The Role of Verb Argument Structure in Sentence Processing: Distinguishing Between Syntactic and Semantic Effects

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This paper describes an ongoing research program designed to investigate how syntactic and semantic aspects of lexical information become available to the sentence processing system. The two experiments described here distinguished between syntactic and semantic representations by using cross-modal naming and lexical decision in a new way. The relationship between the main verb and the probe word was varied such that the probe word met either the syntactic criteria to be an argument, the semantic criteria, neither, or both the syntactic and semantic criteria. Lexical decision times were sensitive to both syntactic and semantic congruity, while naming times were sensitive only to syntactic congruity. The two tasks were then used to investigate syntactic and semantic representations when verb argument structure was ambiguous. Subcategorized structures were constructed without regard for biasing context, but the contextually inappropriate thematic frame was ruled out while the inappropriate syntactic frame was still available.

The investigation of language understanding is, at heart, an investigation of how different types of linguistic and nonlinguistic knowledge are coordinated to form meaningful representations. As we study sentence com-

¹ The experiments reported here constitute Experiments 2 and 3 of the author’s dissertation, completed at the University of Rochester, Rochester, New York, and are reported in more detail in that manuscript (Boland, 1991). Many thanks to Michael Tanenhaus for helpful comments on an earlier version of this manuscript.

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prehension, the question of how syntactic and semantic information are integrated is especially interesting. Some prominent models of sentence processing (e.g., Frazier, 1989) have placed syntactic and semantic processes into separate, serially ordered modules, with an autonomous syntactic processor providing input to later interpretive processors. The syntactic component of such models does not make use of word meanings or other aspects of lexical knowledge, except for major syntactic category. However, other models of sentence processing (e.g., Tanenhaus, Boland, & Garnsey, 1992) provide an extensive role for lexical knowledge. Lexical knowledge is uniquely suited for integrating syntactic and semantic knowledge because lexical heads place syntactic and semantic constraints on their arguments.

Verbs provide the clearest example of the potential interface between lexical access and sentence processing. More than any other word in a sentence, the matrix verb defines the situation that sentence describes, including the number and types of participants. The participants, or arguments, are specified syntactically by the verb's subcategorization frame(s) and semantically by thematic roles, which describe each argument's mode of participation. For example, rob and steal both subcategorize for a noun phrase argument (as the direct object), but rob assigns its argument the role of Patient whereas steal assigns its argument the role of Theme. Thus, Mary robbed Paul, and she stole money. A verb need not appear early in a sentence in order to play a key role. When verbs precede their arguments (e.g., when word order is subject–verb–object, or SVO), subcategorization and/or thematic knowledge could allow a listener to anticipate upcoming arguments. When verbs follow their arguments, verb-based information could verify previously assigned structures and interpretations, or it could provide new knowledge that instigates (re)organization of the before-mentioned arguments. In the current paper, I have focused on English, an SVO language.

Verb-based knowledge may be particularly well-suited for the integration of syntactic and semantic representations since verbs place syntactic and semantic constraints on their arguments. However, the use of subcategorization and thematic roles have often been conflated in sentence processing research because both are part of a verb's lexical representation, and thus potentially available upon recognition of the verb.

It is important to distinguish between syntactic and semantic sources of information if we are to test models of sentence processing that separate syntactic and semantic processes into ordered modules.

Unfortunately, most research on the use of lexical knowledge in sentence processing has focused on whether lexical information is used or ignored during initial syntactic analysis (for recent summaries, see Boland & Tanenhaus, 1991, and Mitchell, 1989). This focus on the initial syntactic analysis may be misplaced. Tanenhaus et al. (1992) have demonstrated that provisional semantic interpretation can precede bottom-up computation of structure in some circumstances. For example, upon reading Which library did John donate...? subjects may already have assigned library the role of Recipient, although its syntactic position is downstream in a prepositional phrase (Which library did John donate money to ...?). If semantic interpretation is not wholly dependent upon syntactic analysis, the role of lexical knowledge in semantic processes should also be the subject of investigation, along with the exploration of how the syntactic and semantic processes interact.

The current experiments distinguish between syntactic and semantic processing by using naming and lexical decision in a new way. Subjects heard a sentence fragment and saw a naming or lexical decision target just before the offset of the last word in the auditory sequence. Response times were fastest when the target was a good continuation of the sentence, and thus easily integrated into the current representation. For reasons that are discussed below, the syntactic representation is most important in the naming task, while syntactic and semantic representations are both relevant for lexical decisions. Thus, lexical decision picks up both syntactic and semantic congruity effects, while naming picks up only syntactic congruity effects. This paradigm is quite different from the way naming and lexical decision have been used to investigate lexical access. The effects predicted here are postaccess effects that reflect the ease with which the target can be integrated into the context. The paradigm is also quite different from Shapiro and colleagues' (e.g., Shapiro, Zurif, & Grimshaw, 1989) use of cross-modal lexical decision as a secondary task to measure processing load.

In the following section, I will briefly describe the relevant task differences between naming and lexical decision. Experiment 1 is a methodological study that establishes that cross-modal naming and lexical decision can be used to distinguish between syntactic and semantic processes. Experiment 2 uses this paradigm to investigate the use of subcategorization and thematic role information for verbs with multiple argument structures.
CROSS-MODAL INTEGRATION EFFECTS

Schuberth and Eimas (1977) found that lexical decisions were facilitated by congruous sentence context and inhibited by incongruous context (e.g., SOCKS < CAMPUS after The puppy chewed the...). This effect has sometimes been called “sentential priming,” but in most cases, recognition of the probe word is not facilitated. The difference in response latencies probably reflects how easily the probe word was integrated into the current representation of the sentence. Importantly, naming is less sensitive to sentence-level information than is lexical decision (e.g., Seidenberg, Waters, Sanders, & Lauger, 1984). This may be because naming merely requires the retrieval of motor codes whereas lexical decision involves an explicit yes/no decision. High-level information, like sentential context, could be considered as evidence in the decision process.

It is not surprising that lexical decision is sensitive to syntactic context (Goodman, McClelland, & Gibbs, 1981; Gorrell, 1989, 1991; Seidenberg et al., 1984; West & Stanovich, 1986; Wright & Garrett, 1984) because lexical decision is sensitive to postaccess processes and decision bias (Balota & Chumbley, 1984; Forster, 1979; Seidenberg et al., 1984). In contrast, naming has sometimes been viewed as an uncontaminated measure of lexical access. The task merely requires the retrieval of articulatory codes—there is no decision criterion to be manipulated by external variables. Given this, the evidence suggesting that naming is sensitive to syntactic congruency is somewhat surprising (O’Searghda, 1990; Peterson, Burgess, Dell, & Eberhard, 1989; Tyler & Marslen-Wilson, 1977; West & Stanovich, 1986). However, syntactic context effects in naming are consistent with the privileged role syntactic knowledge plays in language production. Unlike language comprehension, which requires us to abstract the message, speaking requires us to place our ideas into syntactic frames. The centrality of those syntactic frames can be seen in the structural integrity of speech errors (Garrett, 1975; Stemberger, 1985), the manner in which intonation and pause patterns reflect syntactic structure (Cooper, Paccia, & LaPointe, 1978; Grosjean, Grosjean, & Lane, 1979), and the phenomenon of structural priming in picture descriptions (Bock & Kroch, 1989). The same process that prevents us from accidentally substituting a noun for a preposition may also inhibit our ability to pronounce a syntactically incongruent word in a naming experiment.

In addition to the work on syntactic context, there is a large body of work demonstrating that naming (e.g., Forster, 1981; O’Searghda, 1990; Stanovich and West, 1983) and lexical decision (Fischler & Bloom, 1985; Kleiman, 1980; O’Searghda, 1990; Schwanenflugel & Shoben, 1985) are sensitive to predictive context. However, it is unlikely that these effects arise from the same source as syntactic context effects. Strongly constrained sentence contexts (e.g., She mailed the letter without a...) are likely to generate preaccess activation of the predicted lexical item (“true” priming), while syntactic context effects are probably the result of a postaccess filter. Semantic context effects on unpredictable targets have not been carefully examined. Weak effects of semantic congruency for unpredictable targets are sometimes found in lexical decisions (Fischler & Bloom, 1985; Kleiman, 1980; Schwanenflugel & Shoben, 1985—but not Forster, 1981, or Gorrell, 1991), but not in naming (Forster, 1981). Nonpredictive syntactic and semantic context effects will be investigated in Experiment 1. If both naming and lexical decision are sensitive to syntactic congruity, but only lexical decision is sensitive to (nonpredictive) semantic effects, then the two tasks could be useful for distinguishing between syntactic and semantic representations.

EXPERIMENT 1

Experiment 1 compares the sensitivity of cross-modal naming and lexical decision with regard to syntactic and semantic context effects. Semantic context effects were further subdivided into a thematic role manipulation and a plausibility manipulation. Three subsets of stimuli were used, one designed to test sensitivity to syntactic context, a second for thematic context, and the third for plausibility. One group of subjects was tested using the naming task and one group was tested using the lexical decision task. In each case, the task can be considered sensitive to the context manipulation if responses are faster to the congruent conditions than to the incongruent conditions. I expected lexical decision to be sensitive to both syntactic and thematic congruity, whereas naming would be sensitive only to syntactic congruity.4

The syntactic contrast used “simple transitive” verbs [example (1a) below] and sentential complement verbs (1b) in the auditory contexts.

4 The plausibility manipulation was included to distinguish lexically based semantic context from semantic context that is more directly dependent upon real-world knowledge. I expected lexical decision to be sensitive to both thematic congruity and plausibility, but that the thematic effect would be somewhat larger. More dramatically, if one or both tasks was sensitive to thematic congruity but not plausibility, it would provide evidence for a thematic level of processing.
The two verb types were crossed with nominative and accusative pronoun targets so that each target and context appeared in both congruent and incongruent conditions. The pronoun pairs *HE/HIM* and *THEY/THEM* were each used with four transitive and four sentential complement verbs. In addition, each target was presented after *The next word is...*, in order to collect a baseline response time.

(1) a. The slow waitress hit THEY/THEM  
   b. The liberal politician insisted THEY/THEM  
(2) The respected lawyer convinced the TEAMS/BEDS  
(3) To which nursery school/military base did Hank deliver the CRA-
YONS

The thematic contrast, illustrated in (2), used verbs that require an animate, sentient noun phrase as the direct object. Importantly, the congruent (animate) target was not a predictable completion for the sentence, but it satisfied the thematic requirements of the verb. Because any noun phrase satisfies the verb's syntactic requirements, if a task is selectively sensitive to syntactic congruency, there should be no difference between congruent and incongruent conditions. The animate and inanimate targets were matched for length and frequency, and naming norms for the targets in isolation revealed no differences between the two groups.

The plausibility contrast, illustrated in (3), used targets that were syntactically and thematically appropriate. Two auditory versions of each context were constructed, one with a plausible wh phrase and one with an implausible wh phrase.

Sentence completion norms ascertained that the average predictability of the targets in all three contrasts was very low, about .01. An additional 36 items of various sorts were used as distractors. Eighteen of these had pronounceable, nonword targets in the lexical decision versions. No instructions were given regarding a relationship between the contexts and the targets; it was assumed that integration of the two would occur spontaneously in the congruent conditions. Yes/no comprehension questions were presented visually after 25% of the targets to ensure that subjects attended to the auditory contexts. In no case was it necessary to integrate the target with the context to answer the comprehension question. After the completion of the experiment, subjects were required to rate each version of each critical sentence (randomly ordered) on a scale of 1 (horrible) to 7 (very natural).

**Ratings.** Mean acceptability ratings across both naming and lexical decision subjects are given in Table I. No differences were found between the two groups. The congruent condition was rated significantly higher than the incongruent condition in each of the four types of contrasts, but the size of the congruency effect was dependent on the type of contrast, with the smallest congruency effect in the plausibility contrast.

**Naming.** The naming data are summarized in Table II. The overall effect of congruency did not approach significance. The only reliable congruency effect was found for accusative pronouns in the syntactic contrast. This effect, together with the lack of a congruency effect else-

| Table I. Mean Acceptability Ratings for Experiment 1, Averaged Across Naming and Lexical Decision Subjects; Difference Scores (Congruent — Incongruent) Given in the Right-Most Column; *N* = 72 |
|------------------|---------|---------|-------|
|                  | Congruent | Incongruent | Difference |
| Accusative (*HIM/THEM*) | 6.58    | 1.51    | 5.07  |
| Nominative (*HE/THEY*)  | 4.62    | 1.76    | 2.86  |
| Thematic             | 6.16    | 2.36    | 3.80  |
| Plausibility         | 6.62    | 5.27    | 1.35  |

| Table II. Mean Naming Latencies (RT) for Experiment 1; Difference (Δ) Scores (Incongruent — Congruent) Given in the Right-Hand Column for Each Contrast; *N* = 32 |
|------------------|---------|-------|
| Condition        | RT      | Δ     |
| Accusative contrast |         |      |
| Simple transitive | 514     | 19    |
| Sentential complement | 533  |       |
| Baseline         | 496     |       |
| Nominative contrast |       |      |
| Simple transitive | 527     | -6    |
| Sentential complement | 533  |       |
| Baseline         | 509     |       |
| Thematic contrast   |         |      |
| Animate           | 570     | -12   |
| Inanimate         | 558     |       |
| Plausibility contrast |      |     |
| Plausible         | 568     | -8    |
| Implausible       | 560     |       |

5 The data for all experiments were analyzed once with subjects as a random variable, and once with items as a random variable. Differences reported here were reliable at *p* < .05 by both subjects and items in an ANOVA unless otherwise noted. A complete report of the results can be found in Boland (1991).
where, gave rise to an interaction between contrast and congruency. Although there was no congruency effect for nominative pronouns, both experimental conditions were slow compared to the baseline, suggesting that the syntactic complexity of the (congruent) sentential complement condition canceled out the congruency effect.

These results support the hypothesis that naming is sensitive to syntactic processes, but not thematic processes or general plausibility. It is difficult to pronounce a word when either (1) it doesn’t fit the syntactic context, or (2) integrating it into the context requires creating complex syntactic structure, as in the nominative pronoun conditions. In contrast, subjects did not find it difficult to pronounce words that were thematically incongruent or implausible.

**Lexical Decision.** Decision latencies are summarized in Table III. Unlike the naming latencies, decision latencies were shorter in the congruent conditions, overall. This suggests that both syntactic and semantic congruity influenced response time. The planned comparison of accusative targets after congruent and incongruent contexts approached sig-

![Table III](image)

<table>
<thead>
<tr>
<th>Condition</th>
<th>RT</th>
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<tr>
<td>Accusative contrast</td>
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<tr>
<td>Simple transitive</td>
<td>606</td>
<td>23</td>
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<tr>
<td>Sentential complement</td>
<td>629</td>
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<tr>
<td>Baseline</td>
<td>678</td>
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<tr>
<td>Nominitive contrast</td>
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<tr>
<td>Simple transitive</td>
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<tr>
<td>Sentential complement</td>
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<tr>
<td>Baseline</td>
<td>768</td>
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<tr>
<td>Thematic contrast</td>
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<tr>
<td>Animate</td>
<td>702</td>
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<tr>
<td>Inanimate</td>
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<tr>
<td>Plausibility contrast</td>
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<tr>
<td>Plausible</td>
<td>761</td>
<td>19</td>
</tr>
<tr>
<td>Implausible</td>
<td>823</td>
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Both of these effects were significant in the subject analysis, but not the item analysis. It is disturbing that many of the effects failed to reach significance in the item analysis. I believe this is due to insufficient power, which is exacerbated by the fact that the design is completely within subjects, but only partially within items. See Boland (1991) for details.

**Syntactic and Semantic Effects**

As before, the planned comparison of nominative targets after congruent and incongruent contexts did not approach significance. Although the pattern of responses in the thematic contrast is reversed from that obtained with naming (i.e., the congruent targets are numerically faster than the incongruent targets), this effect did not approach significance. In the plausibility contrast, the targets were faster after plausible contexts than implausible contexts by subjects, and marginally faster by items.

**Discussion**

The plausibility effect in lexical decision, but not naming, supports the hypothesis that the two tasks are differentially sensitive to semantic representations. However, the pattern of data across the two tasks leaves two things to be explained: the lack of a syntactic congruency effect for nominative pronouns in both tasks, and the lack of a thematic congruency effect in the lexical decisions.

There are several plausible reasons why the nominative contrast would either not produce a congruency effect, or produce a smaller effect than that for the accusative conditions: The sentential complement structures were more complex than the direct object structures, they lacked the usual complementizer *(that)*, the target was not coreferential with the matrix subject as is common, and the nominative targets could not complete the context sentences. Each of these factors made the congruent nominative condition more difficult than the congruent accusative condition. Consistent with this, subjects responded more slowly to the sentential complement conditions than the transitive conditions overall, though this effect was not significant in the items analysis.

Trueswell, Tanenhaus, and Kello (1992) found comparable results using a similar task and materials: They failed to find a reliable subcategorization preference effect for nominative pronouns, but the effect was reliable for accusative pronouns. Significantly, the Trueswell et al. task incorporated a postpronunciation grammaticality judgment that explicitly required subjects to integrate the target and context, and congruent nominative conditions with no complementizer were judged ungrammatical on 18% of the trials.

There is no obvious way to control for the difference in syntactic complexity, but the congruent nominative condition could be made easier by including a complementizer in the contexts, as shown below in (4). The word *that* can be either a complementizer or a determiner, but it is much more likely to be a complementizer when it appears after a verb (Tanenhaus & Juliano, 1993). Thus, it provides a structural cue for a
sentential complement and might help equalize the difficulty of the nominative and accusative conditions. Pilot data, using materials like those shown in (4) and visually presented contexts, demonstrate a small effect of congruency for the nominative conditions. That is, TOOLS, which must be nominative, is faster in the sentence complement context (4d) than the direct object context (4c). The opposite pattern is found when the probe word is TOOL—the direct object context (4a) is faster than the sentence complement context (4b).

(4) a. The laboratory technician returned that TOOL
b. The laboratory technician replied that TOOL (would be useless)
c. *The laboratory technician returned that TOOLS
d. The laboratory technician replied that TOOLS (would be useless)

The other puzzling aspect of the data is the nonsignificant trend of thematic congruency in lexical decision. It is logically problematic, given the effect of plausibility, because the thematically incongruent condition was implausible as well as thematically aberrant. Furthermore, the ratings data indicate that the thematic conditions contained a stronger language violation than the plausibility conditions. The most likely explanation is that the thematic effect was obscured by preaccess expectations. That is, if a context is sufficiently constraining to allow subjects to predict an upcoming target, responses will be slowed dramatically if any target other than the predicted one is presented—even if the actual target is congruent with the context. None of the targets on the critical trials were predictable from the context, but some contexts were more constraining than others. There may have been a crucial difference between thematic and plausibility conditions in the way the contexts constrained potential targets. To the extent that the thematic conditions allowed subjects to generate expectations about potential targets, both the congruent and the incongruent targets would have violated subjects expectations, diminishing the thematic effect. In the plausibility conditions, the implausible contexts were more constraining than the plausible contexts. This makes it more likely that expectations would have been generated, and hence violated, in the implausible condition compared to the plausible condition, thereby enhancing the plausibility effect. The sentence completion norms collected prior to the experiment are consistent with this explanation. (See Boland, 1991, for details.)

The present results add to the evidence in the literature suggesting that naming and lexical decision are both sensitive to syntactic congruency, but only lexical decision is sensitive to semantic congruency.

This task difference provides an important tool with which to examine sentence processing, and, specifically, the on-line use of syntactic and semantic knowledge.

**EXPERIMENT 2**

The above paradigm was used in Experiment 2 to explore how subcategorization and thematic knowledge become available to the sentence processing system and how they influence construction of syntactic and semantic representations. The focus is on verbs with multiple argument structures. We know from the lexical access literature that multiple senses of ambiguous verbs are normally accessed in parallel, even in the presence of biasing context (e.g., Swinney 1979; Tanenhaus, Leiman, & Seidenberg, 1979). It is reasonable to suppose that when a verb is recognized, all of its senses and arguments became available until one is chosen based on context and frequency. The initial availability of various argument structures would impact parsing and interpretation if lexical knowledge is used at an early stage. For instance, a garden path would occur if one verb form was chosen as the most likely, but proved incorrect. And the parallel activation of syntactic frames maps directly onto a parsing model in which alternatives are constructed in parallel.

Experiment 2 was designed to determine whether multiple argument structures are made available when verbs with multiple senses are recognized. I used ten “ambiguous” verbs like pass, which have different meanings with different numbers of arguments. Passing an alley involves just two arguments, a subject and an object, but passing a salt shaker has three arguments: a subject, a direct object, and an indirect object. Thus, (5a) below is unacceptable but (5b) is fine. For each verb, a pair of contexts like those in (5) were constructed such that one strongly biased the two-argument meaning, and one strongly biased the three-argument meaning. The verb was the last word in the auditory context, and the visual target was a monosyllabic name.

(5) a. Ambiguous, two-argument bias: *Which dark alley did Linda pass Bill?

b. Ambiguous, three-argument bias: Which salt shaker did Linda pass Bill?

If multiple syntactic and thematic representations are initially formed at ambiguous verbs like pass, a target like BILL could be integrated into
the contextually inappropriate syntactic or thematic frame during some window of time before the contextually appropriate frames were selected. Because of the task difference investigated in Experiment 1, integration effects in naming are likely to reflect syntactic integration, whereas integration effects in lexical decision should reflect both syntactic and semantic integration.

Two control conditions using unambiguous verbs are necessary. The first used transitive verbs that only subcategorize for two arguments in (6a) below. This condition is a baseline at which integration of the target is never possible. The other control condition (6b) distinguishes between semantic and syntactic integration by using nonalternating dative. These verbs have three thematic roles but subcategorize for a prepositional indirect object, so that *TED is thematically congruent, but syntactically incongruent. If naming latencies for the two control conditions are equivalent and longer than naming latencies for the “salt shaker” condition, it will verify that naming is only sensitive to syntactic integration, and not thematic integration. Lexical decision latencies should be shorter for the thematically congruent (6b) compared to (6a) if lexical decision is sensitive to thematic integration. Note that pass is an alternating dative that can take a noun phrase indirect object. Thus, the ambiguous three-argument condition should allow both syntactic and thematic integration under any account. It will provide a standard of integration against which to compare the other conditions.

(6) a. Unambiguous verb, two-argument bias: Which pie did Mrs. Jones smell... *TED
b. Unambiguous verb, three-argument bias: Which pie did Mrs. Jones recommend... *TED

Thus, the complete design is a 2 (verb is ambiguous or unambiguous) × 2 (two arguments or three arguments) factorial. Sentence completion norms confirmed that the contextus biased the ambiguous verbs as expected. Fifty-eight sentence fragments of various types served as distractors. About 30% of them were obviously cut off in mid-sentence. A different common first name probe was assigned to each critical and distractor item. The critical targets were monosyllables, 3-4 letters in length. For the lexical decision version, 24 names were altered among the distractor items. The resulting nonnames were nonwords as well. The usual lexical decision instructions were modified slightly because the targets were proper names rather than common nouns. Naming and lexical decision norms were collected on the critical targets without contexts and there was no difference between the ambiguous and unambiguous groups in either task condition. The choice of proper names as targets ensured that all targets were equally unpredictable.

Naming. Mean naming times are displayed in Fig. 1. As in Experiment 1, syntactic integration effects were found, but no semantic effects were seen with this task. The main effect of verb type (ambiguous or unambiguous) reflects syntactic integration. Responses to both ambiguous verb conditions were slow because the target was not syntactically congruent in either case. The short latencies for the two ambiguous verb conditions suggest that the target was found syntactically congruent in both cases—and the two-argument condition could not have been syntactically congruent unless the inappropriate subcategorization frame was available. In a planned comparison of the three-argument conditions, the ambiguous condition was faster than the unambiguous condition. This is clear evidence of a syntactic integration effect because the two conditions differ only on the syntactic dimension: Both provide a thematic role for the target. There was no effect of argument number, which would have

![Graph](image-url)

Fig. 1. Mean naming latencies for Experiment 2, given in milliseconds. From left to right, the conditions are ambiguous verb two-argument bias; ambiguous three-argument bias; unambiguous, two-argument verb; and unambiguous, three-argument verb. N = 40.
reflected semantic integration. The two ambiguous conditions did not differ from one another, nor did the two unambiguous conditions.

**Lexical Decision.** The data pattern obtained with lexical decision (Fig. 2) is strikingly different from that obtained using the pronunciation task. The main effect of verb type is significant by subjects, but not by items. To the extent that it is real, it reflects the syntactic integration effect that was also found with the naming task. The most striking effect is the main effect of argument number, with two-argument conditions slower than three-argument conditions. The facilitation of the unambiguous three-argument condition compared to the unambiguous two-argument condition is evidence of semantic integration because the three-argument condition offers a thematic role for the target but the two-argument condition does not. The difference in ease of integration between the two ambiguous conditions can be explained if only the contextually appropriate thematic frame was available. This pattern of data confirms that lexical decision is sensitive to both syntactic and semantic representations. The robust nature of the thematic integration effect is important because no reliable thematic effects were observed in Experiment 1.

**Discussion**

The combined naming and lexical decision results suggest that multiple subcategorization frames are made available at the verb without regards to context, but thematic frames are regulated by (top-down) contextual information. The multiple access of subcategorization frames is straightforwardly consistent with the multiple access of word meanings, but the restricted access to thematic frames at first appears inconsistent. However, the syntactic and semantic results can be reconciled in a coherent model that integrates lexical access and sentence processing. Suppose that all of a verb’s thematic frames are accessed in parallel, but quickly evaluated with regard to context. If context interacts with thematic assignment at an early stage of processing, while syntactic processing proceeds without using contextual information, the above pattern of results would be obtained. Such a system would optimize error detection and recovery because the independently derived syntactic and semantic analyses could check each other.

Note that, in the current experiment, targets were presented just before verb offset—well within the time period in which multiple word meanings are found to be activated. Why weren’t multiple thematic frames still active? In fact, multiple thematic frames probably were available, but the task used here could not provide evidence of them. Meaning activation is tested directly by probing with a semantic associate. If there were an analogous test of thematic frame activation, one might find all frames temporarily activated. The current studies did not provide a direct test of thematic frame activation because the target word itself bore no relationship to the verb or any thematic frame. It was only when the target word was taken to be a continuation of the sentence that a relationship appeared. But if the target did not continue the sentence in a sensible way, lexical decision times would be slowed. If all thematic frames were activated by the ambiguous verbs, the obtained results would still be predicted by the plausibility difference between the two and three argument conditions. Thus, the current results are consistent with the parallel activation of thematic frames at a lexical level, and the rapid, context-guided selection of a single thematic frame at the sentence level. This can be contrasted with the parallel activation of syntactic frames, which are maintained at the sentence level.

The idea that all alternative thematic frames are initially made avail-
b. Unambiguous verb, three-argument bias: Which pie did Mrs. Jones recommend Ted (eat)?

CONCLUSIONS

These experiments were designed to investigate how lexical information becomes available to the sentence processing system, and how it is used to build syntactic and semantic representations. Experiment 1 substantiated differences in the sensitivity of cross-modal naming and lexical decision that allowed me to distinguish between the use of subcategorization and thematic frames in Experiment 2. The use of verbs with multiple argument structures provided a means by which to explore the interaction among syntactic, thematic, and contextual information. It is clear from the results that contextual information is used to evaluate semantic representations at an early stage while syntactic representations inconsistent with context are temporarily maintained. Such a system provides fast and accurate preliminary interpretations based upon contextual information and the thematic role frames associated with the verb. When this information is ambiguous, some garden paths will inevitably occur, whereupon the alternative syntactic frame could guide error recovery.

Semantic representations are richer than syntactic representations, so selecting a single semantic representation early allows for maximal interpretation and cost-efficiency. Semantic representations are probably costly to build and maintain, whereas syntactic representations may be reflexively easy to build and compact to store. I have argued that semantic processing is not completely dependent upon syntactic processing, but the degree to which semantic processing is independent may be a function of how ambiguous the syntactic representation is. Thus the semantic processing system would not ignore helpful syntactic information, but when the structure is ambiguous or unavailable, the semantic processing system is not necessarily delayed.

The current model of sentence processing is quite similar to the model suggested by Gorrell (1989). He also proposed that multiple syntactic representations were constructed and only a single semantic representation was considered at a time. However, in Gorrell's model, the semantic interpretation lagged behind the syntactic analysis, and the initial semantic interpretation was built from the first syntactic analysis to become available, i.e., the simplest one. In the current model, the semantic interpretation is guided by contextual information, and there is
no apparent lag between the computation of syntactic structure and interpretation.

The current model can also be contrasted with Ferreira and Henderson (1990), in which a verb’s thematic frames become available when the verb is recognized and remain available until the syntactic system outputs an incompatible structure. Meanwhile, the syntactic system always outputs the simplest structure based on heuristics, not subcategorization information. If the initial syntactic analysis breaks down, an error message is sent to the thematic processor. If the thematic processor still has access to alternative thematic frames, the corresponding structural information is sent back to the parser to aid in reanalysis. This model would result in more frequent garden paths than the model currently proposed because the initial representations are never informed by prior context and the syntactic system initially ignores subcategorization.

In conclusion, this methodology has the potential to provide a great deal of information about the on-line development of syntactic and semantic representations of sentences, and how the two are coordinated. As a first step, I have investigated how syntactic and thematic information is accessed when a verb has more than one argument structure. The data suggest that subcategorization information is made available in parallel and multiple syntactic representations are constructed, but the contextually guided thematic system quickly selects a single semantic representation. This implies a model in which semantic interpretations are formed quickly and accurately, guided by top-down contextual information, but do not constrain initial syntactic analyses. Because syntactic and semantic representations are formed independently, one can check the other, and in the event of a mistake, the alternative syntactic frame could guide the recovery process.

REFERENCES

Syntactic and Semantic Effects


