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Verb Argument Structure in Parsing and Interpretation: Evidence from wh-Questions

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The hypothesis that readers use verb argument structure information to generate and evaluate likely syntactic alternatives and assign provisional interpretations was evaluated using wh-questions, such as *Which client did the salesman visit while in the city?* Using a word by word, self-paced reading task with a "makes sense" judgment, we manipulated the plausibility of the wh-phrase with respect to the semantic role that it would play if it were the direct object. We also manipulated the preferred argument structure of the verb, using (1) transitive verbs that typically occur with only a direct object; (2) objective control verbs that typically are used with both a direct object and an infinitive complement; and (3) dative verbs that are typically used with both a direct object and an indirect object. The results showed clear and immediate effects of argument structure. Sentences with implausible wh-phrases were judged to stop making sense at the verb for simple transitive verbs. However, sentences with object control verbs and dative verbs were judged to make sense as long as the wh-phrase could be plausibly interpreted as one of the verb's arguments. Thus, the bias to initially interpret a wh-phrase as the direct object of a verb was blocked when the filler was implausible in the direct object role if the verb provided another argument position. In addition, interpretation of the wh-phrase began at the verb, prior to the gap, even when the syntactic position of the gap was ambiguous. The results are taken as support for constraint-based lexicalist models of processing.

Reconciling the apparent immediacy of interpretation with the local indeterminacy of the linguistic input is a major challenge for theories of on-line comprehension. Consider that the interpretation of a sentence is strongly constrained by its syntax, but the syntactic structure is often temporarily ambiguous as the sentence unfolds over time; nonetheless, many

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aspects of interpretation are constructed incrementally (e.g., Marslen-Wilson, 1973; for a recent review, see Tanenhaus & Trueswell, 1995).

In constraint-based models of comprehension, the most likely syntactic alternatives are evaluated using a combination of syntactic, semantic, and discourse constraints (e.g., Bates & MacWhinney, 1987; Taraban & McClelland, 1988; Spivey-Knowlton, Trueswell, & Tanenhaus, 1993). In recent constraint-based lexicalist models, lexical representations play a central role in defining and evaluating alternatives during ambiguity resolution and facilitate the development of provisional interpretations (Boland & Tanenhaus, 1991; MacDonald, Pearlmutter, & Seidenberg, 1994a, 1994b; Trueswell, Tanenhaus, & Garnsey, 1994; Trueswell & Tanenhaus, 1994). Provisional interpretations are partial semantic commitments that are both consistent with, and constrained by, syntax. Most syntactic constraints can be viewed as either being lexically represented or as having lexical triggers (MacDonald et al., 1994a). For example, syntactic and semantic (thematic) information about possible complements are encoded in the argument structure of a verb. Recognition of a verb activates, in parallel, the set of argument structures linked to the verb, with the strength of activation for each alternative determined by its relative frequency for that verb (MacDonald et al., 1994a, 1994b; Trueswell et al., 1994). Thus, multiple argument structures are treated similarly to other types of lexical ambiguities. Both thematic and syntactic information constrain argument selection because both are encoded in the lexically specified argument structures. In addition, thematic information can be used to develop partial interpretations even when the syntactic structure is indeterminate, a point that we will develop when we discuss argument structure in more detail.

Thus far, work within the constraint-based lexicalist framework has been somewhat narrowly focused on a few types of attachment ambiguity, such as reduced relative/main clause ambiguities. In this article, we focus on another important class of syntactic structures, sentences with filler-gap dependencies (e.g., *Which client did the salesman visit while in the city?*). The experiments that we report had four primary goals. First, to provide information about how the semantic and syntactic aspects of verb argument structure are used in assigning fillers to gaps. Second, to determine whether thematic constraints interact with the availability of alternative argument structures in filler-gap assignment as predicted by the constraint-based lexicalist framework. The third goal was to test the hypothesis that access to thematic information allows for provisional interpretation of a filler prior to the occurrence of explicit syntactic evidence about gap location. The fourth goal was to contrast predictions made by constraint-based lexicalist models about when argument structure information is used in filler-gap assignment with predictions made by lexical filtering models (e.g., Frazier, 1987; Mitchell, 1989). In these models, detailed lexical information, including both the syntactic and semantic aspects of argument structure, is not used to guide initial structural commitments. Lexicalist constraint-based models can also be contrasted with models that do emphasize the use of lexical information in parsing, but that clearly order the use of syntactic and semantic information, with construction of a syntactic representation occurring prior to any semantic analysis (e.g., Ford, Bresnan, and Kaplan, 1982).

Before describing our experiments in detail, it is necessary to outline our assumptions about verb argument structure. We then discuss some relevant properties of filler-gap constructions and briefly review related work on the processing of these constructions. Finally, we develop some detailed predictions about how argument structure information is used in filler-gap assignment.

Argument Structure

We take the argument structure(s) of a verb to be the syntactic and semantic characteristics of a verb's immediate complements, or "arguments." Thus, a verb's arguments are lexically specified and differ in this respect from "adjuncts," which occur more freely because their

syntactic and semantic properties are only weakly dependent upon the verb in the phrase that they modify. We will use the verbs *donate* and *give* to illustrate the properties of argument structure, beginning with the syntactic aspects. *Donate* and *give* are both members of the verb class called "datives."

Like all English verbs, *donate* requires a subject noun phrase when it appears as the main verb in a clause. It also licenses, or subcategorizes for, two additional types of syntactic arguments within the verb phrase: a noun phrase (NP) and a prepositional phrase (PP). *Donate* can be used with both of these arguments together, as in (1a), or with each alone as in (1b) and (1c). These examples correspond to three different "subcategorization frames."

(1) a. Chris donated a gift to the charity.
b. Chris donated a gift.
c. Chris donated to the charity regularly.

Give can occur with these subcategorization frames also, which the reader can verify by substituting *gave* for *donated* in (1). In addition, *give* allows both of its internal arguments to appear together as NPs, as in (2a). *Donate* does not allow this "double-object" option and thus (2b) is ungrammatical, as indicated by the asterisk.

(2) a. Chris gave the charity a gift.
b. *Chris donated the charity a gift.

The semantic component of argument structure specifies, for each argument, the mode of participation, or "thematic role," that it plays in the event denoted by the verb. To a first approximation, the number of roles assigned by a particular verb corresponds to the number of necessary participants in the event that that verb denotes. For example, donating events have three roles associated with them: an Agent (the one doing the donating), a Theme (what is being donated), and a Recipient (the one receiving the donation). In (1a), all three of these roles are assigned to syntactic complements. The Agent role is assigned to the subject NP, *Chris,* the Theme role to the object NP, *a gift,* and the Recipient role to the NP within the prepositional phrase, *to the charity.* The Recipient and Theme roles are not expressed in (1b) and (1c), respectively, though they may be implicitly represented in the interpretation of the sentence as open thematic roles (Carlson & Tanenhaus, 1988; Tanenhaus, Carlson, & Trueswell, 1989; Mauner, Tanenhaus, & Carlson, 1995).

All dative verbs assign similar roles to their arguments and we will use the terms Agent, Recipient and Theme as convenient labels for these roles. However, we are actually assuming that a thematic role is a lexically specific concept with a prototype structure that reflects the semantic features of the entities that are typically introduced in particular argument positions by an individual verb (Tabossi, Spivey-Knowlton, McRae, & Tanenhaus, 1994; McRae & Amyote, 1994). For example, a child is a good Recipient in general, but it would be a more typical give-Recipient than a donate-Recipient. This approach to thematic roles is similar to Dowty's (1989) concept of an "individual thematic role."

The combination of subcategorization frames and thematic roles results in three distinct argument structures for *donate,* shown in (3).[1] These argument structures correspond to the sentences in (1) above. The argument structure in (4) occurs with the double object construction illustrated in (2). We list only the "internal arguments"—those arguments that canonically follow the verb; we have not included the subject NP because the current studies focused exclusively on the interpretation of internal arguments, and all of the experimental sentences contained a subject NP that could be unambiguously assigned the role of Agent. We as-

[1] On some accounts, when *donate* is used in the argument structure represented in (3c) its scope is greater than in (3a,b), and it could thus be viewed as a different "sense" of the verb. We have not made such fine distinctions among senses here, in part because of the way in which we believe argument structures are represented. In our view, argument structures are sets of lexically specified syntactic and thematic constraints. Thus, the lexical entry for *donate* contains all of the argument structures in (3), together with other lexically specified information. Our use of the term "argument structure" is therefore somewhat different from how it is often used in the linguistic literature to refer to the number of logical arguments that a verb allows.

sume that when a verb is recognized, all of its possible argument structures are activated in parallel (Boland, 1995; Shapiro, Zurif, & Grimshaw, 1989; Trueswell et al., 1994).

(3) a. [NP<Theme> PP<Recipient>]
b. [NP<Theme>]
c. [PP<Recipient>]
(4) [NP<Recipient> NP<Theme>]

Filler-Gap Sentences

In a filler-gap construction, there is a grammatical dependency between a fronted phrase, a "filler," and an empty syntactic position, or "gap," that occurs later in the sentence. The filler is linked to the gap and it receives the thematic role that it would have been assigned if it had occurred in the syntactic position of the gap. For example, in sentence (5) there is a gap after *donate* in the position that would normally be occupied by an NP. *Which gift* "fills' the gap and is assigned the Theme role just as if it had occurred in the canonical direct object position. In this article, we use an underline to mark the gap position and subscripts to co-index the gap and the filler.

(5) Which gift$_i$ did Bill donate $\_\__i$ to the charity?

Much of the recent work on filler-gap sentences has concentrated on whether gaps correspond to empty categories, with the hypotheses motivated by predictions drawn from different syntactic theories (for recent reviews, see Fodor, 1989, 1993). In contrast, our work is more directly related to an earlier tradition in which sentences with filler-gap dependencies are viewed as containing a temporary structural ambiguity that is resolved when the position of the gap has been identified (see Fodor, 1978). Filler-gap sentences with fronted wh-phrases are particularly well-suited for investigating how argument structure is used to resolve the ambiguity because the wh-phrases are unambiguously marked as fillers, so it is clear that a gap must be found, and the verb's argument structure specifies the set of possible arguments that could be replaced with a gap as well as the syntactic and semantic constraints that are relevant for evaluating the filler with respect to the possible gaps.

The role of argument structure in gap-filling emerged as a central issue in an important article by Fodor (1978), in which she argued against two structural models of gap filling, gap-as-first-resort and gap-as-last-resort, in favor of a lexical expectation model. Fodor proposed that the parser posits a gap after verbs that are typically used transitively, but waits for direct structural evidence of a gap if the verb is typically used intransitively. Subsequent experimental investigations on the role of transitivity preferences in gap-filling have produced mixed results; some studies found effects of transitivity (e.g., Clifton, Frazier, & Connine, 1984; Stowe, Tanenhaus, & Carlson, 1991), while others have not (e.g., Clifton & Frazier, 1988). We will not attempt to reconcile the inconsistencies among these studies because the results presented here suggest that a simple dichotomy between transitive and intransitive preference verbs is not detailed enough to capture the relevant possibilities. For example, intransitive verbs that subcategorize for infinitive complements (e.g., *hesitate*) are likely to behave differently than intransitive verbs that do not subcategorize for any internal arguments (e.g., *sneeze*).

In contrast to the mixed results with regard to transitivity preferences, the literature has clearly established that there is a strong early-filling bias for verbs that are typically used transitively.[2] For example, Stowe (1986) compared sentence pairs like those illustrated in (6) in a self-paced reading study. Note that (6a) contains a filler (*which guest*) that must be assigned to a gap, but that there is a pronoun (*us*) serving as the direct object of the first verb that could potentially provide a gap site. Reading times to *us* were longer in the wh-conditions (6a), where there was a possible gap after *invited*, compared to *us* in the control sentence (6b), where there was not a possible gap.

[2] Some recent studies have demonstrated clear effects of prosody on filler-gap assignment (cf. Nagel, Shapiro, & Nawy, 1994). How prosodic constraints interact with lexical constraints in spoken language is an important issue, but one that we will not address here because we used only visually presented materials.

This result suggests that readers initially assumed that *which guest* was the object of *invite*, positing a gap after the verb. The gap analysis then had to be revised at *us*, resulting in longer reading times at that point. Similar "filled-gap" effects have been reported by Crain and Fodor (1985) and by Clifton and Frazier (1988), and studies using cross-modal lexical priming tasks have also found evidence for gap-filling at the verb (for a recent review, see Nicol, 1993; Nicol, Fodor, & Swinney, 1994; but cf. Mc Koon, Ratcliff, & Ward, 1994; McKoon & Ratcliff, 1994).

(6) a. I wonder which guest$_i$ the hostess invited us to meet $\_\__i$ at the party.
b. I wonder if the hostess invited us to meet the guest at the party.

Garnsey, Tanenhaus, and Chapman (1989) also found evidence for gap-filling at the verb, using filler-gap sentences like those illustrated in (7), where the thematic fit between a wh-filler and an object gap is manipulated. In these sentences, the gap occurs immediately after *read* and is associated with the Theme role: *book* is a plausible Theme for a reading event, but *food* is not. Because the implausibility of (7b) depends upon interpreting *food* as the Theme of *read*, the place in the sentence where the implausibility is first noticed provides information about when the gap has been posited and filled. Garnsey et al. measured event-related brain potentials (ERPs) as subjects read the sentences. This paradigm was used because an enlarged negative wave 400 milliseconds post-stimulus (an N400) is associated with semantic anomalies (Kutas & Hillyard, 1980). Garnsey et al. found that the N400 was larger at the verb when the filler was implausible, indicating that the filler had been interpreted at the verb, or at least evaluated as a potential direct object, resulting in a semantic incongruity. Note that, at the verb, the sentence could still be completed plausibly if *food* is not taken to be the Theme of *read*.

(7) a. I wonder which book$_i$ the boy read $\_\__i$ in class yesterday.
b. *I wondered which food$_i$ the boy read $\_\__i$ in class yesterday.

These results provide additional evidence of the early filling bias. They also would seem to indicate that thematic constraints are not used in filler-gap assignment, because the fact that the semantic properties of the wh-phrase were not thematically appropriate for the object gap did not prevent the wh-phrase from being assigned to that position. Additional evidence that plausibility might not be used in initial filler-gap assignment comes from Swinney and Osterhout (1990). They found priming for a syntactically appropriate but pragmatically implausible filler at a potential object gap. For example, *boxer* but not *boy* was primed after *beaten*, in sentences like *Everyone watched the enormous heavyweight boxer$_i$ that the small 12-year old boy on the corner had beaten $\_\__i$ so brutally*. The result is not surprising, given that *boy* can not be both the subject and the direct object (or both the Agent and the Theme) of *beaten; boxer*, on the other hand, is syntactically appropriate as the direct object even though it is implausible for a 12-year-old boy to beat up a heavyweight boxer. The priming data have commonly been taken as evidence that filler-gap assignment does not make use of plausibility or real-world knowledge.

It could be argued then, that the Garnsey et al. (1989) and Swinney and Osterhout (1990) results support a lexical filtering view, in which gaps are initially posited without considering thematic constraints (e.g., Frazier & Clifton, 1989; Clifton & De Vincenzi, 1990). However, constraint-based models would also predict the pattern of results found by Garnsey et al. and Swinney and Osterhout, because lexical constraints "over-ruled" plausibility in both cases. As outlined below, it is our position that a fronted phase will be coindexed with a potential direct object gap if it is plausible in the role assigned to the direct object position, or failing that, if there are no other plausible thematic roles made available by the verb.

Provisional Interpretation

Consider how the processing system could use argument structure information when processing a sentence with a filler-gap dependency, such as (8) or (9). The wh-phrase is clearly marked as a filler that must be co-indexed

with an NP gap. When *donate* is encountered, its argument structures (shown in (3) above) are activated. The argument structures, together with other syntactic constraints, specify that an NP gap could occur immediately after the verb or within a prepositional phrase. The thematic roles associated with each of these potential gap sites provide semantic constraints that can be used to evaluate the thematic fit of the wh-phrase for each of these potential gaps.

(8) Which painting$_i$ did Bill donate $\_\__i$ to the charity?

(9) Which charity$_i$ did Bill donate a painting to $\_\__i$?

Access to thematic roles when the verb is encountered would also allow for provisional interpretation of the filler. For example, the wh-phrases in (8) and (9) would be assigned different provisional roles. In (8), *which painting* fits the role of donate-Theme better than it does the role of donate-Recipient, so it would be interpreted as the Theme and assigned to a gap immediately after the verb. This would be compatible with either the [NP<Theme>] or the [NP<Theme> PP<Recipient>] argument structure. In contrast, *which charity* fits the Recipient role better than it does the Theme role. A recipient role assignment would be consistent with either the [NP<Theme> PP<Recipient>] or the [PP<Recipient>] argument structure. Thus, provisional interpretation of the filler at the verb would mean assigning a thematic role to the wh-phrase and eliminating incongruent argument structures. Moreover, this could occur before enough syntactic information was available to uniquely identify a subcategorization frame.

As we have seen, the argument structures of a dative verb like *donate* would make available two specific roles, a donate-Theme and a donate-Recipient. These roles are associated with distinct types of syntactic complements (NP or PP) and specific gap sites. The thematic and syntactic information is equally specific for potential gaps that would immediately follow a verb, as in (8), and gaps that would occur later, as in (9). However, the argument structures of many verbs provide less specific information about downstream gap sites. Verbs that subcategorize for infinitive complements are one such example.

Consider "object control" verbs, like *remind*. Object control verbs subcategorize for a direct object NP and an infinitive complement, as shown in (10), which has the argument structure [NP<Agent/Theme> Infinitive Complement<Event>]. The direct object has the thematic properties of both a Theme and an Agent because it functions as the object of the main verb (*remind*) and the understood subject of the embedded verb (*see*). Both the direct object of the main verb and the object of the verb in the embedded infinitive complement are possible gap sites, as shown in (11).

(10) Bill reminded Chris to see the movie.

(11) a. Which friend$_i$ did Bill remind $\_\__i$ to see the movie?

b. Which movie$_i$ did Bill remind his friend to see $\_\__i$?

Whereas the direct object receives its thematic role from the main verb, the object of the infinitive complement receives its role from the embedded verb. Thus, the gap in (11b) is licensed by the infinitive complement and the filler is assigned its thematic role by the verb in the infinitive complement. This raises the question of whether verbs like *remind* could actually provide information about their downstream complements that would be useful for provisional interpretation.

One possibility is that the potential gap site in (11b) would not become available until the verb in the complement was encountered. If this were the case, the only gap site made available at *remind* would be the object gap, which receives the Agent/Theme role. However, it is also possible that access to the argument structure [NP<Agent/Theme> Infinitive complement<Event>] would provide some general thematic information about potential gaps in the infinitive complement. In the absence of additional information about the upcoming verb in the complement, the default for a reminding event might be a generic verb, with prototypical verb features.

The characteristics of a "generic" verb can

be pieced together out of probabilistic data. Most verbs are followed by a subcategorized NP that is assigned the role of Theme (Juliano & Tanenhaus, 1994), and embedded verbs within reminding events are likely to follow this pattern. Therefore, the most activated argument structure for the (projected) verb in the infinitive complement would be [NP<Theme>]. The Theme in this argument structure would have the prototypical features that emerged from combining the properties of those verbs that typically occur in infinitive complements following *remind.* In order to distinguish this thematic role from the lexically specific roles we have discussed so far, we will refer to it as a "generalized theme," i.e., a role that contains prototypical Theme features. Put another way, the semantic representation provided by the [NP + Infinitive Complement] argument structure for *remind* would be *Remind Somebody to Do Something,* where *Do* is a prototypical verb and *Something* is a generalized theme. At *remind* in (11b), *which movie* would be provisionally interpreted as the Theme of the unspecified verb in the upcoming complement because its thematic fit to the generalized theme role is much better than its fit to the Agent/Theme role (as the direct object of the main verb).

The current studies manipulated the plausibility of a fronted wh-phrase for an object gap using the same logic as was used in the Garnsey et al. (1989) study (see also Boland, Tanenhaus, & Garnsey, 1990, and Stowe et al., 1991). The critical materials contain three types of verbs: simple transitive verbs such as *visit,* which typically are used with only a single NP complement; dative verbs such as *donate,* which are typically used with two internal complements, and object control verbs such as *remind,* which are typically used with both an NP complement and an infinitive complement. We assume that recognition of a verb activates its argument structures and that the thematic fit of the wh-phrase is evaluated in parallel for each potential gap site by comparing the semantic features of the filler with the features of the thematic roles associated with each potential gap site. Thus, thematic fit can be used to assign the wh-phrase a provisional role as soon as the verb is encountered. We will refer to this as the provisional interpretation hypothesis. The central predictions of the provisional interpretation hypothesis can be illustrated using the examples in (12). In these sentences, there is an object gap after the verb. The filler is implausible in the role assigned to that gap, but the word after the verb rules out all other possible gap sites.

(12) a. Which prize$_i$ did the salesman visit $\_\__i$ while in the city?
b. Which charity$_i$ did the executive donate $\_\__i$ after meeting the deadline?
c. Which movie$_i$ did your brother remind $\_\__i$ to watch the show?

In sentence (12a), the simple transitive verb *visit,* provides only one possible gap site, an object gap after the verb. Thus, the sentence should become odd immediately at the verb, as in the Garnsey et al. (1989) study, because it is implausible for a salesman to visit a prize. In contrast, the argument structures of the dative verb, *donate,* and the object control verb, *remind,* each provide an additional gap site in which the filler would be plausible. In (12b), *which charity* would be provisionally interpreted as the donate-Recipient at the verb because *charity* is a plausible donate-Recipient. Therefore, readers should not find sentence (12b) odd until the word *after,* which rules out all of the argument structures in which *charity* could be the Recipient. In (12c), *which movie* would initially be interpreted as the generalized theme of the reminding event at the verb, but that interpretation would become untenable at the word, *to.*

We report five experiments that used a word-by-word paradigm with a makes-sense judgment, which we call the "stop-making-sense task." In Experiment 1, sentences contained simple transitive verbs or object control verbs, and a fronted wh-phrase that was either plausible or implausible with respect to a potential gap immediately after the verb. There was a plausibility effect at the verb for the simple transitive verbs, but not for the object control verbs, as predicted by the constraint-based lex-

icalist approach. In Experiment 2, we again manipulated the plausibility of the filler for object control verbs—this time using the filled-gap logic (Stowe, 1986), described earlier. A filled-gap effect was found for the plausible fillers but not the implausible fillers, indicating that plausibility information prevented assignment of the filler to the object gap. This result also demonstrates that the stop-making-sense task is sensitive to lexically-supported revision effects. Experiment 3 replicated Experiment 1 and also demonstrated that dative verbs behave similarly to object control verbs. Finally, Experiments 4 and 5 used dative verbs to provide more detailed information about the specificity of the provisional interpretations that readers are constructing.

EXPERIMENT 1

Experiment 1 was conducted to investigate the relationship between argument structure and filler plausibility in filler-gap sentences using simple transitive and object control verbs. Both classes of verbs are typically followed by a noun phrase and thus offer a potential gap site immediately after the verb as the direct object. This is the only gap site provided by the argument structure of simple transitive verbs like *visit*, but object control verbs like *remind* offer another potential gap site within the infinitive clause, for what we have called a generalized theme. We created sentence pairs by manipulating the plausibility of a fronted wh-phrase as the direct object. This is illustrated in (13), where the first noun in the wh-phrase is plausible and the second is implausible. The filler was always coindexed with a direct object gap, and this became clear one word after the verb. Thus, sentences with implausible fillers were globally implausible. It is possible to complete the "implausible" sentence fragments in (13) in a plausible way if the filler is not assigned to a direct object gap, as in (14). However, as discussed earlier, there is a clear bias to interpret a filler as an argument of the verb rather than as an adjunct.

(13) a. Which client/prize did the salesman visit . . .

b. Which child/movie did your brother remind . . .

(14) Which prize$_i$ did the salesman visit Chicago to obtain $\_\__i$?

The provisional interpretation hypothesis predicts that the timing of the plausibility effect will interact with verb type. The simple transitive sentences should exhibit a plausibility effect at the verb, replicating Garnsey et al. (1989), while the object control sentences should not exhibit a plausibility effect until it is clear that the implausible filler must be assigned the role for which it is implausible. At the verb, the implausible fillers should be given a provisional interpretation consistent with a later argument position.

We used the word by word, stop-making-sense judgment task introduced by Boland et al. (1990) to detect local plausibility effects. Sentences were presented one word at a time, with the words accumulating across the screen. The subject controlled the presentation rate by pushing a button after reading each word. The button press caused the next word to appear, unless the subject pressed a "no" button, indicating that the sentence had stopped making sense. Thus, the subject sets a criterion for a "no" judgment, and local processing difficulty increases the likelihood that the subject will respond "no" at a given word. Previous studies have demonstrated that stop-making-sense judgments are sensitive to a number of syntactic and semantic incongruities (cf. Boland et al., 1990; Mauner et al., 1995; Tanenhaus & Carlson, 1990; Murphy, 1990). In general, we have found that the task shows the same pattern as other self-paced reading tasks, with increases in "no" judgments corresponding to regions in a sentence where processing difficulty would lead to longer reading times. However, the judgments yield more stable data than standard reading time measures. In addition, the effects tend to be more local, typically beginning immediately at the word that triggers an incongruity. This is important for several of the current experiments, where the critical predictions are tied to processing at a specific word in the sentence.

There are two potential concerns with the task that are important to address. The first is that the task might be insensitive to small increases in processing difficulty. This concern, in particular, arises because word by word judgment times are slower than in "normal" self-paced reading. Note, however, that the crucial issue is not how much time elapses between the presentation of successive words, but rather if there are theoretically relevant sources of processing difficulty, such as small revision effects, that might be missed by the task. This is unlikely because stop-making-sense judgments are sensitive to very subtle differences among sentences, including small differences in the difficulty of bridging inferences (cf. Mauner et al., 1995). Most relevant here is the fact that the task is sensitive to purely syntactic effects, as reported in Boland (1995). Boland compared indirect object questions in which the questioned Recipient was the filler for a prepositional object gap, as in (16a), to those like (16b), in which the gap immediately follows the verb. It has been recognized for some time that readers and listeners prefer the former to the latter (Fodor, 1978; Langendoen, Kalish-Landon, & Dore, 1974). Boland found that the number of "no" judgments at the word *this* increased in (16b) compared to (16a), even though there was independent evidence that readers had already made the appropriate thematic assignments by that point in the sentence.

(16) a. Ellen asked which advisor$_i$ Nancy read her doctorial thesis to $\_\__i$ this afternoon.

b. Ellen asked which advisor$_i$ Nancy read $\_\__i$ her doctorial thesis this afternoon.

Furthermore, in a whole sentence version of the task, violations of syntactic constraints on the antecedents of "surface" anaphors are reflected in increased proportions of "no" judgments, even when there are only trends in the same direction in self-paced reading (Tanenhaus & Carlson, 1990; Mauner et al., 1995; Murphy, 1990). Nonetheless, it is important to consider the possibility that the task might be insensitive to small lexically based revision effects, especially when comparing predictions from constraint-based lexicalist models and lexical filtering models. This issue is addressed empirically in Experiment 2.

A second concern about the task is that it might force readers to make commitments earlier than they would normally have made them, resulting in "no" judgments at points in the sentence where readers would otherwise not have encountered difficulty. While this is a potential concern, all of the important positive effects that we report, (i.e., increases in "no" judgments) have been observed with other tasks. Our most striking new results actually come from potential anomalies that subjects do not detect.

Method

Subjects. Thirty-two male and female undergraduates at the University of Rochester completed the experiment, either in partial fulfillment of course requirements or for a minimal sum. All subjects were native speakers of English.

Materials. We selected 12 simple transitive and 12 object control verbs for use in the experiment. The first set of verbs occur with a noun phrase argument when the dominant sense of the verb is used. A few of these verbs had additional (optional) argument positions (e.g., *read*—which can take an indirect object), but the implausible filler was implausible in each of these roles. The object control verbs we selected are typically used with a noun phrase complement (the direct object) and a subcategorized infinitive complement.

A sentence set, consisting of two sentences that were identical except for a fronted wh-phrase, was constructed for each verb. In all cases, the wh-phrase was the filler for a gap immediately after the main verb. Plausibility of the filler for this gap was manipulated within each sentence set, such that one version was plausible and one version was implausible. Whenever possible, the source of the implausibility was the violation of a thematic constraint, such that the semantic features of the implausible filler did not match the requirements of the thematic role assigned by the verb

to its (first) internal argument. This was straightforward for the object control sentences because object control verbs place strong semantic constraints on their direct objects, which must have both Recipient-like properties and Agent-like properties. Sample sentence sets for each verb type, along with the critical word-positions, are shown in Table 1. See the Appendix for a complete list of the critical materials.

Plausibility and verb type were counterbalanced across two lists. Each list contained six plausible and six implausible sentences of each verb type. In addition to the 24 critical sentences, each list contained 80 distractor sentences for a total of 104 trials. Twenty-four of the distractor sentences where wh-questions that were similar in length to the critical sentences and matched for verb type. However, these wh-distractors contained an overt NP as the object of the matrix verb (the gap position in the critical sentences), with the actual gap later in the sentence. These fillers were included to discourage subjects from developing an early-filling strategy based on characteristics of the experimental materials. Eight of the 24 wh-distractors were implausible either because of the direct object or the questioned noun phrase. The remaining 56 distractor sentences were of various syntactic types. Six were implausible, with the implausibility becoming apparent at various points across the sentences. Altogether then, 26 of the 104 sentences (25%) became implausible at some point in the sentence.

Procedure. Sentences appeared on an IBM PC monitor one word at a time. Subjects controlled the presentation rate by pressing a button. The words accumulated across the screen, from left to right. All of the critical sentences fit on a single line. Subjects were asked to read as rapidly as they could while maintaining good comprehension. They were instructed to continue pressing the button for each new word as long as the sentence continued to make sense. If the sentence stopped making sense, they were to press a "no" button. When a "no" response was given, presentation of the sentence stopped and a new trial began. At the end of a sentence, the last button press caused either a period or a question mark to appear.

Before the experiment began, subjects were shown sample sentences that did and did not make sense. An explanation of when and why the sentence stopped making sense was given for each example that did not make sense (e.g., *You can't wear a house*). None of the examples were similar to the critical sentences. Subjects then completed a set of 20 practice sentences in order to become accustomed to the task. Most subjects completed the experiment in about 20 min.

Results

Beginning at the subject noun of the matrix clause, a count was kept of the number of trials in each condition on which a subject responded "no," meaning that the sentence had stopped making sense. This was done for four word positions, the subject noun, the matrix verb, and the next two words in the sentence. In the transitive sentences, these two words were part of either an adverbial phrase or a prepositional phrase. In the object control sentences, the third and fourth positions were the infinitive marker *to* and the verb in the infinitive clause. Once a subject judged a sentence to be implausible, presentation of that sentence

TABLE 1
SAMPLE MATERIALS USED IN EXPERIMENT 1, WITH CRITICAL WORD POSITIONS DEFINED

		N	V	V+1	V+2
Transitive					
Plausible	Which client did the	salesman	visit	while	in the city?
Implausible	Which prize did the	salesman	visit	while	in the city?
Object control					
Plausible	Which child did your	brother	remind	to	watch the show?
Implausible	Which movie did your	brother	remind	to	watch the show?

stopped and thus no further button presses were recorded.

A summary of the cumulative percentage of "no" responses is shown in Fig. 1 for the plausible and implausible conditions for simple transitive and object control sentences. At the subject, there were fewer than 1% "no" responses across all four conditions. However, the percentage of "no" responses sharply increased (to 14%) at the matrix verb for the implausible transitive sentences, while the percentage for the implausible object control sentences remained at 3%. One word later, at the *to*, there was a sharp increase for the implausible object control sentences (up to 14%). By V + 2, our last critical word position, subjects had responded "no" for only 1 and 2% of the transitive plausible and object control plausible sentences respectively, compared to 56 and 38% of the implausible transitive and implausible object control sentences. A 2(list) × 2(verb type) × 2(plausibility) analysis of variance (ANOVA) confirmed that there was a reliable effect of plausibility [$F1(1,30) = 111.50$, $p < .01$; $F2(1,20) = 108.41$, $p < .001$]. In addition, the main effect of verb type was reliable by subjects and marginal by items [$F1(1,30) = 19.43$, $p < .01$; $F2(1,20) = 3.90$, $p < .10$], and the interaction was reliable by subjects and by items [$F1(1,30) = 24.16$, $p < .01$; $F2(1,20) = 6.76$, $p < .05$].

While the cumulative percentage of "no" responses late in the sentences provides an index of overall plausibility, our hypothesis made specific predictions about when subjects would begin pressing "no" in the implausible transitive condition compared to the implausible object control condition. However, the cumulative percentage of "no" responses at each word position is a problematic measure because the percentage at each position is strongly correlated with the percentage at the preceding position. To minimize the dependence of later values on earlier ones, the data were transformed following the procedure used in Boland et al. (1990). The number of "no" responses at each word position was converted to a percentage of the "remaining possible no's" in the following way. There were six trials per condition, so at the beginning of the sentence the maximum number of trials on which a subject could respond "no" was six. At later word positions, the number of remaining possible no's was equal to six minus the number of trials on

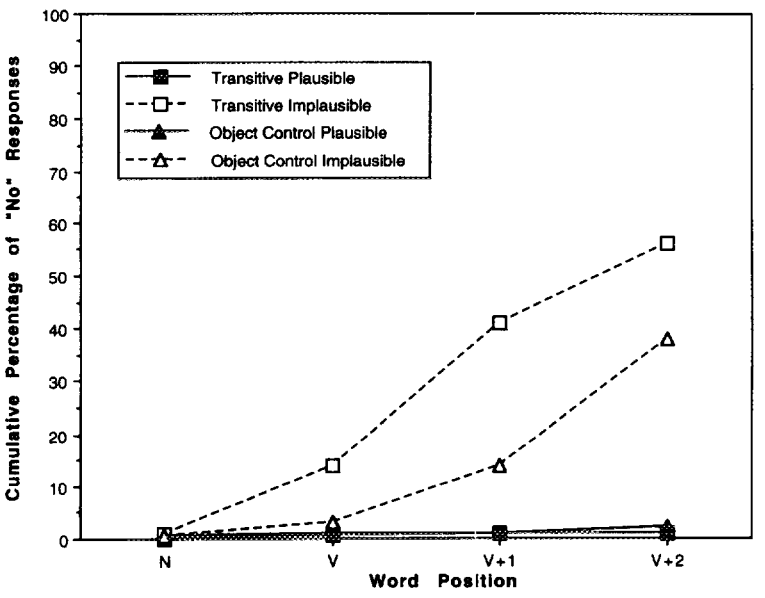

FIG. 1. A summary of the data from Experiment 1: the cumulative percentage of "no" responses for each condition at each word position.

which the subject had already responded "no" (earlier in the sentence). If "no" was pushed for all of the trials in a given condition for a subject or item before the end of the sentence, the later word positions were assigned a value of 100% rather than 0%.

Percentages of "remaining possible no's" for both subjects and items were submitted to a 2(list) × 2(verb type) × 2(plausibility) × 4(word position) ANOVA. There were significant main effects by subjects and by items for verb type [$F1(1,30) = 25.31, p < .01$; $F2(1,20) = 5.11, p < .05$], plausibility [$F1(1,30) = 76.05, p < .01$; $F2(1,20) = 66.27, p < .01$], and word position [$F1(3,28) = 24.60, p < .01$; $F2(3,18) = 26.12, p < .01$].[3] The verb type by word position interaction was significant [$F1(3,28) = 7.88, p < .01$; $F2(3,18) = 5.97, p < .01$], as was the plausibility by word position interaction [$F1(3,28) = 26.14, p < .01$; $F2(3,18) = 23.45, p < .01$]. In addition, the crucial three-way interaction of verb type, plausibility, and word position was observed, as predicted by the provisional interpretation hypothesis [$F1(3,28) = 8.57, p < .01$; $F2(3,18) = 5.63, p < .01$].

Differences among the conditions at particular target positions were evaluated using planned comparisons of both the subject and the item means. At the matrix subject, there were no effects of either plausibility or verb type, and there was no interaction [Fs < 1.00]. At the matrix verb, the predicted interaction of plausibility and verb type was found [$F1(1,30) = 12.69, p < .01$; $F2(1,20) = 7.38, p < .05$], with more "no" responses in the implausible transitive condition compared to either the plausible transitive condition [$F1(1,30) = 19.53, p < .001$; $F2(1,20) = 20.57, p < .001$] or the implausible object control condition [$F1(1,30) = 12.79, p < .01$; $F2(1,20) = 6.96, p < .05$]. There was no difference between the two object control conditions [$F1(1,30) = 2.79, p < .10$; $F2 < 1.00$]. One word later (V + 1), the interaction was still obtained [$F1(1,30) = 29.33, p < .001$; $F2(1,20) = 18.44, p < .001$] because there were more "no" responses for the implausible transitive condition than the implausible object control condition [$F1(1,30) = 29.40, p < .001$; $F2(1,20) = 17.21, p < .001$]. However, in addition to the plausibility effect for the transitive verbs [$F1(1,30) = 75.35, p < .001$; $F2(1,20) = 68.74, p < .001$], there were more "no" responses in the implausible object control sentences compared to the plausible object control sentences [$F1(1,30) = 12.48, p < .01$; $F2(1,20) = 4.92, p < .05$]. At V + 2, there was no longer an effect of verb type, nor an interaction [Fs < 1.00]. The effect of plausibility remained [$F1(1,30) = 39.67, p < .001$; $F2(1,20) = 40.14, p < .001$], with the two implausible conditions both having more "no" responses than the plausible conditions [transitive: [$F1(1,30) = 25.02, p < .001$; $F2(1,20) = 19.74, p < .001$]; object control: [$F1(1,30) = 42.05, p < .001$; $F2(1,20) = 20.41, p < .001$]. In addition, the two implausible conditions no longer differed [Fs < .10].

Discussion

A plausibility effect was obtained at the matrix verb for sentences with simple transitive verbs, but was absent at that point in sentences with object control verbs. The interaction of plausibility and verb type at the matrix verb demonstrates that readers made use of argument structure in assigning fillers to gaps. Thus, thematic constraints clearly influenced filler-gap assignment in the object control sentences at the verb. The plausibility effect at simple transitive verbs replicates earlier results by Tanenhaus, Stowe, and Carlson (1985); Stowe et al. (1991); Garnsey et al. (1989); Swinney, Ford, Frauenfelder, and Bresnan (1988); and Swinney and Osterhout (1990): plausibility information by itself does not determine filler-gap assignment.

These results also provide evidence that lexically-based syntactic constraints influenced filler-gap assignment because a plausibility effect was seen one word after the object control verbs, the point at which all gap sites were

[3] Throughout the paper, we report the Huynh–Feldt (Huynh & Feldt, 1976) adjusted probability values for all analyses involving the word position factor, which has more than two levels, since the results at different positions are not independent of one another. We present the original, unadjusted degrees of freedom.

ruled out except the object gap immediately following the verb. These results are consistent with an emerging body of literature suggesting that argument structures are made available in parallel and thematic constraints, together with other constraints, allow the processor to settle upon a single representation (e.g., MacDonald et al., 1994a; Trueswell et al., 1994). Within this constraint-based lexicalist framework, thematic information allows readers to develop a provisional interpretation for the filler at the verb. In the case of simple transitives, there was only one possible argument position, so the filler was assigned that role, and plausibility effects arose immediately. In the case of object control verbs, the semantic features of the fillers were evaluated with regard to all potential argument positions in parallel. The fact that no plausibility effects were seen for the object control sentences at the verb suggests that both the plausible and implausible fillers were assigned one of the thematic roles offered by the object control verb. Most likely, the plausible fillers were acceptable in the direct object role, and the "implausible" fillers were found to be better suited to a later role, as a generalized theme. Our hypothesis that the fillers were, in fact, provisionally interpreted in this way will be tested in Experiment 2.

While the results of Experiment 1 are consistent with the provisional interpretation hypothesis, they could also be accommodated by lexical filtering models, in which initial gap assignment does not take into account lexically specific information. Filtering models assume that detailed lexical information is used to evaluate and, if necessary, revise the initial syntactic commitments. The crucial assumption, under the lexical filtering account, is that reanalysis effects that are guided by argument structure information are either too rapid or too subtle to be detected by our task. If so, the interaction between plausibility and verb type could be a consequence of differences in the ease of reanalysis after a gap had been posited. According to this account, a gap is posited and filled immediately upon encountering a verb for both simple transitive and object control verbs. The resulting syntactic representation is then evaluated using argument structure information. When the wh-phrase is implausible for the object gap (i.e., the possible gap after the verb), rapid reanalysis is possible for sentences with object control verbs, but not simple transitives, because only the argument structure of object control verbs makes available an alternative gap site. On this view, the plausibility effects observed in Experiment 1 reflect a difficult kind of reanalysis (i.e., not lexically driven), or perhaps reflect that the reader settled on an implausible interpretation because no other alternative was available. This account assumes that the judgments reflect the outcome or the difficulty of reanalysis, but are insensitive to the both the initial implausibility of the object gap analysis and the reanalysis process for the object control sentences.

It is difficult to completely rule out a reanalysis interpretation because, in principle, one could always propose cost-free reanalysis. However, it is possible to test whether or not the stop-making-sense task is sensitive to lexically aided reanalysis using the filled-gap logic. Thus, we can provide a critical test of whether the stop-making-sense task is sensitive to the type of reanalysis assumed by a lexical filtering explanation. Experiment 2 was conducted for this purpose.

EXPERIMENT 2

This experiment used the filled-gap logic introduced by Stowe (1986) and Crain and Steedman (1985) to further test predictions made by the provisional interpretation hypothesis, and to establish whether judgments in the stop-making-sense task would be sensitive to a lexically-aided reanalysis process of the type that lexical filtering models might appear to in explaining the absence of plausibility effects at the verb for object control sentences in Experiment 1. Recall that filled-gap effects are reflected in increased processing difficulty when a noun phrase occurs in a position where the reader had initially posited a gap. Experiment 2 used the object control verbs with the plausible and implausible wh-phrases from Experiment 1 (see (17a) and (17b)). Our control condition, illustrated in (17a), did not contain a long-distance

dependency. In addition, we included two types of sentences with simple transitive verbs: filler-gap sentences with a plausible filler (18b), and a control condition without a long distance dependency (18a). Thus, verbs were either object control (17) or simple transitives (18), and sentences were in declarative form with no long distance dependencies (as in (17a) and (18a)), or contained a long-distance dependency (as in the (b) and (c) versions).

(17) a. Samuel asked whether Mark reminded them to watch the child.
b. Which child$_i$ did Mark remind them to watch $\_\_{}_i$?
c. Which movie$_i$ did Mark remind them to watch $\_\_{}_i$?

(18) a. I wondered whether the lawyer visited them for the client last week.
b. Which client$_i$ did the lawyer visit them for $\_\_{}_i$ last week?

This experiment provides a partial replication of Experiment 1 because once again, we predicted no plausibility effect at the verb for sentences with object control verbs. However, Experiment 2 differed from Experiment 1 in that filler plausibility was manipulated with respect to a possible, rather than an actual, direct object gap. Thus, all sentences, even those with "implausible" fillers, were globally plausible. The critical word position is the pronoun *them*. Plausibility of the filler was manipulated only for the object control sentences, because we knew, based on the results of Experiment 1, that subjects would judge the simple transitive sentences with implausible fillers implausible at the verb, and thus an "implausible transitive" condition would provide no useful data at the pronoun.

The central predictions from the constraint-based lexicalist model are these. There should not be a plausibility effect at the verb for object control sentences, replicating the results of Experiment 1. In addition, there should be more "no" responses at the pronoun (*them*) for sentences with plausible fillers compared to sentences with implausible fillers, which should not differ from the control condition. The logic behind these predictions is as follows. For the filler-gap sentences with plausible fillers ((17b) and (18b)), the reader should provisionally interpret the wh-phrase as the object of the verb. When the pronoun is encountered, this interpretation will have to be revised, resulting in some processing difficulty that will be reflected in more "no" responses. For the object control verbs with wh-phrases that are implausible with respect to the possible object gap (17c), there should not be a filled-gap effect because thematic fit has been used to rule out an object gap assignment in favor of provisional interpretation of the filler as a generalized theme.

Recall that lexical filtering models could explain the absence of a plausibility effect at the verb for object control sentences with implausible fillers by claiming that our task was not sensitive to lexically guided reanalysis. If this were the case, then there should be a filled-gap effect at the pronoun in sentences with plausible fillers after simple transitive verbs but not after object control verbs. The reason is that the argument structure of an object control verb provides another gap site, whereas the argument structure of a simple transitive verb does not. Therefore, reanalysis should be easier for the object control verbs. Thus, the argument structure contrast which lexical filter models would have to use at the verb to account for the results in Experiment 1 is also relevant at the pronoun.

Method

Subjects. Thirty undergraduates at the University of Rochester completed the experiment in partial fulfillment of course requirements. All subjects were native English speakers.

Materials. Experimental items were constructed using simple transitive and object control verbs as in Experiment 1. Two types of sentences were constructed: wh-constructions in which a questioned phrase filled a late gap (as the object of an embedded verb), and control sentences without long distance dependencies. Examples of the experimental conditions and critical word-positions are presented in Table 2. A complete list of the critical materials is in the Appendix. Items containing object control verbs had two versions of the wh-construc-

TABLE 2
SAMPLE MATERIALS FROM EXPERIMENT 2, WITH CRITICAL WORD POSITIONS DEFINED

		N	V	Pronoun	V+2	V+3
Object control						
Wh-plausible	Which child did	Mark	remind	them	to	watch
Wh-implausible	Which movie did	Mark	remind	them	to	watch
Declarative	Sam asked whether	Mark	reminded	them	to	watch
Transitive						
Wh-plausible	Which star did the	assistant	watch	them	photograph	last
Declarative	I wonder whether the	assistant	watched	them	photograph	the

Note. Sentence endings have been truncated.

tions in addition to the control condition. The only difference between the two versions was the wh-phrase, which was either plausible or implausible as the direct object of the matrix verb. All fillers were plausible in the actual gap position, so the implausibility was strictly local. The wh-constructions were modified slightly to construct the declarative control condition: the phrase that was fronted in the wh-constructions appeared in its canonical argument position and the sentence began with a short clause consisting of a subject, a verb, and the word, *whether.* All sentences were globally plausible.

Twelve sets of transitive sentences (two versions per set) and 18 sets of object control sentences (three versions per set) were constructed and balanced across three lists. Each list contained eight transitive items (four of each condition) and 18 object control items (six of each condition). In addition, there were ten transitive and ten object control distractor sentences modeled after the critical sentences. However, the wh-sentences in this set had a gap in the direct object position (unlike the critical sentences), and a few were implausible. Ten additional transitive items were added to balance the proportion of sentences with each verb type on a list. Each list contained 34 additional distractor sentences of various types, many of which included pronouns, making 90 total items per list.

Procedure. The procedure used in Experiment 1 was used again here.

Results

A record of which button was pressed was kept for five word positions in each critical sentence.[4] For all sentences, the first three positions were the subject noun, the main verb, and a direct object pronoun. The final two positions were either the first two words of an adverbial phrase, a prepositional phrase, or an embedded infinitive complement. Because of the different numbers of sentence versions for the two verb types, the data from each verb type were analyzed separately. The data for the object control sentences are illustrated in Fig. 2, and the data for the simple transitive sentences are illustrated in Fig. 3.

For the object control sentences, subjects had responded "no" by the last word position on approximately 22% of the plausible wh-sentences, 10% of the implausible wh-sentences, and 6% of the declarative sentences. The percentages at the final position were submitted to a 3(list) × 3(sentence type) ANOVA. There was a main effect of sentence type by subjects and by items [$F1(2,26) = 15.42$, $p < .01$; $F2(2,14) = 9.44$, $p < .01$]. This reflects a filled-gap effect at the pronoun for the plausible wh-condition only, as predicted by the provisional interpretation hypothesis.

In the simple transitive sentences, subjects had responded "no" on approximately 30% of

[4] For Experiments 2–5, we also recorded button-press latencies. The latency data were generally uninformative so we do not report them. The problem is that, once people press "no," that trial is aborted and no further reading times are collected. Thus, there are fewer reading times later in the sentence, increasing variability. We should note, however, that increased "no" judgments were generally accompanied by longer reading times, and we did not see longer reading times for implausible fillers at places were there were not also increases in "no" judgments. Tables and statistics describing the button-press latencies are available from the first author.

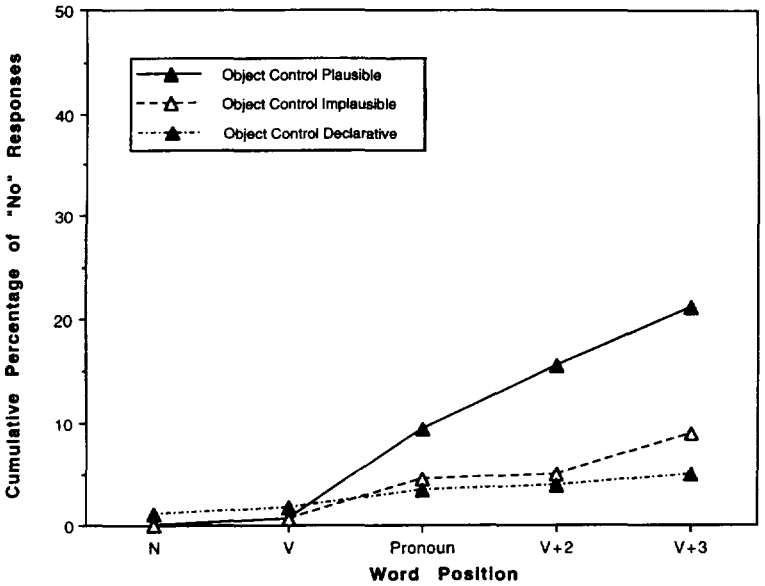

FIG. 2. The cumulative percentage of "no" responses for each object control condition in Experiment 2. Note that the scale has been reduced because all sentences were globally plausible, and thus there were relatively few "no" responses.

the wh-sentences and 10% of the declarative sentences by the last word position. Cumulative percentages of "no" responses at the final word position, by subjects and by items, were submitted to a 3(list) × 2(sentence type) ANOVA. There was a main effect of sentence type in both subject and item analyses [$F1(1,27) = 14.44; p < .01$; $F2(1,9) = 7.37, p < .05$], with

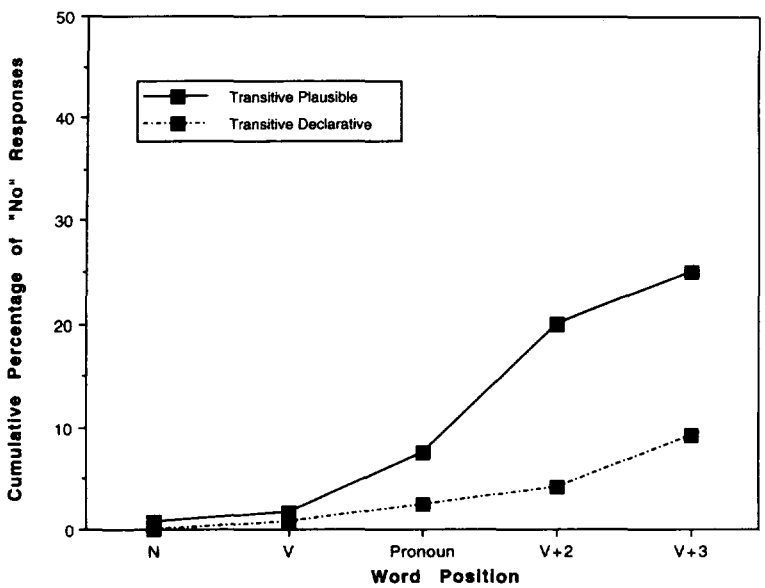

FIG. 3. The cumulative percentage of "no" responses for each simple transitive condition in Experiment 2. Note that the scale has been reduced because all sentences were globally plausible, and thus there were relatively few "no" responses.

more "no" responses in the sentences with gaps. This reflects the filled-gap effect predicted by all three hypotheses.

As in Experiment 1, the cumulative percentages at each word position were transformed into the percent "no" responses out of "remaining possible no's" in order to examine the pattern of effects across word positions. The transformed percentages, for subjects and for items, from the object control verb conditions were submitted to a 3(list) × 3(sentence type) × 5(word position) ANOVA. There were main effects of sentence type [$F1(2,26) = 7.62$, $p < .01$; $F2(2,14) = 8.67$, $p < .01$] and word position [$F1(4,24) = 5.58$, $p < .01$; $F2(4,12) = 6.11$, $p < .01$], and an interaction between the two [$F1(8,20) = 4.69$, $p < .01$; $F2(8,8) = 2.90$, $p < .01$].

The provisional interpretation hypothesis predicted a filled-gap effect for the object control verbs, but only for wh-sentences with plausible fillers. Planned comparisons revealed that there were, in fact, more "no" responses for the wh-sentences with plausible fillers compared to the declarative control sentences at the pronoun as predicted [$F1(1,27) = 10.61$, $p < .01$; $F2(1,24) = 9.04$, $p < .01$], and no difference between wh-sentences with implausible fillers and control sentences [$Fs < 1.00$]. In addition, the primary finding of Experiment 1 was replicated: there was no difference in the proportion of "no" responses between the plausible and implausible versions of the object control wh-sentences at the verb [$Fs < 1.00$].

The percentages of remaining possible no's from the transitive conditions were submitted to a 3(list) × 2(sentence-type) × 5(word position) ANOVA. There were main effects of sentence type [$F1(1,27) = 6.20$, $p < .05$; $F2(1,9) = 7.32$, $p < .05$] and word position [$F1(4,24) = 6.61$, $p < .01$; $F2(4,6) = 5.44$, $p < .01$], and an interaction between the two [$F1(4,24) = 4.62$, $p < .01$; $F2(4,6) = 2.74$, $p < .01$], consistent with the predicted filled-gap effect.

Discussion

A filled-gap effect was observed for object control and transitive sentences with plausible fillers. This provides direct evidence that plausible fillers were interpreted as the direct object immediately at the verb for both verb types and is consistent with the provisional interpretation hypothesis. The absence of a plausibility effect at the verb for object control sentences replicated the primary effect of Experiment 1. Finally, as predicted by the provisional interpretation hypothesis, there was no filled-gap effect for (object control) sentences with implausible fillers.

In the discussion of Experiment 1, we considered the possibility that a lexical filtering model could account for the absence of a plausibility effect at the verb for object control verbs by postulating that makes-sense judgments are not sensitive to rapid reanalysis when argument structure provides an alternative gap site. However, Experiment 2 shows that the task is clearly sensitive to filled-gap effects for object control verbs, where argument structure could also guide renanalysis. While we cannot categorically rule out the possibility that reanalysis at the verb based on argument structure is easier than lexically-guided reanalysis at the pronoun one word later, an argument based on task sensitivity seems extremely implausible given the results of Experiment 2.

Having established in Experiments 1 and 2 that thematic information mediates filler-gap assignment, we can now ask, what is the nature of the thematic constraints that bear on filler-gap assignment? We explored this question in Experiment 3, using dative verbs.

EXPERIMENT 3

In the first two experiments we demonstrated that filler-gap assignment is mediated by thematic fit for object control verbs. We have been assuming that thematic fit is evaluated by comparing the features of the wh-phrase with the prototypical features of the thematic roles for each potential gap site. However, the thematic fit manipulations used for object control verbs also allow for an explanation based on a more restricted notion of thematic fit in which only semantic features that are grammatically encoded are used for initial thematic role evaluation. Caplan, Hildebrandt, and Waters (1994) have made just this proposal, basing their hypothesis on Chomsky's (1965)

notion of selectional restrictions. For object control verbs, a plausible object must have Agent-like properties: usually it must be animate and sentient. All of the implausible wh-phrases that we used were inanimate. Because animacy is grammatically marked in some languages, it is likely to count as a selectional restriction. In contrast, there is no plausible selectional restriction that could be used to rule out a wh-phrase as a Theme for the simple transitive verbs. This is because the semantic features required of a Theme are highly dependent upon the particular verb. For example, both *kick* and *believe* assign the role of Theme to their immediate complement, but there is no single semantic feature that could be used to determine whether or not an NP was an acceptable Theme; one can kick an object or a person, but not an idea, while one can believe a person or an idea, but not an object.

For the object control verbs in Experiments 1 and 2 then, a selectional restriction (animacy) could have been used to reject the inanimate wh-fillers. However, the implausible fillers for the simple transitive verbs could not have been rejected on the basis of selectional restrictions because there is not a well-defined selectional restriction associated with the Theme role for these verbs. In order to provide evidence about whether a selectional restriction account is viable, we included dative verbs in Experiment 3. Dative verbs, like object control verbs, provide multiple gap sites. However, dative verbs are like simple transitives in that the Theme role cannot be ruled out using a semantic feature that is a plausible candidate for a selectional restriction. Therefore, a selectional restriction account would predict that thematic fit would not mediate gap-filling for dative verbs, whereas a more conceptual view of thematic role evaluationk like the one we proposed, would predict that dative and object control verbs would pattern together, in contrast with simple transitive verbs.

In experiment 3, simple transitive, object control, and dative verbs were used in the embedded anomaly paradigm from Experiment 1. As in that experiment, all sentences had fronted wh-phrases and a direct object gap, so sentences with implausible fillers were globally implausible. The goals of this experiment were first, to replicate the pattern of plausibility effects observed in Experiment 1 for simple transitive and object control verbs, and second, to use dative verbs to investigate the nature of the thematic constraints used to assign fillers to argument positions.

Method

Subjects. Thirty-six undergraduates at the University of Rochester completed the experiment either in partial fulfillment of course requirements or for a nominal sum. All subjects were native English speakers.

Materials. We selected 12 simple transitive verbs, 12 dative verbs (some of which were alternating datives), and 12 object control verbs for use in the experiment. Many of the verbs had several alternative argument structures, but none of the simple transitive verbs had one of the more complex structures as a possibility. Although both object control verbs and dative verbs can be used with only a single internal argument (e.g., *Tom told Bill,* and *John sent his assistant*), we chose verbs where the role associated with the second internal argument seems to be a necessary part of the event described by the verb even if it is not explicit in the sentence. Completion norms were collected on subject + verb fragments to confirm that the verbs had the desired characteristics. In fact, sentence fragments with simple transitive verbs were completed with a single argument 81% of the time; fragments with dative verbs were completed with both a direct object and an indirect object 53% of the time; and fragments with object control verbs were completed with a direct object and an infinitive complement 52% of the time. Thus, for all three verb types, subjects produced the expected structure more than half the time, and no other structure was nearly as frequent.

Sentence sets were constructed for each individual verb in the same way that they were constructed for Experiment 1. Plausibility of the filler was manipulated with respect to a direct object gap. The implausible fillers were plausible as a Recipient (in the sentences with

dative verbs) or as a generalized theme (for sentences with object control verbs), but the sentences with implausible fillers were always ultimately implausible, because the actual gap was in the direct object position. Sample sentence sets for each verb type, along with the critical word-positions, are shown in Table 3. The full set of critical sentences is in the Appendix. Two lists were created such that one version of each item appeared on each list, and there were equal numbers of plausible and implausible trials using each verb type. In addition to the 36 critical trials, there were 64 distractor sentences, for a total of 100 trials. All items were ordered randomly.

Procedure. The procedure used in Experiment 2 was used again here.

Results

A record of which button was pressed was kept for six word positions in each critical sentence, beginning at the subject noun of the matrix clause. A summary of the data is provided in Fig. 4. At the verb and one word later, there were markedly different patterns between sentences with simple transitive verbs and those with object control verbs, as seen in Experiment 1. Simple transitive sentences showed increased numbers of "no" responses for the implausible versions, beginning at the verb. Object control sentences did not exhibit plausibility effects until one word after the verb, when there were increased numbers of "no" responses. As predicted by the provisional interpretation hypothesis, the dative sentences behaved more similarly to the object control sentences than to the simple transitive sentences; in fact, the numbers are nearly identical for the dative and object control conditions.

At each word position, a count was kept of the number of trials in each condition on which a subject responded "no," and the data were transformed as in Experiments 1 and 2. A 2(list) × 3(verb type) × 2(plausibility) × 6(word position) ANOVA was performed on both subject and item means. There were main effects of plausibility [$F1(1,34) = 99.88$, $p < .01$; $F2(1,30) = 158.57$, $p < .01$] and word position [$F1(5,50) = 40.59$, $p < .01$; $F2(5,26) = 26.94$, $p < .01$], and an interaction between the two [$F1(5,30) = 35.66$, $p < .01$; $F2(5,26) = 22.05$, $p < .01$]. The three-way interaction between verb type, plausibility, and word position was reliable in the subject analysis, but not the item analysis [$F1(10,25) = 2.65$, $p < .05$; $F2(10,52) = 1.70$, $p > .10$].

Differences among the conditions at particular word positions were evaluated using planned comparisons. As expected, there was an interaction between verb type and plausibility at the verb [$F1(2,33) = 6.34$, $p < .01$; $F2(2,30) = 6.65$, $p < .01$]. This interaction arose because a plausibility effect was found at simple transitive verbs [$F1(1,34) = 14.95$, $p < .01$; $F2(1,30) = 49.99$, $p < .01$], but not at dative verbs [$F1(1,34) = 3.73$, $p < .10$; $F2(1,30) = 1.77$, $p > .10$] or object control verbs [$F1(1,34) = 3.60$, $p < .10$; $F2(1,30) = 3.31$, $p < .10$]. Note, however, that there were marginal effects in the subject analysis at dative verbs and in both the subject and item analyses at object control verbs. These plausibility

TABLE 3
SAMPLE MATERIALS FROM EXPERIMENT 3

		N	V	V+1	V+2	V+3	V+4
Transitive							
Plausible	Which star did the	assistant	watch	all	through	the	night?
Implausible	Which stone did the	assistant	watch	all	through	the	night?
Object control							
Plausible	Which girl did the	woman	remind	to	watch	the	show?
Implausible	Which movie did the	woman	remind	to	watch	the	show?
Dative							
Plausible	Which poem did the	babysitter	read	in	a	funny	voice?
Implausible	Which poem did the	babysitter	read	in	a	funny	voice?

Note. Critical word positions are marked.

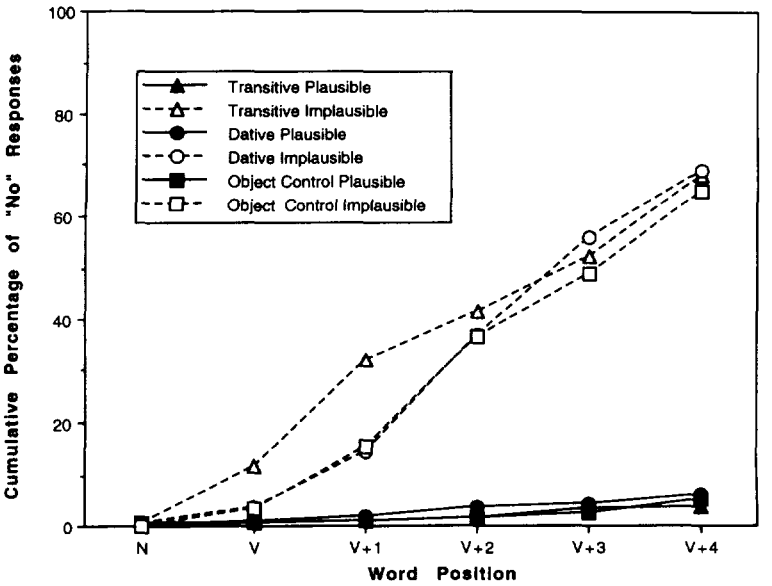

FIG. 4. The cumulative percentage of "no" responses for Experiment 3.

effects reached significance one word later, at V + 1 [datives: $F1(1,34) = 11.95$, $p < .01$; $F2(1,30) = 6.44$, $p < .05$; object control: $F1(1,34) = 16.74$, $p < .01$; $F2(1,30) = 9.23$, $p < .01$], which forced the assignment of the fillers to the direct object gap.

Discussion

As predicted by the provisional interpretation hypothesis, plausibility effects were found earlier for sentences with simple transitive verbs than for sentences with either object control or dative verbs. This suggests that filler-gap assignment is regulated by a rich evaluation of semantic constraints rather than only grammatically encoded selectional restrictions, such as animacy.

Unlike Experiments 1 and 2, Experiment 3 did exhibit a marginal effect of plausibility at the verb for sentences with dative and object control verbs, suggesting that the implausible filler was immediately taken to be the direct object on a small number of trials. One possible explanation suggested by the constraint-based lexicalist framework is that some of the object control and dative verbs used in Experiment 3 occur relatively often with only a single internal argument (i.e., without an infinitive or an indirect object, respectively), whereas in Experiments 1 and 2 our object control verbs tended to occur with both a direct object and an infinitive complement. We are exploring the role of frequency effects within these verb classes in ongoing work, and we will return to this issue in the general discussion.

Before concluding that the results support the provisional interpretation hypothesis, we considered the possibility that the simple transitive conditions contained a more salient anomaly than did the dative or object control conditions. We tested this by collecting acceptability ratings from 8 subjects who did not participate in the experiment itself. Plausible and implausible versions of the critical materials were randomly mixed. Subjects rated each sentence on a scale from 1 to 7, where 1 was very acceptable, and 7 was very unacceptable. The results are summarized in Table 4. The implausible sentences in the transitive condition were actually judged to be more acceptable than those in the dative or object control conditions. Though the number of subjects is small, the verb type by plausibility interaction is reliable [$F(2,6) = 10.48$, $p < .05$], with the largest plausibility effect in the dative conditions. Thus, the interaction between verb type, plausibility, and word position found above cannot be due to a difference in the degree of

TABLE 4
ACCEPTABLITY NORMS (SCALE: 1—HIGH TO 7—LOW) FOR PLAUSIBLE AND IMPLAUSIBLE CONDITIONS FOR EACH VERB TYPE USED IN EXPERIMENT 3

	Plausible	Implausible	Difference
Transitive	1.6 (.42)	4.9 (.70)	3.3
Dative	1.6 (.46)	5.7 (.52)	4.1
Object control	2.4 (.84)	5.7 (.72)	3.3

Note. The difference between plausible and implausible means is g ven at the far right. Standard deviations are given in parentheses.

implausibility in the materials; it must be due to the difference in argument structure.

At this point, it will be useful to briefly summarize the results obtained across the first three experiments. The key finding is that the word position where plausibility effects occur in a filler-gap sentence depends upon the argument structure of the verb. When the argument structure of the verb provides only one possible gap site, then a gap is posited and interpreted. However, if the argument structure of the main verb provides alternative gap sites, the filler will be assigned the thematic role with which it has the most semantic overlap. When the filler is a better match for the verb's second argument, we have assumed that it is interpreted as such. Thus, after reading *Which movie did Mark remind . . . , movie* would have to be interpreted as the generalized theme for a gap site which had not yet been encountered. However, this notion is difficult to test directly using object control verbs, because the interpretation of the filler as a generalized theme would not be very specific. The filler would receive a more specific thematic role (e.g., a *watch*-Theme or an *about*-Theme) from a verb or preposition later in the sentence. In contrast, dative verbs assign a specific thematic role to their second argument. In Experiments 4 and 5, we used sentences with dative verbs to provide direct evidence that provisional interpretation of arguments does take place at the verb, even when the gap site does not immediately follow the verb.

EXPERIMENT 4

In the preceding experiment, we concluded that the absence of a plausibility effect at the verb for sentences that began with fragments such as *Which bank did the executive send . . .* was evidence that readers had interpreted *which bank* as the Recipient of *send.* Experiment 4 directly tested this claim, using sentences with dative verbs in which the wh-phrase was an unlikely Theme, but a good Recipient. As shown in (19), the plausibility of the wh-phrase was manipulated with respect to how likely it was to be a Recipient of the particular Theme used in the sentence. If the wh-phrase is interpreted as the Recipient at the verb, plausibility effects could be seen in the direct object noun phrase.

(19) a. Which uneasy pupils$_i$ did Harriet distribute the science exams to $\_\__i$ in class?
b Which car salesman$_i$ did Harriet distribute the science exams to $\_\__i$ in class?

Dative verbs are more restrictive than object control verbs with regard to the possible syntactic categories of the second argument. This experiment used nonalternating datives (like *donate*), which are the most restrictive. The Recipient must be expressed as a prepositional phrase; thus, the actual Recipient is not the wh-phrase, but the prepositional phrase (*to* plus the gap that is coindexed with the wh-phrase). If plausibility effects are observed before the word *to*, the data would rule out models of gap-filling in which a filler can not be interpreted until the word licensing the gap has been countered. Pickering and Barry (1991) have made a similar argument, but their point is that these gaps need not be explicitly represented as part of the syntactic structure; our work is neutral on this issue.

Method

Subjects. Thirty undergraduates at the University of Rochester completed the experiment either in partial fulfillment of course requirements or for a nominal sum. All subjects were native English speakers.

Materials. Acceptability norms were collected for double object constructions (e.g., *Which poem did Martha dedicate Ted?*) on a set of 23 dative verbs. Ten subjects rated each sentence "good" or "bad" in a forced choice paradigm. Ten verbs that were usually rated "bad," and which the authors also found to be unacceptable in the double object construction, were selected for use in the experiment. These verbs were used to construct ten sentence pairs of the type illustrated above in (19). The members of each pair were identical except for the wh-phrase. All wh-phrases were plausible Recipients, in general, but plausibility was manipulated in relation to the particular Theme in the sentence. The wh-phrase was never a good Theme of the verb in the sentence. The complete set of critical sentences is in the Appendix.

Two experimental lists were created, such that one version of each critical item was on each list, and equal numbers of plausible and implausible items were on each list. The 10 critical trials were randomly ordered with 68 distractor trials. Twelve of these were embedded wh-constructions in which the filler served as the direct object of the matrix clause. All of these sentences were plausible. Four other distractor trials were anomalous for various reasons. Finally, there were an additional 32 distractor sentences of various types, all of which were plausible.

Procedure. The procedure used in the previous experiments was used again here.

Results

A record of which button was pressed was kept for seven word positions in each critical sentence beginning at the verb and continuing to the end of the sentence or until the subject pressed the "no" button. As shown in Fig. 5, subjects began responding "no" to the implausible sentences at the second word of the direct object (an adjective) and responded "no" in increasing numbers until leveling off just before the end of the sentence. By the end of the sentence, subjects had responded "no" to 74% of the implausible sentences and 11% of the plausible sentences.

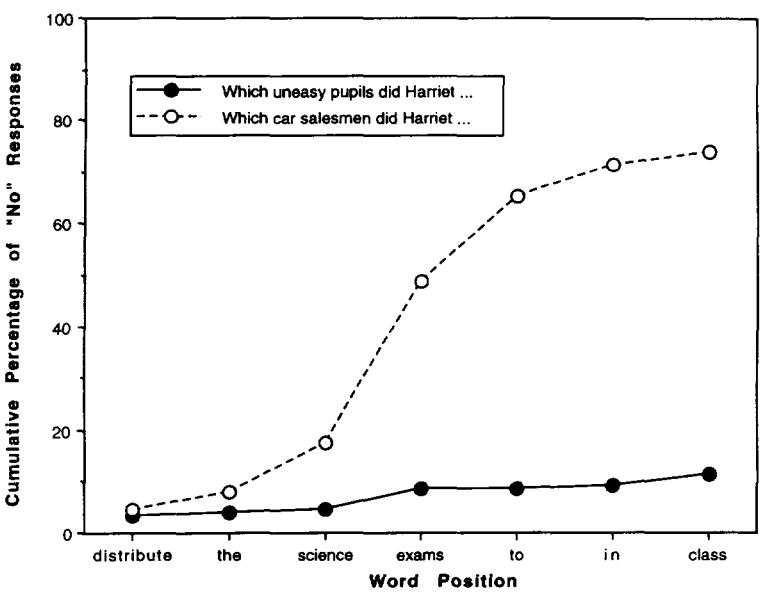

FIG. 5. The cumulative percentage of "no" responses for Experiment 4.

The percentage of "no" responses out of the "remaining possible no's" was computed as in the previous experiments. The percentages for each condition at each word position for both subjects and items were submitted to a 2(list) × 2(plausibility) × 7(word position) ANOVA. There were main effects of plausibility [$F1(1,28) = 95.78, p < .01$, $F2(1,8) = 66.65$, $p < .01$] and word position [$F1(6,23) = 11.76$, $p < .01$; $F2(6,3) = 7.31$, $p < .01$], and an interaction [$F1(6,23) = 9.18, p < .01$; $F2(6,3) = 6.66, p < .01$]. Planned comparisons revealed that there were more "no" responses in the implausible condition compared to the plausible condition beginning at the adjective within the direct object noun phrase [$F1(1,28) = 7.50$, $p < .05$; $F2(1,8) = 7.48$, $p < .05$]. The plausibility effect remained significant until the last word in the sentence.

Discussion

The data indicate that thematic constraints are used to assign provisional interpretations to fillers at the verb, even for argument positions not directly following the verb. The crucial evidence for this is that plausibility effects arose at the earliest possible point—early within the direct object noun phrase. Thus, these data are inconsistent with models of gap-filling in which the filler cannot be interpreted until the word that licenses its gap is encountered (in this case, the word *to*).

Because this experiment used nonalternating datives, the verb's argument structure fully specified both the semantic and the syntactic constraints on the Recipient argument. Thus, it is possible that subjects used argument structure information to anticipate the word, *to*, and project a structure that included the preposition and the gap following it. The final experiment was designed to investigate whether the provisional interpretation observed here would be observed in sentences where the verb allows multiple syntactic realizations of the later argument. While we cannot test this with the extreme case of object control verbs, we can explore this issue using alternating datives (like *give*), which allow two different syntactic realizations of the Recipient.

EXPERIMENT 5

Experiment 5 used alternating datives in the paradigm from Experiment 4 to test the hypothesis that the filler will be interpreted as the Recipient even when the verb has two consistent argument structures, providing two ways in which the Recipient could be expressed syntactically. The two possible argument structures are illustrated in (20).

(20) a. grant: [NP<Theme> PP<Recipient>] . . . grant the maternity leave to the secretary.
b. grant: [NP<Recipient> NP<Theme>] . . . grant the secretary the maternity leave.

Method

Subjects. Thirty-two undergraduates at the University of Rochester completed the experiment either in partial fulfillment of course requirements or for a nominal sum. All subjects were native English speakers.

Materials. Sixteen sentence pairs like those shown in (21) were constructed using dative verbs. All sentences contained embedded questions with a gap after the preposition. Except for the alternation pattern of the verb, the constraints on the materials were identical to those in Experiment 4. The distractor trials from Experiment 4 were used again here.

(21) a. Bob wondered which bachelor$_i$ Ann granted a maternity leave to $\_\__i$ this month?
b. Bob wondered which secretary$_i$ Ann granted a maternity leave to $\_\__i$ this month?

Procedure. The same procedure was used as in the previous experiments. Subjects completed 20 practice trials before beginning the experiment.

Results

A record of which button was pressed was kept for eight word positions in each critical sentence beginning at the subject of the matrix clause and continuing to the end of the sentence

or until the subject pressed a button indicating that the sentence had stopped making sense.

By the end of the sentence, subjects had responded "no" on 16% of the plausible trials and on 62% of the implausible trials. These data are presented in Fig. 6. In order to evaluate hypotheses about specific word positions, the cumulative percentages were converted to the percentage of "no" responses out of "remaining possible no's" as before. Mean percentages for both subjects and items were submitted to a 2(list) × 2(plausibility) × 8(word position) ANOVA. There were main effects by subjects and by items for plausibility [$F1(1,30) = 60.32$, $p < .01$; $F2(1,14) = 54.06$, $p < .01$] and word position [$F1(7,24) = 10.98$, $p < .01$; $F2(7,8) = 5.36$, $p < .01$]. The interaction of plausibility and word position was also significant [$F1(7,24) = 11.93$, $p < .01$; $F2(7,8) = 6.64$, $p < .01$].

Differences between the conditions at particular target positions were evaluated using planned comparisons. There were more "no" responses for implausible items (11.9%) compared to plausible items (9.1%) at the adjective in the direct object noun phrase, and this relatively small difference was reliable [$F1(1,30) = 18.24$, $p < .01$; $F2(1,14) = 7.55$, $p < .05$]. There were no reliable differences at earlier positions, but all later positions demonstrated reliable plausibility effects.

Discussion

Experiment 5 replicated and extended the results of Experiment 4: thematic constraints were used to assign the filler to the thematic role most consistent with its semantic features. Thus, the wh-phrase was provisionally interpreted as the Recipient at the verb. It was important to replicate the provisional interpretation effect in sentences where the filler could be assigned to more than one syntactic position, ruling out the possibility that provisional interpretation is restricted to cases in which there is only one possible argument structure.

In both Experiments 4 and 5, subjects began rejecting the implausible sentences at the first content word within the direct object noun phrase. This provides clear evidence that the wh-phrase had already been interpreted as the Recipient of the verb. In other words, thematic assignments were made when the verb was recognized, even though the gap site was several words downstream. The results support the predictions of the provisional interpretation hypothesis, and provide evidence against pars-

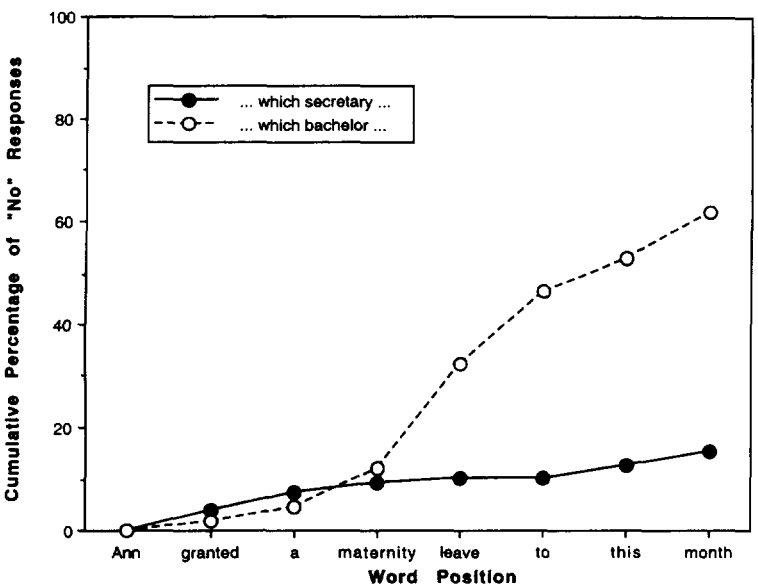

FIG. 6. The cumulative percentage of "no" responses for Experiment 5.

ing models that either ignore argument structure information or do not permit interpretation of a filler phrase until its gap has been directly licensed.

General Discussion

The experiments reported here provide important evidence regarding how argument structure information is used in interpreting filler-gap sentences. We replicated Garnsey et al.'s (1989) finding that a filler is sometimes interpreted as the object of a verb, even when it is implausible in that role, resulting in plausibility effects at the verb. However, these plausibility effects were limited to verbs with argument structures that provided only a single gap position. Plausibility effects at the verb were almost completely eliminated when a filler that was an implausible direct object could have been plausibly interpreted in a role associated with another available argument position. This was true for dative verbs, which assign a specific role to an alternative gap site, and for object control verbs, which do not. (We argued that object control verbs assign a generalized theme role ot their downstream gap location.) We also demonstrated that the filled-gap effect, which occurs when an object gap is mistakenly posited after a verb, is eliminated when the filler is an implausible object if the verb provides an alternative gap site in which the filler could plausibly be interpreted.

Consistent with other results in the literature, we found that readers have a bias to interpret a filler as the direct object of a potentially transitive main verb (e.g., Frazier & Clifton, 1989; Nicol & Swinney, 1989; Stowe, 1986). However, when the argument structure of the verb provides multiple gap sites, that bias is mediated by the thematic fit of the filler to the alternatives. In addition, we presented evidence that readers were able to assign a provisional interpretation to the filler at the verb, even when the gap was several words downstream and when the syntactic position of the gap was ambiguous.

Taken together, these results provide strong support for a constraint-based lexicalist model of gap-filling in which the filler is evaluated against potential gap sites that are made available by a verb's argument structures, using both the syntactic and thematic constraints provided by the argument structures. The view that recognition of a verb is accompanied by parallel access to its argument structures is consistent with results from a growing body of literature examining the time-course with which verb-specific information becomes available (Boland, 1993; Gorrell, 1991; McElree, 1993; MacDonald, 1994; Marslen-Wilson, Brown, & Tyler, 1988; Shapiro, Zurif, & Grimshaw, 1989; Shapiro, Nagel, & Levine, 1993; Tanenhaus, Garnsey, & Boland, 1990; Trueswell, Tanenhaus, & Kello, 1993). The conclusion that arises from most of these studies is that both subcategorization and thematic information become available as soon as a verb is encountered.

When viewed from a constraint-based lexicalist perspective, the thematic effects that we found for filler-gap sentences are strikingly similar to recent results from other domains in the syntactic ambiguity resolution literature. In particular, our finding that thematic effects are mediated by the availability of lexical alternatives is consistent with work on reduced relative clause ambiguities (MacDonald, 1994; MacDonald et al., 1994a; Trueswell, in press; Trueswell, et al., 1994;), and on prepositional phrase attachment ambiguities (Spivey-Knowlton & Sedivy, 1995). For example, in the well-known reduced relative/main clause ambiguity (e.g., *The defendant examined by the lawyer turned out to be unreliable*), readers and listeners have a strong bias to interpret the ambiguous segment (*the defendent examined . . .*) as a main clause, with the subject NP as Agent of a past tense verb. Under a reduced relative reading, the verb is a passive participle and the subject NP plays the role of Theme. The main clause preference is reflected in processing difficulty when the prepositional phrase *by the lawyer*, which supports the correct reduced relative interpretation, is encountered. In a classic study, Ferreira and Clifton (1986) found that the initial main clause bias persisted even when the subject NP did not have the appropriate semantic properties to be the instigator

of the action, but could easily have been the thing that was acted upon. At the time, this result was taken as evidence that thematic constraints are initially ignored in parsing. Later, several studies demonstrated that strong thematic constraints can completely eliminate processing difficulty with reduced relatives (Trueswell, et al., 1994; Burgess, Tanenhaus, & Hoffman, 1994). However, the effectiveness of the thematic constraint depends upon the frequency with which the ambiguous verb form occurs as a passive participle as compared to a simple past tense verb (MacDonald et al., 1994b; Trueswell, in press).

The data we reported here on thematic effects in filler-gap assignment strongly parallels the data on thematic effects in relative clause analysis. The congruity effects at the verb reported by Garnsey et al. (1989), like the congruity effects at the verb reported by Ferreira and Clifton (1986), represent the special case in which thematic constraints are incompatible with the dominant syntactic alternative that is made available by the verb. Under conditions where the verb makes available multiple argument structures, thematic constraints clearly affect syntactic ambiguity resolution in both domains. Thus, results that initially appeared to support an encapsulated syntactic processing system turned out to represent one end of a continuum.

It is important to note that we have focused on a few specific argument structures, and, in doing so, we selected verbs with clear argument structure preferences. Given our data, it might be tempting to make a categorical distinction between verbs that occur with a single internal argument (simple transitives) and verbs that occur with multiple arguments. However, we believe that a more detailed examination of argument structure effects in gap-filling would show graded effects, depending upon the relative frequency of alternative argument structures. For example, we might expect to see some plausibility effects at the object control verb, *bribe,* in a sentence such as *Which ticket did they bribe the judge to ignore?* because *bribe* is typically used with only a noun phrase complement, even though it has an alternative argument structure that contains an infinitive complement. In contrast, no plausibility effects would occur with the object control verb, *urge,* which is nearly always used with both a noun phrase complement and an infinitive complement. Similarly, dative verbs differ in the relative frequency in which they occur with one or two internal arguments. A plausibility effect might be expected at *deliver,* which often occurs with only a direct object, but little or no plausibility effect should be seen at *dedicate,* which nearly always occurs with both a direct and an indirect object. Verbs that are typically used intransitively also vary in how often they are used with another complement. For example, *sneeze* can not take any type of subcategorized complement, but *hesitate* is often used with an infinitive complement. Thus, larger plausibility effects might occur at *sneeze* in *Which doctor did Bill sneeze in front of?* compared to *hesitate* in *Which doctor did Bill hesitate to visit?* We expect that a detailed investigation into graded distinctions among the argument structures of various verbs will also provide insight into the inconsistencies in the data on transitivity preferences in filler-gap sentences.

We have argued that the results presented here are difficult to account for in a lexical filter parsing model, in which a gap is initially posited using only major syntactic category and then lexical information is used to evaluate the initial assignment and guide reanalysis. Our arguments are based on two aspects of the data. First, interactions with argument structure were seen at the first possible word position. Second, robust plausibility effects were found for simple transitive verbs, but were almost completely eliminated for object control verbs and for dative verbs. However, there are two aspects of the results that a proponent of lexical filtering might argue are suggestive of a lexically blind stage in the gap-filling process.

The first is that there were occasionally small suggestions of plausibility effects at the verb for object control and/or dative verbs, though they were never reliable. These results could be taken as evidence for a very fast, nearly cost-free revision stage. However, we strongly suspect that these effects reflect an occasional trial where only one argument position was

strongly activated for a particular object control or dative verb. Research that explicitly manipulates argument structure frequency should tease apart these alternatives.

The second is the task that was used. One could argue that results obtained with a stop-making-sense task might not reflect an early stage in processing, either because the task itself is insensitive or because the task invites more complete semantic processing than normal reading. Clearly, it will be useful to replicate the results presented here with other dependent measures; for example, the materials used in Experiment 2 could easily be adapted for use in an eye-monitoring experiment. Nonetheless, there are several aspects of our results that suggest that these concerns are unlikely to compromise our conclusions. The concern about sensitivity is central because the strength of our conclusions depends upon the task being sensitive to small changes in processing difficulty. In particular, a proponent of lexical filtering might argue that small revision effects which are supported by argument structure information are too subtle to be reflected in the judgments. However, Experiment 2 clearly demonstrated that this was not the case. Filled-gap effects were detected with object control verbs, despite the fact that argument structure was available to guide reanalysis.

The concern that the task leads to more complete semantic processing, or that it exaggerates the degree to which each word is interpreted on-line, is more difficult to address. However, in the cases where we report that sentences were judged to be anomalous early, i.e., at the verb or at a filled gap, anomaly effects have also been observed with other tasks. The novel results that we report are the absence of congruity effects when argument structure provides another alternative. In other words, subjects were systematically failing to detect a potential incongruity.

It is important to note that even if our assumptions about the sensitivity of this task prove to be incorrect, our results still provide a new and detailed exploration of how argument structure information can be used in filler-gap assignment. In particular, we have demonstrated that the availability of alternative argument structures mediates gap assignment, that the argument structures can be used to evaluate the degree of thematic fit between the filler and the thematic roles associated with each of the potential gap sites, and that such an evaluation can take place prior to the point in the sentence where the gap is found. These results place clear constraints on models of gap-filling even if it turns out that, contrary to our claims, some argument structure information is used during reanalysis rather than during an initial stage.

Finally, we return to the issue of provisional interpretation with which we began this article. We argued that access to argument structure could allow the processing system to assign provisional interpretations that are consistent with the likely syntactic alternatives. The data we presented provide preliminary support for this hypothesis. We clearly showed that readers interpret a filler prior to encountering its gap, even when the argument structure of the verb would provide more than one potential gap site. Presumably, similar results would be found with auditory materials, although we assume that prosodic information would provide additional constraints on the interpretation.

Our data do not distinguish among two alternative accounts of provisional interpretation. One account maintains that provisional interpretation of the filler is accompanied by a syntactic commitment to a particular argument structure, and thus a specific gap site. The other account, which we favor, maintains that provisional interpretation does not require a specific syntactic commitment as long as the interpretation is consistent with the likely syntactic alternatives. Consider the fragment, *Chris reminded . . .*, focusing on the "told" sense of *remind* where *Chris* is the Agent of the reminding event. This sentence could be continued with several different argument structures. including a noun phrase followed by a prepositional complement (e.g., *Chris reminded Bill about the movie*); a noun phrase followed by an infinitive complement (e.g., *Chris reminded Bill to go to the movie*), and a noun phrase followed by a sentence complement (e.g., *Chris reminded Bill that the movie was*

playing downtown). Each of these argument structures includes an object of the reminding event and an entity or event about which someone is being reminded. Thus, provisional interpretation could be made to a common thematic structure before more specific syntactic information was available.

Clearly, these suggestions are preliminary, and it will be important in future research to better understand the nature of the thematic commitments that readers and listeners make during on-line comprehension. For example, recent constraint-based models have assumed that alternative argument structures compete with one another during processing (e.g., MacDonald et al., 1994a; Trueswell & Tanenhaus, 1994; Spivey-Knowlton & Sedivy, 1995). This assumption is likely to be correct for argument structures that would result in incompatible semantic and syntactic commitments on the part of the reader or listener (i.e., interpreting *the defendant* as the Agent or the Theme in a fragment such as *the defendent examined. . .*). However, when a thematic commitment is consistent with several syntactic alternatives, it is less clear that these argument structures would be in competition (i.e., interpreting *Chris* as the Agent of *remind* in the fragment, *Chris reminded. . .*, or interpreting *which movie* as a generalized theme in *Which movie did Chris remind. . .*). More generally, questions about the relationship between provisional semantic and syntactic commitments are likely to play a central role in understanding how lexical representations are used to facilitate incremental interpretation.

Appendix

Experiment 1

A slash separates plausible and implausible fibers.

Sentences with Simple Transitive Verbs

Which star/meal did the assistant watch through the entire night?

Which leader/market did the rioters follow down the main street?

Which client/prize did the salesman visit while in the city?

Which room/rate did the maid clean early every Monday morning?

Which truck/crowd did the workers unload into the empty storeroom?

Which painting/promise did the firemen save from the burning house?

Which customer/contract did the secretary call on the office phone?

Which car/eye did the maniac pass on the right side?

Which book/food did the child read in bed at night?

Which key/bar did the watchman lose on the way home?

Which structure/afternoon did the biologist see with the powerful microscope?

Which package/sentence did the passenger leave on the bus seat?

Sentences with Object Control Verbs

Which diver/event did the coach persuade to watch the professionals?

Which pen-pal/article did your friend convince to write longer letters?

Which actor/script did the producer force to use an accent?

Which girl/place did the wizard warn to leave here quickly?

Which daughter/disease did the mother urge to remember his childhood?

Which students/classes did the university hire to teach the lab?

Which administrator/topic did the teacher advise to introduce her substitute?

Which aunt/hospital did Martha Simpson coax to visit her grandfather?

Which parent/car did the salesman pressure to insure the house?

Which actor/style did the drama coach encourage to imitate a drunk?

Which child/movie did your brother remind to watch the show?

Which suspect/procedure did the detective command to follow the patrolman?

Experiment 2

Simple transitives. For each verb, the wh-version is given first, and then the declarative control version. The wh-versions always had a plausible filler.

Which customer did the secretary call you about on Monday?

I knew whether the secretary called you about the customer on Monday.

Which leader did the rioters follow you to listen to?

He didn't know whether the rioters followed you to listen to the leader.

Which guest did the caterer charge us for adding on?

She didn't know whether the caterer charged us for adding on the guest.

Which reforms did the conservatives block you from getting passed?

He knew whether the conservatives blocked you from getting the reforms passed.

Which band did the agent describe us as sounding like?

I wondered whether the agent described us a sounding like the band.

Which client did the lawyer visit them for last week?

I wondered whether the lawyer visited them for the client last week.

Which boy did the girl criticize us for talking to?

I wondered whether the girl criticized us for talking to the boy.

Which group did the politician praise us for contributing to?

She knew whether the politician praised us for contributing to the group.

Which structure did the biologist see them discover with excitement?

He knew whether the biologist saw them discover the structure with excitement.

Which teacher did the child imitate you talking excitedly to?

We found out whether the child imitated you talking excitedly to the teacher.

Which employer did the detective investigate them for in secret?

I found out whether the detective investigated them for the employer in secret.

Which star did the assistant watch them photograph last night?

I wonder whether the assistant watched them photograph the star last night.

Object control. For each verb, the wh-versions are given first, with a slash separating plausible and implausible fillers, and then the declarative control version is given.

Which diver/event did the coach persuade them to watch more quietly?

He wondered whether the coach persuaded them to watch more quietly?

Which brother/dance did Sue invite us to attend last week?

Beth didn't know whether Sue invited us to meet her brother next week.

Which students/classes did the university hire her to teach this term?

I found out whether the university hired those students to teach this term.

Which actor/script did the producer force them to use on Broadway?

She found out whether the producer forced them to use that actress on Broadway.

Which patients/chores did the nurse allow you to neglect every morning?

Robert asked whether the nurse allowed you to neglect the patients every morning.

Which suspect/procedure did the detective command you to follow very carefully?

O'Hara wondered whether the detective commanded you to follow that suspect very carefully.

Which administrator/topic did the teacher advise you to introduce on Monday?

I wondered whether the teacher advised you to introduce that administrator on Monday.

Which aunt/hospital did Martha coax him to visit in September?

They knew whether Martha coaxed him to visit her aunt in September.

Which daughter/disease did the mother urge him to cure without drugs?

They asked whether the mother urged him to cure her daughter without drugs.

Which parent/car did the salesman pressure them to insure more heavily?

John knew whether the salesman pressured them to insure their parents more heavily.

Which runner/method did the coach encourage them to imitate during practice?

Susan wondered whether the coach encouraged them to imitate that runner during practice.

Which vandal/problem did the salesclerk tell you to report before noon?

Herbert wondered whether the salesclerk told you to report the vandal before noon.

Which sister/doll did Mommy teach him to kiss at bedtime?

Joanne wondered whether Mommy taught him to kiss his sister at bedtime.

Which pen/pal-article did Randy convince you to write this week?

I asked whether Randy convinced you to write your pen-pal this week.

Which girl/place did the wizard warn them to leave right away?

I wonder whether the wizard warned them to leave that girl right away.

Which scientist/statistic did the editor permit you to cite at length?

Alice asked whether the editor permitted you to cite that scientist at length.

Which child/movie did Mark remind them to watch this evening?

Samuel asked whether Mark reminded them to watch the child this evening.

Which patients/epidemic did the nurses help him to control with medication?

Ann wondered whether the nurses helped him to control those patients with medication.

Experiment 3

Plausible and implausible fillers are separated by a slash.

Simple Transitive

Which client/contract did the secretary call before going to lunch?

Which star/stone did the assistant watch all through the night?

Which teacher/desk did the child imitate for her bored classmates?

Which reforms/habit did the conservatives block with their combined votes?

Which patient/injury did the doctor visit on his morning rounds?

Which guest/shape did the caterer charge for the last-minute cancellation?

Which supporters/menace did the politician praise during his campaign speech?

Which employee/shoulder did the detective investigate for the software company?

Which criminal/diagram did the lawyer defend before the grand jury?

Which candidate/disease did the girl criticize for the embarrassing scandal?

Which structure/afternoon did the biologist see through the powerful microscope?

Which leader/market did the rioters follow down the deserted street?

Object Control

Which sister/movie did your mother remind to watch the show?

Which actor/script did the director force to use an accent?

Which homeowner/jewelry did the salesman pressure to insure the house?

Which daughter/instrument did the mother urge to practice more often?

Which administrator/topic did the teacher advise to introduce her substitute?

Which athlete/match did the coach persuade to watch the professionals?

Which runner/bribe did the trainer encourage to take longer strides?

Which friend/store did the girl convince to write longer letters?

Which suspect/procedure did the detective command to follow the patrolman?

Which relatives/suggestion did the woman coax to visit her grandfather?

Which apprentice/location did the wizard warn to leave here quickly?

Which students/classes did the university hire to teach the lab?

Dative

Which note/bank did the executive send after meeting the deadline?

Which amount/farmer did the banker loan without a new application?

Which wish/traveler did the leprechaun grant after he was captured?

Which poem/baby did the babysitter read in a funny voice?

Which film/audience did the salesman show at the medical convention?

Which baseball/uncle did the child toss into the tree branches?

Which towels/suite did the maid deliver after she was reprimanded?

Which prize/volunteer did the society award during the annual banquet?

Which strike/player did the pitcher throw in the seventh inning?

Which present/cousin did the teenager mail early in the week?

Which painting/customer did the artist sell at the art show?

Which boxes/store did the truck bring early in the morning?

Experiment 4

Plausible and implausible fillers are separated by a slash.

Which honorary post/cabinet post did the President appoint the young student to last May?

Which military base/preschool nursery did Hank deliver machine guns to last week?

Which close friend/complete stranger did Suzanne dedicate her new book to with love?

Which college student/preschool student did Carol explain an intricate theorem to in detail?

Which elder statesman/foot soldier did Churchill attribute the privacy law to in 1933?

Which college advisor/chubby toddler did Ted express his political dreams to rather shyly?

Which city hospital/political party did people donate the most blood to last year?

Which uneasy pupils/car salesmen did Harriet distribute the science exams to in class?

Which campus party/public library did John contribute some cheap liquor to Friday night?

Which junior assistant/division head did David delegate the routine typing to most often?

Experiment 5

Plausible and implausible fillers are separated by a slash.

I wonder which schoolmate/business Bill lent his new pencil to yesterday morning.

Jerry wondered which swans/crowd David threw the bread crumbs to in Washington.

Ellen asked which advisor/toddler Nancy read her doctoral thesis to this afternoon.

Bob wondered which secretary/bachelor Ann granted a maternity leave to this month.

The workers remembered which clerk/exhibit Harold awarded a large bonus to at Christmastime.

The priest noticed which families/charities Sam gave a warm smile to on Sunday.

The kids watched which elephant/whale Janet tossed some fresh hay to rather nervously.

Alan knew which company/country Jeff brought his revised resume to for consideration.

Henry remembered which neighbor/child Sam loaned the sharp axe to years ago.

Tom found out which client/peasant Karen sold the diamond earrings to quite easily.

Mike wondered which terrorists/daughter Ken mailed the large ransom to at midnight.

Hilary found out which woman/brother Tim offered the alimony payment to in court.

Boris noticed which infant/politician Andrea sent the little rattle to from Ohio.

Pat asked which hospital/graveyard Margaret took the flu vaccine to on Monday.

The lawyer forgot which niece/nephew Amelia willed her wedding gown to before dying.

Ted noticed which playmate/gangster Alice handed the coloring book to very politely.

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