varying degrees of preference for one structure over the other. The preferences are determined by a sentence completion pre-test. The transitive preference verbs (7) and complement clause preference verbs (8) are placed in auditory sentence fragments, and followed by visual probes which are consistent with a transitive sentence structure \((\text{them})\), or a complement clause sentence structure \((\text{they})\). \(\text{Them}\) and \(\text{they}\) are semantically plausible continuations in all cases, as they can refer both to animate and inanimate objects.

7. The smart gentleman demanded \(\text{them}/\text{they}\)
8. The brilliant surgeon believed \(\text{them}/\text{they}\)

If the transitive continuation \(\text{them}\) is named faster than the complement clause continuation \(\text{they}\) for the transitive preference verbs, and vice versa for the complement clause preference verbs, this would suggest that the verb subcategory preferences do have an effect on the parse. Moreover, if the
subcategory preference operates in a graded manner, the advantage in parsing difficulty for the preferred over the non-preferred continuation for a verb should correlate with the strength of the preference of the verb for the preferred over the non-preferred subcategory structure. The strength of preference of a verb for one subcategory structure over another is measured by the difference in the completion percentages for those structures in the verb preference pre-test. If the strength of preference for one subcategory structure over the other is low, then the preferred continuation should be parsed only slightly more easily than the non-preferred continuation. However, if the strength of the preference is high, then the preferred continuation should be parsed much more easily.

METHODS

Pre-test

We pre-tested verbs which are able to take both a transitive (TR) and a complement clause (S) structure, to determine their preference for each structure. Subjects were given written fragments containing the verbs (e.g. “The old man observed . . .”) and were asked to write down, as quickly as possible, the first completion that came to mind. Forty native speakers of British English completed the pre-test. The sentence fragments in which the verbs were embedded were all of the form: determiner + adjective + animate noun + past-tense verb (following Trueswell et al., 1993; Boland, 1993). As the initial noun phrases in the pre-test were the ones which we used in the experiment, they were matched for total frequency and total syllable length. All the adjectives and animate nouns had frequencies in the range 1–75 (Johansson & Hofland, 1989), and syllable lengths of 1–4. And they were combined so that each phrase had a similar total frequency (51–75) and total syllable length (4–5). We tested a total of 93 verbs. To obscure the regularities of the test fragments, these were distributed among 120 fillers, which consisted of a variety of syntactic constructions.

Sentence completions were scored according to the structural categories in Table 1. Verbs which had the highest percentage of completions falling in the NP category were classed as transitive preference verbs. Verbs which had the highest percentage of completions falling in the combined th-S and (th)-S categories were classed as complement clause preference verbs. The (NP) category was not counted towards transitive preference, as there is controversy as to whether these noun phrases can be classed as direct objects of the main verb (Borsley, 1991; Burton-Roberts, 1986). To ensure that this did not affect the experiment, verbs were used in the experiment only if they generated a low number of completions of this type in the pre-test.
TABLE 1
Pre-test: Sentence Completion Scoring Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Example</th>
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<tr>
<td>NP</td>
<td>Noun phrase (which can be taken to be the direct object of the main verb), e.g. <em>The old man observed them.</em></td>
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<tr>
<td>(NP)</td>
<td>Noun phrase (over which there is disagreement as to whether it serves as the direct object of the main verb), e.g. <em>The old man observed them leaving the room.</em></td>
<td></td>
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<tr>
<td>th-S</td>
<td>That-clause (with overt complementiser), e.g. <em>The old man observed that they were happy.</em></td>
<td></td>
</tr>
<tr>
<td>(th)-S</td>
<td>That-clause (with no overt complementiser), e.g. <em>The old man observed they were happy.</em></td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>Adjective or adverb phrase, e.g. <em>The old man observed carefully.</em></td>
<td></td>
</tr>
<tr>
<td>PP</td>
<td>Prepositional phrase, e.g. <em>The old man observed through binoculars.</em></td>
<td></td>
</tr>
<tr>
<td>wh-S</td>
<td>Wh-clause, e.g. <em>The old man observed what she was doing.</em></td>
<td></td>
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<tr>
<td>vb-S</td>
<td>-ing participle or infinitive, e.g. <em>The small boy admitted stealing.</em></td>
<td></td>
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<tr>
<td>DS</td>
<td>Direct speech, e.g. <em>The young girl declared “go away”.</em></td>
<td></td>
</tr>
<tr>
<td>pass</td>
<td>Passive, e.g. <em>The new baker established in 1983 was moving.</em></td>
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Materials

*TR and S Preference Verbs.* We selected TR and S preference verbs from the pre-test for which the (th)-S form was not unusual (i.e. not less than 40% of all that-clause completions). This ensured that the verbs would not appear odd in the reduced complement sentence structures in the experiment, when followed directly by *they*. The verbs also had a low number of (NP) completions (i.e. not more than 10%). The verbs were rarely followed by the target words used in the experiment: *them* and *they* (i.e. not more than 5%). Therefore, the target words were not predictable.

Twelve S preference verbs fitted the above criteria. A set of 16 TR preference verbs were chosen which matched the S preference verb set for median verb frequency, mean syllable length, and mean preferred and non-preferred completion percentages. The statistics of the verb sets are given in Table 2. (See Appendix for full item listing.)

The verbs were presented in the experiment within the same sentence fragments in which they appeared in the pre-test. Each sentence fragment was paired with the continuation probe (*them* or *they*), to be presented visually for naming. The sentence fragments were rotated across two versions, to be presented to different groups of subjects, so that no subject heard the same sentence fragment twice.

The TR preference verb fragments were recorded in short sentences with *they* following the verb, and the S preference verb fragments were recorded in short sentences with *them* following the verb. These pronouns were consistent with the non-preferred structure. *They* or *them* plus the sentence
end were subsequently edited out. This ensured that if there were any clues to the sentence structure in the reading of the initial fragment, they were in the direction opposite to the preference of the verb. Also, if any clues were given preceding the word to the onset of the probe word, then the visually presented probe did not mismatch with these clues.

**Paradigm Check.** A paradigm check condition was included to check that the experiment was sensitive to syntactic processing, in case no effects were found in the verb preference conditions. Sixteen items were produced. These items consisted of sentence fragments followed by a “grammatical” continuation probe, which was a syntactically valid continuation, and an “ungrammatical” probe, which constituted a major syntactic category violation. Both probes were semantically plausible, being derived from the same word; for example, *My cousin always behaves . . . kindly* (grammatical probe) / *kindness* (ungrammatical probe). The grammatical and ungrammatical probes were matched for frequency and letter length across the set.

To ensure that subjects were integrating the auditory sentence fragments with the visual probe words in the experiment, after each item they were asked to decide whether the probe word was a good or bad continuation of the sentence fragment. The paradigm check items also served as a check that subjects were doing this properly. The grammatical probe words in the paradigm check condition were clearly good continuations, and we expected them to be judged to be so by the subjects. Similarly, the ungrammatical probe words were clearly bad continuations.

The paradigm check sentence fragments were recorded in short sentences with their grammatical probe words following. The probe word plus the sentence end were subsequently edited out.

**Fillers.** Twice as many fillers as test items were added to each version of the experiment (i.e. 88). This gave a total of 132 items in each version of the

<table>
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<th><em>S Preference Verbs</em></th>
<th><em>TR Preference Verbs</em></th>
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<tbody>
<tr>
<td>Median frequency</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Mean syllable length</td>
<td>1.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Mean S completion (%)</td>
<td>58</td>
<td>22</td>
</tr>
<tr>
<td>Mean TR completion (%)</td>
<td>25</td>
<td>67</td>
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experiment. The same filler items were used in each version. The fillers contained the same proportion of syntactically preferred, syntactically non-preferred and syntactically invalid continuations as the test items. So that *them* and *they* did not always follow the det + adj + noun + verb test sentence fragments only, we included 16 *them* and 16 *they* targets in the fillers following a variety of sentence fragment structures. In addition, so that the det + adj + noun + verb structures were not always followed by *them* and *they*, we included 16 sentence fragments of this structure in the fillers, followed by a variety of probe words. The remaining fillers consisted of a variety of sentence fragment structures, followed by a variety of continuation probes.

For the practice session, 12 additional items were constructed which reflected the different types of item in the experiment. Practice and filler items were recorded in short sentences with their probe words following. The probe word plus the sentence end were subsequently edited out.

For each version, the items were pseudo-randomised to ensure maximum separation between similar items. Each sentence fragment appeared in the same position as its corresponding fragment in the other version. Three filler items were placed at the start of the test session, and after a halfway break in the test session.

**Procedure**

The sentence fragments were recorded by a rehearsed native speaker of British English, and were sampled and digitised using the BLISS sound editing system. The experiment was run using DMASTR (K. Forster, personal communication) to provide the visual targets and the timing of the naming responses, and tape generated from VMASTR to provide the auditory sentence fragments and synchronising pulses.

The subjects were seated in a sound-proofed booth, in front of a microphone and computer screen, wearing headphones. A warning tone was played out over the headphones to signal the start of the trial. Two seconds later, a sentence fragment was played out. At the offset of the last word in the fragment, the probe word was immediately displayed in upper-case letters for 500 msec on the computer screen. The subjects named the word into the microphone as quickly as possible. Their responses were timed from the onset of the probe word to a time-out of 2 sec. The experimenter noted down any errors in the naming response. One and a half seconds after the offset of the probe word, the question “Good or Bad Continuation?” was displayed on the computer screen for 4 sec. The subjects wrote down the answer to this question on a score sheet beside them. There was a 1 sec gap before the start of the next trial. The test session lasted approximately 20 min, with a break halfway through.
Subjects
Thirty-four native British English speakers from the Centre for Speech and Language subject pool participated in the experiment. None of them had done the pre-test.

RESULTS AND DISCUSSION

Paradigm Check

The paradigm check condition tested whether the methodology used in this study is sensitive to syntactic processing. Therefore, we will consider the data from this part of the experiment first. If the methodology is sensitive, then we expect naming latencies to grammatical continuations to be faster than to ungrammatical continuations.

We ran ANOVAs on the raw naming latency data. Twenty-six data points (5.9%) were treated as missing data in the analysis: 3.8% were due to naming errors, 0.5% were misses, 1.4% were lower outliers (naming latencies less than 100 msec) and 0.2% were upper outliers (naming latencies greater than 1000 msec). Of the remaining data, 11 data points (2.5%) exceeded ±2 standard deviations from the mean naming latency for each subject, and were replaced with the ±2 standard deviation cut-off values. The mean naming latencies for the grammatical and ungrammatical continuations of the paradigm check items are given in Fig. 1.

In the subject analysis, continuation type (grammatical vs ungrammatical) appeared as a within-group factor, and version (A vs B) appeared as a between-groups factor. In the item analysis, continuation type (grammatical vs ungrammatical) appeared as a within-group factor, and version (1 vs 2) as a between-groups factor.

A 2 (version) × 2 (continuation type) analysis showed a significant effect of continuation type on both the subject and item analyses \([F_1(1,32) = 5.21, P < 0.05; F_2(1,11) = 6.13, P < 0.05]\). The grammatical continuations were named significantly faster (421 msec) than the ungrammatical continuations (434 msec). This showed that the naming latencies in this experiment were sensitive to syntactic processing.

After the subjects named the visual probe, they were asked to judge whether the visual probe was a good or bad continuation of the sentence fragment. The mean percentage of grammatical continuations judged as

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1 Two items produced a large number of naming errors (53 and 29% respectively) and were removed from the analysis. A third item was removed for which 35% of subjects produced naming latencies that exceeded 2 standard deviations from their mean naming latencies.
good by subjects was 98%, and the mean percentage of ungrammatical continuations judged as bad by subjects was 96%. These accurate good/bad continuation judgements for the paradigm check items also show that the subjects were integrating the auditory sentence fragments with the visual continuation words.

TR and S Preference Verbs

The TR and S preference verb analyses tested whether the structurally preferred continuation for a verb is parsed more easily than its non-preferred continuation. The analyses also tested whether the difference in parsing difficulty for the two continuations depends upon the strength of a verb’s preference for one structure over the other.

Four data points (0.5%) were treated as missing data in the analyses: 0.1% naming errors, 0.2% lower outliers (naming latencies less than 100 msec) and 0.1% upper outliers (naming latencies greater than 1000 msec). Of the remaining data, 39 data points (4.4%) exceeded ± 2 standard deviations from the mean naming latency for each subject, and were replaced with the
± 2 standard deviation cut-off values. The mean naming latencies for the preferred and non-preferred continuations of the TR and S preference verbs are given in Fig. 2.

Subject and item analyses of variance were carried out to test for significant effects. In the subject analysis, continuation type (preferred vs non-preferred) and verb preference (TR vs S) appeared as within-group factors, and version (A vs B) appeared as a between-groups factor. In the item analysis, continuation type (preferred vs non-preferred) appeared as a within-group factor, and verb preference (TR vs S) and version (1 vs 2) as between-groups factors.

A 2 (version) × 2 (continuation type) × 2 (verb preference) analysis showed a significant effect of continuation type \( [F_1(1,32) = 6.72, P < 0.05; F_2(1,22) = 7.60, P < 0.05] \), but no interaction between continuation type and verb preference \( (F_1 \text{ and } F_2 < 1) \). The preferred continuations were named

\[ \text{Fig. 2. TR and S preference verbs: Mean naming latencies for preferred vs non-preferred continuations. □, Preferred continuation; ■, non-preferred continuation.} \]

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2 Two items were excluded from the analysis. In the experiment, these items immediately followed two of the rejected paradigm check items. The problems caused for subjects with these paradigm check items appeared to have carried over to the following item, adversely affecting it by causing lengthened latencies. (The third rejected paradigm check item was followed in the experiment by a filler.)
significantly faster than the non-preferred continuations (377 vs 389 msec), and this difference did not differ significantly for the TR (10 msec) and S preference verbs (14 msec). The results suggest that there is an effect of structural verb preferences on the parse, allowing the preferred continuation for the verb to be parsed more easily than its non-preferred continuation.

The constraint-satisfaction model predicts not only that there are effects of verb subcategory preference on parsing, as shown above, but that these effects will be graded. If a verb exhibits only a weak preference for its preferred over its non-preferred subcategory structure (as shown by the pre-test completion percentages), then its preferred continuation should be parsed only slightly more easily than its non-preferred continuation (as shown by the naming latencies). However, if the preference is strong, then the preferred continuation should be parsed much more easily.

The differences in the pre-test completion percentages for the preferred minus the non-preferred structures of the verbs were calculated, and these difference scores were correlated with the differences in naming latency for the non-preferred minus the preferred continuations. To eliminate version differences, the naming latencies were normalised, by expressing each data point as a percentage of each subject’s mean naming latency. The differences in completion percentages were found to correlate significantly with the differences in normalised naming latencies (two-tailed): Pearson $r = 0.63$, d.f. = 22, $P < 0.01$ (TR preference verbs: Pearson $r = 0.65$, d.f. = 14, $P < 0.01$; S preference verbs: Pearson $r = 0.63$, d.f. = 8, $P < 0.05$). The higher the pre-test completion percentage difference for the preferred minus the non-preferred structure (i.e. the stronger the preference for one structure over the other), the higher the naming latency difference for the non-preferred minus the preferred continuation. The data are shown in a scatterplot in Fig. 3.

The results of the correlational analysis suggest that verb subcategory preferences do exert a graded influence on processing difficulty. With verbs that only weakly prefer one structure over the other, their preferred continuation is parsed only slightly more easily than their non-preferred continuation. However, with verbs that exhibit a strong preference, the preferred continuation is parsed much more easily. The results therefore support the constraint-satisfaction model.

GENERAL DISCUSSION

This experiment demonstrated, for verbs which subcategorise for transitive and complement clause structures, that when sentential input following the verb accords with the preferred subcategory environment of the verb, it is integrated more easily than if it does not. This suggests that the preference of
a verb for appearing in a particular subcategory structure (its frequency of occurrence in that structure) does exert an influence on parsing. The experiment also showed that the ease of integration of the preferred over the non-preferred sentential input correlated with the strength of the preference of the verb for the preferred over the non-preferred structure. This suggests that verb subcategory preferences do indeed exert a graded influence on parsing.

The results fit with a constraint-satisfaction model of syntactic processing. On this model, subcategorisation information exists in the lexical entries of verbs as differentially activated frames, a frame being more highly activated the stronger the preference of the verb for appearing in that structural environment. The frames directly structure the incoming sentence; the more highly activated a frame, the easier it is to integrate the input into that frame. Therefore, a verb’s preferred subcategory structure is more easily integrated than its non-preferred structure, and the ease of integration correlates with the strength of the preference of the verb for the structure.

This experiment demonstrated results which were necessary for support of a constraint-satisfaction model. However, it has to be considered to what
extent the results could pose problems for alternative models of syntactic processing, such as the modular models outlined in the Introduction. According to Frazier’s model of syntactic processing (e.g. Frazier, 1989), structural rules assign an initial parse to a sentence with reference to the syntactic categories of the words. Other types of processing information, such as verb subcategory preferences, do not influence the initial parse. When a sentence is syntactically ambiguous, a single parse is initially chosen according to general parsing principles, such as “minimal attachment” (Frazier & Fodor, 1978). In minimal attachment, the simplest structure (i.e. that requiring fewest nodes) is applied first. If this structure is later found to be inconsistent with further processing, a re-parse is initiated. Although verb subcategory preference information is not used in the initial parse, it can have an influence at a later stage.

Frazier’s model could account easily for the results of some early studies showing verb subcategory preference effects on parsing (e.g. Holmes et al., 1989). Holmes et al. showed that reduced complement sentences like (9) were easier to parse when they contained complement clause preference verbs as opposed to transitive preference verbs, as predicted by constraint-satisfaction models:

9. The tourist discovered the route was extremely complicated.

However, the use of verb subcategory preference information in the correction of mis-parse could also explain these results, and be consistent with Frazier’s model. According to Frazier’s model, the structurally ambiguous noun phrase (the route) following the main verb would be parsed initially as a direct object of the verb, as this is the simplest structure. On encountering the disambiguating region (was . . .), this analysis would be found to be wrong, and would have to be revised as the more complex complement clause alternative. Verb subcategory preference information could be consulted and used in this revision stage. The revision stage processing could be reflected in the reading times recorded for the disambiguating region, and processing could be easier if the re-parse conforms to the preferred structure of the verb.

However, with the stimuli used in the experiments by Trueswell et al. (1993, experiment 1), Boland (1993) and in this study, it is much harder to argue for a revised interpretation of the results. For example, according to Frazier’s model, the verbs in (10) and (11) would be initially assigned as main clause verbs:

10. The smart gentleman demanded them
11. The brilliant surgeon believed them

If an accusative pronoun follows (e.g. them), this would be assigned as a direct object of the verb. No mis-parse would occur, and there would
therefore be no case for revision. If the accusative pronoun is named faster following transitive than complement clause preference verbs, Frazier’s model cannot account for this by postulating a subcategory preference sensitive revision stage. The results of this experiment are not what would naturally be expected from Frazier’s model.

Despite this, it is still possible to account for verb subcategory preference effects with sentences such as (10) and (11), within a model where an initial parse operates without reference to subcategory preference information. Verb preference information can be hypothesised to trigger structure-checking procedures, even when there is no possibility of re-parsing the input in a different way. The more the verb preference conflicts with the parse, the more checking could take place. These lexical factors could come into play quickly enough to be reflected in the probe in the present experiment, which was immediately after the subcategorised verb (Mitchell, 1989, 1994). Therefore, a two-stage model could be argued in some way to account for the results.

Some readers may feel that the good/bad continuation judgements, which were carried out by the subjects after each item, could have been reflected in the subjects’ naming times for the sentence continuations (them and they). However, the naming latencies were very fast (around 380 msec) and were therefore unlikely to include post-perceptual coherence checking of them and they as continuations for the auditory sentence fragments. Proponents of eye-movement studies may also feel that the cross-modal paradigm used in this experiment could have influenced the results, due to its element of language production in the naming of the sentence continuations. However, Trueswell et al. (1993) demonstrated similar effects of subcategorisation with an eye-movement study as they found with their cross-modal naming paradigm. In their experiment, the paradigm did not therefore appear to be generating the effects.

In summary, the experiment reported in this paper has demonstrated effects of verb subcategory preferences on parsing, the effects being graded according to the strength of the preferences. The results fit elegantly with the direct predictions of a constraint-satisfaction model of syntactic processing.

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REFERENCES


## APPENDIX

*The TR and S preference item sets with their pre-test completion results.*

| TR preference items                                                                 | Preference | NP (%) | All th-S (%) | Difference $|x−y|$ (%) | (NP) (%) | Other (%) | $(th)$-S/ all th-S (%) |
|------------------------------------------------------------------------------------|------------|--------|--------------|-------------|----------|-----------|-----------------------|
| 1. The lazy director indicated                                                     | NP         | 45     | 35           | 10          | 3        | 18        | 64                    |
| 2. The dangerous cyclist revealed                                                 | NP         | 58     | 38           | 20          | 3        | 3         | 47                    |
| 3. The jealous poet maintained                                                    | NP         | 60     | 38           | 22          | 0        | 3         | 60                    |
| 4. The lonely captain confirmed                                                   | NP         | 60     | 38           | 22          | 0        | 3         | 80                    |
| 5. The voluntary worker noticed                                                   | NP         | 58     | 28           | 30          | 8        | 8         | 55                    |
| 6. The remarkable spy guessed                                                    | NP         | 48     | 13           | 35          | 0        | 40        | 100                   |
| 7. The quiet teenager noted                                                       | NP         | 65     | 28           | 37          | 0        | 8         | 45                    |
| 8. The busy professor judged                                                      | NP         | 58     | 20           | 38          | 8        | 15        | 50                    |
| 9. The cheerful author denied                                                     | NP         | 68     | 28           | 40          | 0        | 5         | 64                    |
| 10. The unusual boss mentioned                                                   | NP         | 75     | 20           | 55          | 0        | 5         | 50                    |
| 11. The angry driver feared                                                       | NP         | 73     | 15           | 58          | 0        | 13        | 83                    |
| 12. The enormous guard stressed                                                   | NP         | 80     | 18           | 62          | 0        | 3         | 86                    |
| 13. The sensible priest discovered                                               | NP         | 78     | 15           | 63          | 0        | 8         | 100                   |
| 14. The smooth producer dictated                                                  | NP         | 68     | 5            | 63          | 0        | 28        | 50                    |
| 15. The smart gentleman demanded                                                 | NP         | 90     | 5            | 85          | 0        | 5         | 50                    |
| 16. The wonderful dancer accepted                                                | NP         | 93     | 5            | 88          | 3        | 0         | 50                    |
| **mean**                                                                          | **67**     | **22** | **45**       | **1**       | **10**   | **65**    |                       |
## APPENDIX (CONT.)

The TR and S preference item sets with their pre-test completion results.

<table>
<thead>
<tr>
<th>Preference</th>
<th>NP%</th>
<th>All th-S%</th>
<th>Difference</th>
<th>NP%</th>
<th>Other</th>
<th>(th)-S/ all th-S%</th>
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<td>3. The famous skier confessed</td>
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<td>0</td>
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<td>88</td>
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<td>10</td>
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<td>7. The leading chemist concluded</td>
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