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Case Morphology and  
Thematic Role in  
Word Recognition

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This chapter discusses the effects of thematic role (semantic role) on word processing. One of the two languages studied was Serbian,<sup>1</sup> in which thematic role is tied to a word's case-inflection morphology. The other language was English, which depends on other mechanisms (such as word order and prepositions) to express thematic role. The data in both languages showed that a target word's recognition was slowed by ambiguity in the word's thematic role. This ambiguity effect can account for the fact that, in case-inflected languages like Serbian, there is faster recognition of a word in its nominative case form than in one of its oblique case forms; the nominative case has far fewer thematic role interpretations than other cases and is, therefore, the least ambiguous. The effect of role ambiguity was contrasted with the effect of ambiguity in lexical semantics (polysemy). In contrast to the effect of thematic role ambiguity, polysemy does not slow word recognition and, in fact, tends to speed it. This suggests different processing loci for thematic and semantic ambiguity and is consistent with a modular view of syntactic processing.

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<sup>1</sup>Serbian refers to the language spoken in Serbia. In papers published before the former Yugoslavia split, we referred to the language as Serbo-Croatian.

## INTRODUCTION

This chapter presents experimental evidence on the processing of thematic role. Thematic role (also called semantic role and functional role) is an idea that provides a theoretical bridge between inflectional descriptions of grammatical case and semantics. It works by describing the valency of predicates, as in the following two sentences, *He jumped through the window* and *He recuperated through walking*. In both sentences, the verbs subcategorize for a subject and a prepositional phrase. However, the semantic functions of the two prepositional phrases differ. The thematic roles of the noun in the first sentence and the gerund in the second characterize the ways that they take part in the events denoted by their verbs. Thus, the word *window* takes part by fulfilling the role of *location* denoted by the verb *jump*. The idea of source and destination *locations* are implicit in the verb's meaning. In the second sentence, the word *walking* fulfills the role of *instrument* that is denoted by its verb. In a theoretical description of each verb, one would have to include a listing of these and other thematic roles that are permitted for its arguments. Such a list would contain the roles of *agent* and *location* as permissible roles for the arguments of *jump* and the roles of *patient* and *instrument* as permissible roles for the arguments of *recuperate*.

In languages that have case inflection morphology, there is covariation between case and thematic role. A word's thematic role in a sentence is in part conveyed by its case. Consider Serbian, a heavily inflected Slavic language of the Balkan Peninsula. There are seven cases in Serbian and, together, they convey roles such as *agent*, *experiencer*, *instrument*, *possessor*, etc., with each role being assigned to one case. However, the number of roles, perhaps in excess of 75, is much greater than the number of cases. Within each inflected case there are several different possible roles, thus creating an ambiguity for the listener/reader as to which role was intended by the speaker. This ambiguity is normally resolved by the verb context for the noun; the role of the word *tears* is *location* in the sentence, *He looked through his tears*, but it is *instrument* in the sentence *He recuperated through his tears*. In Serbian, the two sentences are *Gledao je kroz plač* and *Ozdravio je kroz plač*. Note that in Serbian, as in English, the phrase "through (his) tears" is identical in both sentences (*kroz plač*). The grammatical case of *plac* ('tears') is accusative in both sentences; however, the themes of the word differ because of the different verbs: *to look through* denotes a locative function while *to recuperate through* denotes an instrumental function.

Obviously, listeners are able to arrive at the correct interpretations for the different roles played by *tears* in the two sentences. But is there a cost to the processing system in dealing with the initial ambiguity in the noun itself—with the fact that the noun's thematic role must be resolved? This is the major question we explore in this study. In English and in Serbian, the prepositional phrase has

not only the two possible interpretations of *location* and *instrument* but additional ones besides. Does this multiplicity of possible themes influence the processing load? It seems plausible to conjecture that the greater the number of possible themes for a noun (*ceteris paribus*), the greater the processing effort needed to resolve the thematic ambiguity. A second source of uncertainty exists. In a lexical decision task, the subject does not know, typically, the case of the noun that will be presented. There are seven possible cases that have different natural frequencies of occurrence in normal speech or print. Thus, uncertainty about which case form will be presented precedes the uncertainty of thematic role for the particular case form after it is identified. Both uncertainties contribute to thematic role ambiguity. An appropriate unit of this aggregate uncertainty is the information-theoretic index of number of bits of information carried by a noun, as determined by the frequency of occurrence of its case form together with the number of thematic roles which are possible for that case form.

The lexical decision task is a useful way to study the processing demands created by ambiguity in syntactic role because it removes the verb context and presents words or phrases in isolation. By presenting a noun or prepositional phrase without a verb, the noun's thematic ambiguity is maximized. Because it is known that some inflected forms (i.e., some cases) have a greater number of possible thematic roles, we should find their greater thematic ambiguity leading to slower word recognition for nouns with those inflections.

Consider an example of two cases with different numbers of possible roles. The nominative case has few and the genitive case has many; thus, these two cases differ in their potential for thematic role ambiguity. An experiment by A. Kostić (1991; see also A. Kostić, this volume) studied recognition of the same word stem in its different case-inflected forms. His results indicated, as we have been suggesting, that the more thematically ambiguous a word's case was, the slower subjects were to recognize the word in that form as compared to other inflected forms of the same noun. We use Kostić's analysis as a point of departure for the experiments in the present paper. In contrast to Kostić, who studied the effect of ambiguity by observing the correlation between the role ambiguity for a particular case form and speed of word recognition, we manipulated role ambiguity experimentally by varying the noun's phrasal context.

The present research was designed, in part, to address some shortcomings of Kostić's approach. In his chapter in this volume, Kostić presents a formulation, based on information theory, which predicts the reaction time to recognize a noun as a function of its ambiguity, i.e., as a function of that noun's case frequency and its number of alternative thematic roles. He validates the information-theory model by assessing the goodness-of-fit of word recognition latencies to target word ambiguity, as measured in number of bits. He demonstrates that the fitted curves are linear with high correlations. There are two kinds of concerns with this approach. First, there is a theoretical inconsistency in that the relative frequency of case forms are taken into account but the relative frequencies

of each case's thematic roles are not. For Kostić, if a case form has, say, 50 forms, all of these are considered to be of equal likelihood of occurrence, an assumption that is surely false. Yet to ignore the relative frequencies of roles is to obscure the information carried by each role and, therefore, to miscalculate the information load of the case form to which it belongs.

A second concern with Kostić's formulation is that the RT function observed in each experiment is based on only three to five points. (This is a nearly inescapable problem; there are only seven noun cases in all.) Therefore, although the correlations that Kostić obtained are nearly perfect, there are few degrees of freedom involved in determining the best-fitting regression line and, therefore, high correlations would be expected even if the true relationship were not precisely linear. The fact that these fitted functions are statistically significant is not particularly important, as we show below. A more serious problem with the formulation, however, is that fact that the slope of the linear function (of RT to bits) it describes is found to change strongly from one experiment to the next. That is, the estimation of the information load that is said to characterize a particular case form changes from one experiment to another. This inconsistency alone suggests that Kostić's formulation is incomplete.

Moreover, it is well known that quite different theories (based on very different premises) can generate near-identical quantitative predictions; similarity between models is strongest when summary statistics (like group RT functions) are predicted. In order to differentiate among competing models, more detailed data need to be explained. These lessons were learned by the mathematical modelers in psychology in the 1960's (of whom, the senior author was one). For example, it was common for quite different models of paired-associates learning to predict nearly identical group learning curves. A one-element model might make the same general predictions as a stimulus-sampling model, even though the psychological assumptions behind each were very different. However, the various models could usually be discriminated successfully when finer details were predicted, such as distributions of individual learning curves or runs of correct and incorrect responses (cf. Katz, 1966). The universally accepted technique in assessing a model's validity is to compare it with models of equal plausibility. The comparison takes place via goodness-of-fit statistics (such as Chi-Square, or the approach used by Kostić, R-Square). The statistical evidence in favor of goodness-of-fit that is acceptable is evidence that a particular model fits the data better than the alternative models. In contrast, testing only a single model and showing that it has a good fit to the data is not traditionally viewed as strong evidence.

Another way to validate a model is to find independent experimental support for its psychological assumptions. This validation process would buttress the claim of the information-theoretic model of thematic role. Its psychological premises need to be assessed directly, outside of the model itself. The bottom

line is that it is not enough to fit curves to general group behavior in order to assess a quantitative model.

In addition to studying the effects of role ambiguity, we also studied the effects of a second kind of ambiguity: semantic ambiguity (i.e., polysemy). The comparison is of interest because the former is morphological in origin while the latter is semantic; the first type of ambiguity is the property of an inflected grammatical case that generalizes to all words that include it, while the second, polysemy, is the specific property of a given lexical item. As we show below, there is reason to expect that these two kinds of ambiguity will have different effects on word recognition.

Two of our experiments use the lexical decision task, a task in which the subject is presented with a string of letters and is required to decide as quickly as possible if the string is a real word or not. Because the lexical search itself and all subsequent processing are under time pressure, we hoped to stress the processing system, thereby finding effects of the word's thematic ambiguity. But based on requirements of the task, one may ask why we expected a lexical decision task to show effects of *postlexical* processing; it may seem that the task informs us only about processing up to the moment that a word is identified in the mental lexicon and not beyond that point. That the effects we are looking for must be postlexical is obvious: Logically, ambiguity of case function in Serbian cannot arise until *after* a word is recognized. This follows from the facts that identification of the noun's case (and therefore, its thematic ambiguity) depends on first knowing its gender (i.e., its syntactic declension). But information about gender is necessarily lexical; it cannot, in general, be identified by a word's case marking because, in many instances, the same suffix indicates different cases for different genders. For example, the form *čoveka* (*čovek+a*) is the genitive and accusative form for 'man'; the form *žena* (*žen+a*), which has the same suffix inflection as *čoveka*, is the nominative for 'woman.' Thus, any interpretation of the inflectional suffix must *follow* lexical identification of the stem. Therefore, if the lexical decision task is not sensitive to processing after lexical identification, it would be inappropriate to use it to study the processing of thematic ambiguity, which must occur later. However, there is much evidence that the lexical decision task is affected by postlexical as well as by prelexical processing. In spite of its name, the lexical decision task is understood to include more than just the recognition that the target stimulus is (or is not) in the subject's mental lexicon; it also includes postlexical processing of contextual information, as priming studies have shown (Colombo & Williams, 1990; Neely & Keefe, 1989).

For generality, we studied thematic role ambiguity in two languages: Serbian and English. The two languages make for an interesting contrast. The former is a heavily inflected language while the latter is only moderately inflected. Semantic roles for nouns are expressed in Serbian largely through the morphological mechanism of inflection (along with some use of prepositions),

while English depends on word order and a much larger reliance on prepositions to achieve the same goal.

Finally, we sought independent support for the psychological reality of the concept of thematic role itself. We focused on certain roles, such as *instrument*, *location*, etc. In order to assess, in an independent way, the psychological validity of these categories of semantic role, we studied subjective judgments of role in Experiment 1 (in Serbian) and in Experiment 3 (in English). The investigations of the effects on word recognition of thematic role ambiguity were carried out in Experiment 2 (Serbian) and Experiment 4 (English).

### EXPERIMENTS IN SERBIAN

The Serbian language has been a rich source of evidence about the processing of morphology. This heavily inflected language's system of noun case inflection has received much attention from researchers over the past decade (e.g., Lukatela, Feldman, Turvey, Carello, & Katz, 1989; Lukatela, Gligorijević, A. Kostić, & Turvey, 1980). The purpose of a case inflection system is to constrain the functional (thematic) role played by a noun or adjective. For example, in the Serbian sentence, *Jede kašikom* ('He eats with a spoon'), the idea of the spoon's instrumentality is signaled by the inflectional suffix *-om*, the ending for the instrumental case. This contrasts with examples in which the same stem is in the accusative case: *Jede kašiku* ('He eats the spoon') or the nominative case: *Jede kašika* ('The spoon eats'). (In these latter sentences, the meaning may be unusual or nonsensical but they are both grammatically correct sentences). Moreover, each case has more than one possible thematic role: In addition to expressing instrumentality, the instrumental case can function to express accompaniment ('The fork goes with the spoon') or can function to express attribute, as well as other roles, some of which are specific to use with a particular preposition. As an example of the different number of possible roles associated with each case, the nominative case has only four while the accusative case has more than thirty (Dj. Kostić, 1961). A. Kostić (1989) was the first to point out that for words presented in isolation, the various case forms of a stem differ in their degree of role uncertainty.

It seemed to us likely that, in natural discourse, some processing resources must be expended by a listener/reader in order to resolve thematic role ambiguity by means of the available context. Congruent with this account are the reaction time differences due to case, a result first reported by Lukatela et al. (1980). Their lexical decision experiment showed that the nominative case form of an isolated word was recognized faster than the same word stem in any of its other cases (e.g., genitive, dative, etc.). For example, a noun is recognized substantially faster in its nominative case than in its genitive case. It is clear that the effect is not related to differences in the frequency of use of each case; the nominative and genitive cases have roughly the same frequency. The different

recognition times occur even though the stem's semantic content is, of course, the same for all of its cases.<sup>2</sup> This reaction time advantage for the nominative has since been replicated under a variety of conditions (e.g., for print, speech, plurals, and all genders) and is quite robust (Feldman & Fowler, 1987; Katz, Boyce, Goldstein, & Lukatela, 1987; A. Kostić & Katz, 1987).

A word in the nominative case can take on the following themes: *subject* (*Hell is feared by the wicked*), *agent* (*Hell burns the wicked*), *predication* (*War is hell*), or *exclamation* (*Hell!*). Of these, the *subject* and *agent* roles are by far the most frequent, making the nominative very nearly a two theme case. In contrast to the nominative, the genitive case can take on more than 30 themes, such as *possession* (*The toy of the child is blue*), *partitive* (*Give me some of the cheese*), the object of certain verbs (*I am afraid of the cheese*), with certain prepositions such as *except* (*No access except for children*), etc. The different number of functions for the nominative and genitive cases (and for the other five cases as well) offers a possible explanation for the differences in lexical decision speed, an explanation that is in accord with a straightforward application of information theory (A. Kostić, 1991): Words presented in the nominative case yield faster recognition times because they have fewer alternative thematic functions to resolve; they carry a smaller information load. Of course this explanation depends on the assumption that thematic role *must* be resolved before a lexical decision response can be made—that a determination of theme is obligatory. Such an assumption is consistent with our data and the data of Kostić (1991, this volume), but it needs to be established independently as well.

The interpretation of nominative case superiority that we have just presented differs from that given by Lukatela et al. (1980). They saw it as a reflection of the primacy of the nominative case in the mental organization of morphological information. Their "satellite model" characterized the set of inflected case forms as a star-shaped network in which a word in its nominative form is the hub and the words representing its other case forms are satellites connected to the hub. In their model, when any word is perceived, the nominative form is always activated. The nominative form is the "citation" form and carries the main semantic content of the cluster. The other case forms are collectively termed, by convention, the "oblique" forms.

Burani (in press) offered a similar explanation for the primacy of the nominative case form. She pointed out that the nominative form is (1) a form from which the oblique inflected forms can be productively generated, and (2)

<sup>2</sup>Neither can the difference be ascribed to orthographic or phonological differences between the nominative and the other cases. For example, the suffix inflection of a feminine noun in the nominative case is the letter *-a*, which is identical to the genitive case inflection for a masculine noun. The suffix *-a* is not sufficient to determine the case without the additional knowledge of the noun stem's declension. Declension membership is essentially arbitrary and this additional information must be learned, word by word, along with the lexeme's semantic meaning.

the form that is typically unmarked and therefore more natural. However, we may question Burani's first point. Logically, any of the case forms can be the basis for generating all the other forms. Thus, the citation form explanation is an arbitrary one; logically, the recognition process could be organized as a hierarchically structured search with any one of the case forms at the top. With regard to Burani's second point, it might be argued in her support that the nominative case is more natural because its primary themes—*subject* and *agent*—are more central to cognition (beyond language itself) than the other thematic roles. However, this notion, can also be challenged; heavily inflected languages like Serbian typically have a free word order, so that the word in the nominative case often does not precede the rest of its phrase. If the nominative case word were more important to the process of creating a structural description (i.e., in creating logical form or a mental model), it could be expected to always be the first item that was communicated. Although the absence of morphological marking may indicate that the nominative form is more "natural," the cause of that naturalness may be the ease of communicating the nominative's small number of thematic alternatives rather than the particular meaning or content of those functions. Alternatively, even if one considers the nominative form to be more cognitively important, one might view the fact that it has acquired fewer functions as the processing system's way of insuring that perception of the nominative is facilitated, relative to the other case forms. In this view, the focus of the explanation is on the nominative case's reduced information load (its fewer roles) relative to the loads of the oblique cases.

Thus, there are two alternative explanations of the nominative case's superiority in recognition. The question of which is the correct one goes beyond the Serbian noun system itself and addresses, more generally, a fundamental question about the nature of morphosyntactic organization: To what extent can morphosyntactic organization be reduced to principles of information theory, that is to say, to principles that are not uniquely linguistic? Do we explain the superiority of the nominative case in word recognition by its smaller ambiguity (smaller information load)? Or, is its superiority due, instead, to a special grammatical relation with the other cases, i.e., the possibility that, as Burani suggests, it has a special status as the citation form from which the other forms derive? We should note, however, that in the latter explanation, there is no independent rationale for nominative case superiority. It is, in fact, a circular explanation: Citation form is the form that is fastest and any form that is the fastest is the citation form. In contrast, in the information theoretic explanation, the differences between cases are rationalized as differences that occur in the process of resolving different degrees of thematic ambiguity. In the process of word recognition, all inflectional case forms can be accessed with equal ease; the differences between them emerge only in post-access processing when their theme must be resolved. This explanation is based on a general information theoretic principle of

resource-limited processing: When a response requires a choice among alternatives, the more alternatives there are, the slower the response will be.

### Experiment 1

The first experiment attacks the question of the psychological reality of the concept of thematic function. The notion of thematic role has been defined in previous work solely by means of rational analysis—that is to say, by linguistic intuition. A more empirical justification is needed. For example, it seems to the linguist, via introspection, that only the functions of *subject*, *agent*, *predication*, and *exclamation* are expressed by the nominative case in Serbian. The linguist, after arriving at this hypothesis, tests the idea's discriminant validity by looking for instances in which other case forms express one of the same functions; finding none, the idea receives support. Convergent validity is assessed by finding instances in which one of the putative themes is expressed by the nominative. But no such empirical test is given to the discriminant validity of the four themes hypothesized to be distinct functions. Although the linguist is able to draw a distinction among the four themes, that is no guarantee that the four have distinct psychological existences in the mental processing that goes on in language comprehension and production. What is needed is more objective proof that people who are not linguists perceive the same putative roles as the linguist. The test that is needed is one that determines if there is agreement between linguists and nonlinguists on when a case form in two different sentences express a single theme and when they express two different themes. In short, we need to demonstrate that a set of specific themes have convergent and discriminant validity.

The thematic roles of the various cases that we used were culled from linguistic analyses reported by Dj. Kostić (1961). We asked subjects to judge the similarity between two prepositional phrases in sentential context; in all of them, the same preposition was used in both phrases. For some sentence pairs, the phrase expressed the same putative theme in both sentences; in other pairs, the phrase expressed putatively different themes. A representative sample of roles (those studied in our subsequent Experiment 2) was studied. If there is psychological validity to the notion of thematic role, subjects should be able to distinguish reliably between two different themes when they are putatively different even though both phrases use exactly the same preposition. Likewise, similarity of function between two phrases using the same preposition should also be perceived when they are thematically identical. Because the same preposition is used in all comparisons, there is no overt cue to similarity or difference.

### Method and Design

Subjects were high school students in Belgrade. All were native speakers of Serbian. Like secondary school students in most countries, they were not trained

to be highly analytic about language. There were 197 students divided into three instructional conditions (described later). Seventy participated in Instructional Condition 1, 63 in Condition 2, and 64 in Condition 3.

Twenty-six pairs of sentences were created from 30 individual sentences. Sentence length varied from three to six words. Each sentence contained one prepositional phrase consisting of a preposition and a single accusative noun; the preposition was underlined.

In each sentence pair, the comparable phrases used the same preposition. The thematic similarity or dissimilarity between the two sentences was subtle: The words in both sentences were always different (except for the preposition) even when the roles for the nouns were the same. Twelve of the sentence pairs contained the preposition *kroz* and 12 contained the preposition *uz*; both prepositions are associated with three potential thematic roles. Each sentence was paired once with three others. The prepositions in one pair of sentences expressed the same role; for the other two pairings the other two thematic roles associated with that preposition were paired. Finally, the preposition *niz*, which has only one function, was included in two same-function sentence pairs. Thus, there were 26 sentence pairs, half of which were same-theme sentence pairs and half were different-theme pairs. Table 1 presents examples of same-theme and different-theme sentence pairs. See Experiment 2 for English translations of the thematic roles for the other prepositions.

All subjects saw the same list of 26 sentence pairs. The sentence pairs were distributed on three printed pages such that no sentence was repeated on the same page. There were three different orderings of the three pages. The subjects were tested in small groups. The initial instructions asked them to read each sentence pair and "decide whether the underlined prepositions in the two sentences were used in the same way or not." Subjects wrote the appropriate initial letter for "same" or "different" in the blank space between the two sentences.

TABLE 1. Experiment 1. Examples of sentence pairs with same or different thematic roles for an accusative case prepositional phrase.

SAME ROLE	
Spatial	Spatial
(1) Gledao je <u>kroz</u> suze. 'He will look through tears.'	(2) Baciće se <u>kroz</u> prozor. 'He will jump through the window.'
DIFFERENT ROLE	
Spatial	Instrumental
(1) Baciće se <u>kroz</u> prozor. 'He will jump through the window.'	(2) Ozdraviće <u>kroz</u> šetnju. 'He will recuperate through walking.'

Three different kinds of instructions were used. In Instruction Condition 1, subjects were given an example: a single sentence written on a blackboard; the preposition in the sentence was underlined. In Instruction Condition 2, the experimenter wrote a pair of same-function sentences on the blackboard, using a preposition different from the experimental list prepositions. The experimenter stated that the underlined prepositions in the example sentences had the same "idea" but did not provide additional explanation. In Instruction Condition 3, subjects were also given two same-function sentences, but in this case the preposition used was identical to one used in the experimental list they were about to see (the preposition *kroz*). In each condition, after instructing the subjects, the experimenter erased the examples from the blackboard before the subjects began work on their printed list of sentence pairs. Each session lasted about 30 minutes.

### Results and Discussion

Figure 1 presents hits and false alarms. A hit was a "same" response when the two prepositional phrases had the same thematic role; a false alarm was a "same" response when the two phrases had different themes. The figure summarizes the data for each of the three instruction conditions. An analysis of variance was performed on the number of hits and false alarms for each subject. The difference between hits and false alarms was highly significant,  $F(1,194) = 2,819$ ,  $MS_e = 2.55$ ,  $p < .001$ , as might be expected by inspection of Figure 1.

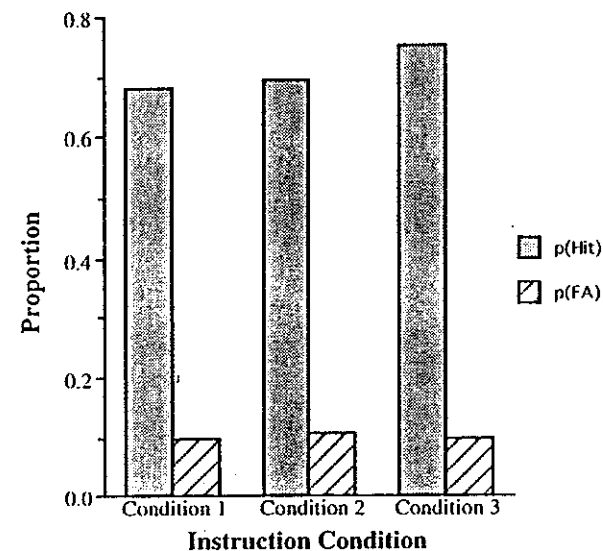


FIGURE 1. Proportion of Hits and False Alarms in judging Serbian prepositional phrase pairs to be equivalent in thematic role. Results are given for each instruction condition.

The mean number of hits was 9.88 (82%), and the mean ratio of hits to false alarms was 7.38:1.

The difference between hits and false alarms varied slightly, but significantly, with instruction condition:  $F(2,194) = 3.75$ ,  $MS_e = 2.55$ ,  $p < .03$ . There was a greater superiority in hit rate for Instruction Condition 3, in which the preposition in the example had been the same as one of the prepositions used in the test itself.

Thus, the results of Experiment 1 show clearly that even secondary school students can discriminate accurately among different functional meanings of accusative case nouns. Having established, with this experiment, a plausible case for the psychological reality of differences in thematic role, we have a reasonable basis for the next experiment in which we study whether the act of recognizing a word is affected by the *number* of different thematic roles that the word's case can assume.

### Experiment 2

In order to study whether thematic role ambiguity affects word recognition, we used a primed lexical decision paradigm. Based on A. Kostić's work (1991) we expected that increased role ambiguity would affect word recognition by slowing it; the greater the ambiguity, the greater the slowing. This expectation is in line, of course, with standard information theory which states that information load increases as the number of alternative states at each processing stage increases. However, a word's thematic role can affect reaction time only if resolving thematic status is something that is *necessary* for the word recognition process—and logically, at least, there is no reason to insist that word recognition include obligatory comprehension of the word's functional status. Logically, a subject need only recognize the string of letters as something in his or her lexicon and neither its thematic function nor any other lexical or syntactic characteristics need take part in the lexical decision. Yet Kostić's data seemed to require the explanation that his subjects did, in fact, process thematic role obligatorily in recognizing the word. However, Kostić's study did not test, directly, the conjecture that it was thematic ambiguity and not some correlate that was responsible for the pattern of word recognition speeds he observed. In the present experiment, we test this notion directly by presenting the target word either in isolation (i.e., ambiguously) or in a thematically disambiguating context. If thematic ambiguity is the reason that word recognition is slow, we would expect word recognition time to be faster when we constrain the context to be unambiguous.

A related question concerns the distinction between morphological processing and semantic processing. We wished to determine whether any thematic role effects we found could be labeled as a product of morphosyntactic processing. One way of strengthening the argument that thematic role effects are

morphosyntactic in nature is to demonstrate that they are not semantic in origin, that they are qualitatively different from the effects of semantic ambiguity.

Polysemy is a useful semantic variable in this regard because it, like functional ambiguity, can be viewed as a kind of uncertainty: Words with many meanings are more lexically ambiguous when presented in isolation. Therefore, according to information theory, polysemy might be thought to be subject to the same dynamics as thematic uncertainty. However, there has been considerable evidence that polysemy affects word recognition speed in the *opposite* direction of thematic uncertainty. Jastrzembski (1981) and Millis and Burton (1989) demonstrated that isolated polysemous words are recognized *faster* than words with a single meaning. From the fact that responses are not slowed, it seems likely that the locus of the polysemy effect is prior to a stage when the word's several meanings collide. Perhaps the lexical decision response is initiated as soon as any one of a word's meanings is accessed; having more meanings may offer a greater likelihood that one of them is rapidly activated. Alternatively, all of the meanings may be activated creating a homogeneous aggregate "buzz" of activation that quickly biases a subject to decide that this high level of activity means that the target stimulus is a word. This latter explanation is consistent with evidence that a word's multiple semantic representations all become activated during word recognition. Consequences of such multiple activations have been detected within 200 ms of word onset, although only the contextually appropriate meaning remains active after that time (cf. Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979, 1982). The explanation that lexical decisions are biased toward a "word" response by an aggregate but diffuse number of activations is also consistent with research by Pugh, Rexer, and Katz (submitted) and Pugh, Rexer, Peter, and Katz (1994) on the effects of a word's orthographic neighborhood (i.e., words that are spelled similarly to the target word) on its recognition.

Lexical and syntactic ambiguity were conjoined factorially in the present experiment. Lexical ambiguity was manipulated by selecting sets of monosemous and polysemous nouns, controlled for length and frequency of usage. Thematic ambiguity was manipulated by presenting some words in the nominative case (low ambiguity) and some in the accusative (high ambiguity). These words were preceded by a neutral "prime" (asterisks). As we stated above, the nominative case form is functionally less ambiguous than the accusative because the former has only four possible roles while the latter has more than 30 (Dj. Kostić, 1961).

In this experiment we used feminine nouns because it is in only that declension that the accusative case is unambiguously accusative. This was important since this case was the object of the experimental priming manipulation. However, the choice of feminine nouns necessarily presented us with a confounded nominative case form: The same form that is feminine nominative is also feminine plural genitive, so any noun with that form is necessarily ambiguous with regard to case. Nevertheless, we continue to call that

form "nominative," partly for the sake of convenience and partly because to do so does not impinge on the use we are making of that form experimentally. Its function, experimentally, is to provide a low-information load noun form against which to gauge the effect on word recognition time of recognizing an accusative form when it has high information load (unprimed by a preposition) versus when it has low information load (primed by a preposition).

In a low information load condition, accusative case nouns were preceded by a preposition prime that reduced their number of possible roles to a single one, removing the accusative target's thematic ambiguity. In this situation, responses to the accusative case form were predicted to be about as fast as responses to the nominative because the disambiguating preposition should make the accusative case noun even less ambiguous than the nominative. Thus, among the three experimental conditions there were effectively only two levels of thematic uncertainty: low ambiguity for both neutral-primed nominatives and preposition-primed accusatives and high ambiguity for neutral-primed accusatives.<sup>3</sup> In line with our discussion above, we predicted that lexical decisions would become faster with increasing *lexical* ambiguity (from monosemy to polysemy) but would get slower with increasing *thematic* ambiguity (from one or a few roles to many). Finally, a finding that the two ambiguity effects do not interact would be consistent with the hypothesis that they have different loci of origin.

### Method and Design

Sixty first year university students from Belgrade University participated as part of their course requirements. All were native speakers of Serbian.

Target word stimuli were selected from an initial set of 400 feminine nouns, four, five, or six letters in length. For control purposes, the stimuli were evaluated, subjectively, for number of semantic meanings and frequency of use. First, 5 university-educated native speakers of Serbian generated, from memory, all the alternative semantic meanings they could think of for each noun. From these, two large subsets were culled in which there was consensus by the judges that a word had either only a single meaning (e.g., *reka*—'river') or more than one meaning (e.g., *ploča*—'phonograph record,' 'desk,' 'tombstone'). These words were also checked against a dictionary of common usage. The two subsets were then presented to 100 Belgrade secondary school students who judged each noun for familiarity. Each noun was rated on a scale from 1 ("I have never heard of this word and I do not know what it means") through 4 ("I am very familiar with this word and use it sometimes") and 5 ("I am very familiar with this word and use it very often"). Only nouns that were rated in categories 4 or 5 by at least 85% of the sample were selected for use in the lexical decision experiment.

<sup>3</sup>It is ungrammatical (and not meaningful) to prime a nominative case noun with a preposition.

Three common prepositions were chosen as primes for the accusative case nouns: *kroz* ('through'), *uz* ('up'), and *niz* ('down'). These are never used in the language with any other case. The first two prepositions, used in combination with a noun, can each express three different thematic roles, while the third can express only one. The three thematic roles conveyed by the preposition *kroz* can be translated, roughly, as follows: (1) through distance, from one side to another, as in 'throughout the woods' (*kroz šumu*); (2) through time, as in 'in two days' (*kroz dva dana*);<sup>4</sup> and (3) by means of, as in 'through (hard) work' (*kroz rad*). The preposition *uz* can indicate (1) direction up, as in 'up the stairs' (*uz stepenice*); (2) next to, as in 'next to the house' (*uz kuću*); and (3) accompaniment, as in 'along with the salad' (*uz salatu*). The preposition *niz* can convey only the single thematic role 'down,' as in 'down the stairs' (*niz stepenice*). Table 2 illustrates the range of functional ambiguity for two nominative case nouns, their accusative case forms, and their accusative case forms within a prepositional phrase. The isolated accusative case form has high thematic role ambiguity while the other two conditions have little or none.

TABLE 2. *The design of Experiment 2, with stimulus examples. The noun target was preceded by either asterisks or a preposition.*

Number of Thematic Roles:	CONDITION		
	Nominative <sup>5</sup> Four	Accusative 10 or more	Preposition + Accusative One role
Monosemous:	* <i>reka</i> river	* <i>reku</i> ... river	<i>kroz reku</i> through the river
Polysemous:	* <i>ploča</i> record desk stone	* <i>ploču</i> ... record ... desk ... stone	<i>kroz ploču</i> through the record through the desk through the stone

<sup>4</sup>In expressions involving number, the appropriate inflection is determined in a complex manner. Linguists consider these inflections to be vestiges of an ancient declension. In none of these, however, can the inflection be confused with the standard nominative singular inflection used in the present experiment.

<sup>5</sup>By ignoring the fact that the feminine genitive plural has the same inflection as the nominative singular, we assume that our subjects' processing strategy involved only singular forms; most forms in the experiment were unambiguously singular and the rest were the ambiguous nominative-singular/genitive-plural form, which were likely to be interpreted as nominative. Also, because the nominative form is so much more frequent than the other, the informational value for the inflection is dominated by the nominative's frequency. Thus, even if the plural form is considered, the ordinal relationships noted in Table 2 still hold.



Each word appeared three times in the master stimulus set. One appearance consisted of the noun in the nominative case preceded by a neutral "prime" (3 asterisks): \*\*\* -*reka*. A second appearance consisted of the same word in the accusative case: \*\*\* -*reku*. A third appearance consisted of the accusative case form preceded by one of the prepositions: *kroz* -*reku*. Each preposition was paired with only one noun, but across stimuli, all prepositions occurred equally often.

A comparable set of pseudowords was generated by changing the initial letter of comparable four-, five-, or six-letter words in a manner consistent with Serbian phonotactic constraints. All stimuli were presented in uppercase letters.

Three experimental stimulus lists were constructed from the master list. Each subject saw only one list. A given stem appeared only once in each list, either in the nominative or accusative case preceded by a neutral prime or in the accusative case preceded by a preposition. Thus, the thematic ambiguity associated with words based on the same stem was counterbalanced across lists. Each list contained all of the monosemous and polysemous words and contained 90 words and 90 pseudowords. Of the 90 words, there were 15 in each combination of semantic and thematic ambiguity. There were 36 practice trials.

As stated earlier, the nominative form is the same as the genitive plural form. However, the latter is much less frequent in language use and, in the experiment itself, there was no support for an interpretation of the stimulus as a plural; all of the stimuli that were unambiguous with regard to case (66%) were singular and, of those that were ambiguous with regard to number, 73% of the time in language use, the usage is singular. We continue to call the ambiguous form "nominative," but it should be noted that a more precise description is that the form has an information load that is low but not quite as low as a "pure" nominative because the genitive plural has a large number of thematic roles.

Each trial began with a brief auditory signal followed by a 500 ms fixation point that appeared in the center of the computer screen. One hundred ms after the offset of the fixation point, a target (with preposition) appeared one line below. The target stimulus remained on the screen until the subject responded, up to a maximum of 1400 ms. From time to time, following a trial (randomly, averaging every 10 trials), the subject was asked by a message on the screen to report aloud the target stimuli. These check trials ensured that the subject attended to the preposition as well as to the target.

## Results and Discussion

The factors of the analyses were Preposition (*kroz*, *uz*, *niz*), Polysemy (one meaning, more than one), and Condition (Nominative, Accusative, Preposition + Accusative). Condition corresponded to thematic ambiguity as follows: ambiguity was low (and roughly equal) for Nominative and Preposition + Accusative but high for Accusative alone. Figure 2 presents the mean RT by Polysemy and

Condition. RT was faster when the target word had more than one meaning. In addition, words presented in the accusative case without a constraining preposition (i.e., high functional ambiguity) were recognized more slowly than words in the nominative case or words in the accusative case that were preceded by a preposition. These results are consistent with a number of other studies that have found that not only is the nominative case form recognized faster than the accusative but is, in fact recognized faster than any of the oblique case forms (e.g., A. Kostić, 1991; A. Kostić & Katz, 1987; Lukatela, Gligorijević, Kostić, & Turvey, 1980). These findings are extended, however, by our principal finding: that priming an accusative noun, and thereby reducing its thematic uncertainty, reduced response times to approximately that of the nominative. Recall that the nominative form is also the form of the genitive plural. Thus, because the nominative form has its information load increased by the many low frequency functions of the genitive case plural, the information of the primed accusative and therefore RT, should be even lower than the accusative in isolation. Inspection of Figure 2 suggests that this is so.

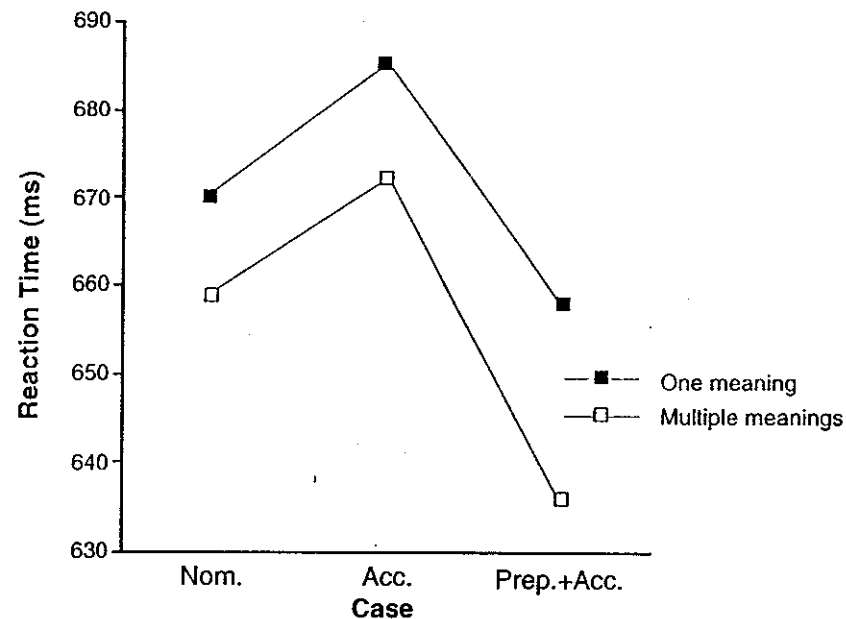


FIGURE 2. RT to Serbian monosemous and polysemous words with few thematic roles (Nominative), many roles (Accusative), and one role (Preposition + Accusative).

These trends were supported by the analyses of variance of RT (error rates were low and not informative). In the subjects analysis, Condition was significant:  $F(2,100) = 26.21$ ,  $MS_e = 2,728$ ,  $p < .001$ . Polysemy was also significant:  $F(1,50) = 17.34$ ,  $MS_e = 2,904$ ,  $p < .001$ . The same effects in the items analysis were: Condition,  $F(2,168) = 5.90$ ,  $MS_e = 3,631$ ,  $p < .003$ , and Polysemy,  $F(1,84) = 3.33$ ,  $MS_e = 4,907$ ,  $p < .07$ .

Some arguments against our interpretation still remain. For example, it might be argued that the common finding that the oblique case forms, such as the accusative, are recognized more slowly is not because they have more possible thematic roles than the nominative but rather because the particular roles they represent are more "difficult" to process. The argument is that it is the *quality* of the roles that affects RT, not the number of roles, per se. That argument seems weak to us because it has been found that recognition speed for all of the cases order themselves exactly as predicted by the number of roles they represent (see A. Kostić, 1991). For this argument, the fact that the number of the roles covaries with the quality of the roles would have to be merely accidental. But such a correlation strikes us as implausible; a case form that is used to process a difficult function should, more naturally, be designed to carry *fewer* functions, not more, so as not to burden that case with a double load of not only more roles but more difficult ones as well. It seems inefficient for language to evolve a given case form that is heavily burdened by many roles each of which is of the greatest processing difficulty. In fact, it is the reverse that seems more plausible: The case form with the least ambiguity (the nominative) might carry few roles because those few require the most processing activity. Nevertheless, we make no claim about qualitative processing distinctions among the various kinds of roles; we have explored here only the mechanism of number.

The results of Experiment 2 were essentially as predicted. They support the claim that a target's thematic ambiguity slows lexical decision time but polysemy does not: If anything, semantic ambiguity facilitates reaction time. In addition, consistent with the two ambiguity effects being at different stages of the word recognition process, no interaction was found between Polysemy and Condition.

## EXPERIMENTS IN ENGLISH

The purpose of the two English experiments was to examine a language whose morphological structure is substantially different from Serbian in order to generalize the ambiguity effects found in that language. In Experiment 3, our intention was similar to that of Experiment 1: to assess the psychological reality of our linguistic descriptions of thematic ambiguity. In Experiment 4, we examined the effects of polysemy and thematic uncertainty on lexical decision, as we did for Serbian in Experiment 2.

A comparison of polysemy across languages is straightforward; all languages have words with more than one meaning. However, the comparison between English and Serbian with regard to thematic ambiguity is a little more complicated. The kinds of noun case roles we examined in Serbian are sometimes conveyed in English in a similar way and sometimes in a different way. For example, the possessive function conveyed by the inflected Serbian form *coveka* can be expressed in English by the inflected form, *the man's*, or by the prepositional phrase, *of the man*. However, with the exception of the possessive, there is no inflection for English nouns comparable to Serbian case (only inflection for number). For purposes of comparison, we needed a way to study both the effects of polysemy and the effects of thematic ambiguity in a primed lexical decision paradigm. We focused on prepositional phrases as the appropriate counterpart to case inflections in English. Fillmore (1968) suggested that prepositions in English are selected on the basis of structural features that are exactly analogous to those that determine particular case forms in case-inflected languages.

### Experiment 3

Central to the logic of the experimental design for Experiment 3 is the assumption that some prepositions carry a higher thematic information load. That is, a noun following certain prepositions will have more possible thematic roles than that a noun following other prepositions. In Experiment 3, like Experiment 1, we sought to establish the psychological reality of the definition of thematic role which was to be the basis for a subsequent experimental test of ambiguity. In Experiment 3 we attempted to provide independent evidence that English-speaking subjects can accurately and reliably perceive distinctions and similarities between prepositional phrases based on their thematic functions. Experiment 3 had two parts: Both had the same goal but differed in method. In Experiment 3a, subjects were required to sort 21 prepositional phrases (presented in sentential contexts) into three equivalence classes without the aid of examples of any of the classes. In Experiment 3b, subjects sorted 25 phrases into five functional classes after viewing examples of each of the five classes. Here, subjects had to choose which of the five types of examples a given test phrase was most similar to.

### Method and Design

*Experiment 3a.* Twenty-two native English speaking undergraduates at the University of Connecticut were presented with sentences containing one of three thematically different kinds of prepositional phrases. The phrases were underlined and all used the same preposition, *with*. The phrases conveyed either (1) manner, as in 'The tired man spoke *with detachment* about the accident,' (2) instrument, as in 'I carried water *with an old bucket*,' or (3) accompaniment, as in

'Potatoes *with gravy* is my cook's specialty.' Subjects were given 21 randomly ordered sentences printed on one page; 7 sentences used each function. Subjects were asked to sort the sentences into three groups of seven "on the basis of how their underlined phrases were used." Subjects indicated group membership by writing the number 1, 2, or 3 next to each sentence, assigning the same number to each sentence they perceived as belonging in the same group.

*Experiment 3b.* Nineteen subjects were given a sorting task with materials and directions similar to those used in Experiment 3a. However, Experiment 3b contained 25 sentences: five sentences with prepositional phrases expressing each of five thematic categories. Again, only the preposition *with* was used. The functional categories were (1) manner, (2) instrument, and (3) accompaniment—as in Experiment 3a—with the addition of (4) description, as in "The comedian *with the lamp shade* was the funniest," and (5) ingredient, as in "Candles *with bees-wax* smell nice." In another departure from Experiment 3a, subjects were given two example sentences for each of the five thematic categories. The categories of the examples were identified only by number.

## Results

*Experiment 3a.* The sentences were numbered for analysis so that the sentences with the *manner*, *instrument*, and *accompaniment* phrases were given the codes 1 to 7, 8 to 14, and 15 to 21, respectively. Subjects' responses were pooled into a proximity matrix. For each pair of sentences in the set of 21, the matrix recorded the number of times subjects classified them both in the same group. The complete-link hierarchical clustering procedure was applied to the proximity data (Milligan & Cooper, 1987). Figure 3 (top) presents the dendrogram summarizing the agglomerative sequence and the distance, alpha, between joined clusters. Sentences/clusters that were reliably perceived as more similar have smaller alphas. A variety of stopping rules were applied (Milligan & Cooper, 1985) which indicated that a three-cluster solution best represented the structure in the proximity data. Examination of the three cluster solution also revealed that 18 of the 21 sentences clustered into the hypothesized groups of *manner*, *instrument*, and *accompaniment*. The three sentences that subjects misclassified (marked by asterisks in Figure 3) were also the last sentences to be joined to their clusters by the procedure. This indicates that there was little intersubject agreement about group membership, which suggests they were perceived to be least like the other sentences in their respective groups.

*Experiment 3b.* The sentences were numbered so that the sentences with the *manner*, *description*, *instrument*, *accompaniment*, and *ingredient* phrases were coded 1 to 5, 6 to 10, 11 to 15, 16 to 20, and 21 to 25, respectively. A complete-link hierarchical clustering procedure was run. The resulting dendrogram is presented in Figure 3 (bottom). The stopping rules indicated a five-cluster solution revealing that subjects' classifications again resembled the proposed

thematic groupings very closely. Only 2 of the 25 sentences were misclassified by the subjects, and again the clustering procedure showed these sentences to be the ones least like the other sentences in their groups.

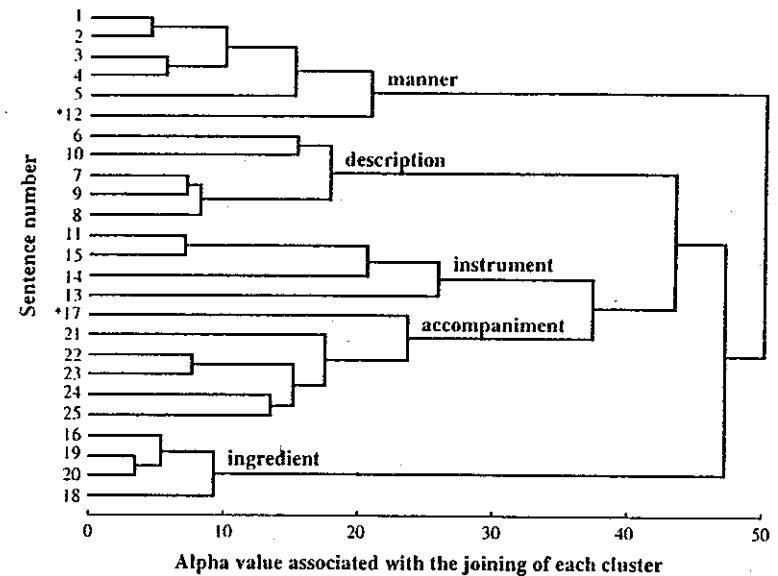
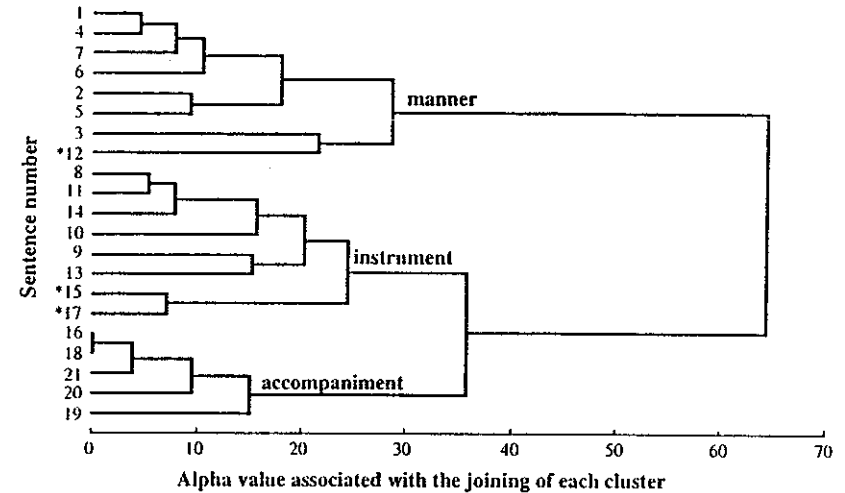


FIGURE 3. Cluster dendrograms for English thematic role three category sort (top) and five category sort (bottom). See text for description. Only the sentences with asterisks were incorrectly grouped.

## Discussion

The results of both parts of Experiment 3 indicate that subjects can discriminate different thematic uses of the preposition *with* accurately and can, as well, accurately identify phrases that do not differ. The results demonstrate divergent and convergent validity for the concept of prepositional phrase thematic role. The results of Experiment 3 show that English-speaking subjects, like their Serbian-speaking counterparts, appear (within the bounds of this study) capable of accurately perceiving thematic role.

## Experiment 4

In Experiment 2, we demonstrated that polysemous Serbian nouns are recognized faster than nouns with only one meaning. This finding was consistent with earlier studies of English nouns that also showed a subtle but stable facilitative effect of polysemy (Millis & Burton, 1989). In the present experiment, Experiment 4a, we looked for such a polysemy effect on English prepositions. Some prepositions have relatively few meanings while others have many. If the polysemy effect generalizes to prepositions, then prepositions with many meanings should be recognized faster in a lexical decision task than prepositions with few.

Most of a preposition's meanings (but not necessarily all) are indications of thematic role. Thematic role is determined in part by the governing verb, but this verb may subcategorize for certain prepositions, and these prepositions, in turn, will constrain the possible thematic roles of the nouns they modify. In a second experiment, Experiment 4b, we studied the effect of the ambiguity projected by the preposition on the prepositional phrase itself. As in Experiment 2, the recognition of the noun in the phrase should be slowed in thematically ambiguous prepositional contexts. Thus, we wished to see if the same prepositions that show *facilitative* effects of polysemy—that are recognized faster when presented in isolation—would also produce an *inhibitory* effect on the nouns they modify. Assuming that the subject cannot avoid comprehending the prepositional phrase (during the process of recognizing the noun), then thematic ambiguity in the phrase should slow the lexical decision response to the noun. The specific predictions were, first: In Experiment 4a, prepositions in isolation that are associated with many thematic meanings will be recognized faster; second, in Experiment 4b, nouns preceded by such prepositions (i.e., nouns in thematically ambiguous prepositional phrases) will be recognized more slowly. Thus, it is the preposition that proximally determines the noun's thematic ambiguity by determining the number of possible roles for the noun.

## Method and Design

Forty-two University of Connecticut undergraduates, all native English speakers, participated in Experiment 4 to fulfill a course requirement. Experiment 4a consisted of a simple lexical decision task with 22 prepositions and 22 pseudowords presented in a different random order to each subject. The words' frequencies (Kučera & Francis, 1967) ranged from 11 to 26,149. Polysemy was operationalized as the number of definitions given in a standard desk dictionary (Funk & Wagnalls, 1964). The words' number of meanings ranged from 2 to 32, but not all of these were prepositional meanings. For example, the word *onto* has not only a prepositional sense (e.g., "Put the sticker *onto* the window") but also a verbal sense (e.g., "I'm *onto* you," meaning "I'm aware of what you're doing"). The preposition *over* has, in addition to its prepositional meaning, an intensifier meaning, as in, "I'll think the matter *over*." The number of specifically prepositional meanings ranged from 1 to 23. (There was a high correlation between total number and number of preposition-only meanings,  $r = .86$ .) Pseudowords were created that matched the words for length and general orthotactic familiarity.

Experiment 4b employed a primed lexical decision paradigm. The 22 prepositions used in Experiment 4a, together with the word *the* served as primes (e.g., *beneath the*). Twelve concrete nouns (five or six letters in length) served as targets; their frequencies of occurrence in printed American English were approximately equal: Kučera and Francis mean = 26.68,  $SD = 4.77$ . Eighty-eight pseudowords, matched to the nouns for length and general orthotactic familiarity, were created. Each preposition prime was paired with four different word targets and four different pseudoword targets, yielding 176 trials. Each noun appeared either 7 or 8 times in the list, each time with a different preposition; each pseudoword appeared only once.

*Procedure.* In Experiment 4a each subject viewed the entire list of prime-target pairs in a different random order. Thus, there were usually several trials between repetitions of the same preposition; when it reappeared, it preceded a different noun. Stimuli were presented on a Macintosh computer screen. Each trial began with a fixation point for 400 ms, followed by a 32 ms blank, followed by the target preposition or pseudoword. The target remained on the screen until a response occurred or the time-out period of 1,400 ms expired. The intertrial interval was 1,400 ms. There were 10 practice trials and 44 experimental trials.

Following Experiment 4a each subject participated in a portion of Experiment 3. This experiment was described previously. Experiment 3 took approximately 20 minutes. Each subject then participated in Experiment 4b. In Experiment 4b a 400 ms fixation point was followed by a 32 ms blank, which was followed, in turn, by the prime (e.g., *beneath the*) for 400 ms. The prime was presented to the left of the screen's vertical midline. At the offset of the prime, the target noun (e.g., *fruit*) appeared to the right of the midline for up to 1,400 ms, as in Experiment 4a. There were 10 practice trials and 176 experimental trials.

## Results and Discussion

*Experiment 4a.* For the simple lexical decision experiment, each subject's data consisted of a reaction time to each of the 22 prepositions and 22 pseudowords. The average error rate was 6.4%. For each subject, the partial correlation between the RTs to words and the number of meanings was calculated with log Kučera and Francis frequency partialled out. The resulting correlations were aggregated over subjects and a mean partial correlation was calculated for the group of subjects. Two mean correlations were obtained, one based on the total number of meanings for each stimulus and the other on only the number of specifically prepositional meanings for each stimulus. Because the stimuli occurred in isolation, there was no context to limit a stimulus exclusively to its prepositional meanings, and it seemed likely that the total number of meanings—both the dominant prepositional meanings and the secondary nonprepositional meanings—would affect the recognition process. That is, the recognition process ought to be sensitive to overall polysemy but insensitive to the syntactic class of the information carried by the stimulus (i.e., whether the meaning was prepositional or not).

The results supported this notion. Although the total number of meanings and the preposition-only number of meanings were both significantly related to RT (as predicted, prepositions with greater polysemy were recognized faster), the relation was stronger by far for the total number of meanings. For the partial correlation between recognition RT and total meanings was  $-.189$ ,  $t(38) = 5.33$ ,  $p < .001$ . But for number of preposition-only meanings, the mean partial correlation was lower (mean  $r = -.087$ ,  $t(38) = 2.49$ ,  $p < .02$ ). The difference between the two mean correlations was significant, indicating that total number of meanings was a better indicator of polysemy (mean difference =  $.101$ ,  $t(38) = 3.62$ ,  $p < .001$ ). Note that, although the average correlation of  $.189$  is low, it is a quite conservative statistic—a partial correlation with the effect of word frequency removed. Because word frequency is itself strongly correlated with number of meanings, by partialing out frequency we are, in effect, removing all of the polysemy effect that is correlated with it. Thus, the remaining polysemy effect represents only its minimum contribution to word recognition latency and is quite conservative. It should be noted further that the  $t$  test on the difference of the partial correlations is a strong test of the effect of polysemy on RT. Although a simple null hypothesis predicts mean correlations of zero for both, a more complex hypothesis might predict that some unknown artifact could increase each subject's correlation in the same direction (either positive or negative), thereby producing a spurious but sizable correlation. But both the correlation based on total number of meanings and the correlation based on preposition meanings alone reflect the same RTs to the same stimulus words and, therefore, both correlations would be affected by a confound in exactly the same way. The

fact that they produce results that are significantly different counters any such artifactual explanation of the facilitative effect of polysemy.

*Experiment 4b.* It had been predicted that the greater the thematic uncertainty of the preposition prime, the slower RT would be to the target noun that follows it because the noun's thematic role would be more ambiguous. Thus, preposition primes that are associated with more potential thematic roles should produce slower target noun recognitions. Mean RTs for each subject were calculated over each of the 22 sets of four noun targets that had been primed by a given preposition. Only correct responses were included; error rate was 2.7%. For each subject, the 22 mean RTs were correlated with the number of meanings for the corresponding prepositions; as before, these were partial correlations in which frequency was partialled out. As in Experiment 4a, separate correlations were calculated for the total number of the prime's meanings and for the number of preposition-only meanings. In contrast to Experiment 4a, in which the polysemy effect predominated, it was expected in Experiment 4b that it should be the number of specifically *prepositional* function meanings, rather than the more general total number of meanings, that should determine lexical decision RT.

The results supported this expectation. The partial correlations between RT and total number of meanings and between RT and number of preposition-only meanings were calculated for each subject, and then each was averaged over subjects. For the total number of meanings, mean partial  $r = .049$ , not significantly different from zero. In contrast, for the partial correlation between recognition RT and number of preposition-only meanings, mean  $r = .090$ ,  $t(41) = 2.68$ ,  $p < .01$ . Note that, unlike the correlations in Experiment 4a, this one is positive, indicating that the greater the number of (prepositional) meanings of the prime (and, therefore, the greater the thematic ambiguity of the phrase), the slower word recognition was. In addition, the difference between all the meanings correlation and the preposition-only meanings correlation was significant (mean difference =  $.041$ ,  $t(41) = 2.18$ ,  $p < .04$ ). Although the mean partial correlation between target recognition RT and thematic ambiguity is small, it is consistent over subjects and indicates that RT to a target word was slowed when the word's role within the prepositional phrase was more ambiguous. As with the statistical test of the correlation difference in Experiment 4a, this difference also is not attributable to the particular stimulus characteristics of the noun targets.

## GENERAL DISCUSSION

An aim of the present work was to study the processing consequences of thematic role ambiguity and to contrast thematic role ambiguity with semantic ambiguity. For generality, we studied two languages, Serbian and English. The two languages have some differences (as well as similarities) in the ways that thematic role is expressed. In Serbian, inflectional morphology plays a major

part in constraining thematic role through the relation between case inflection and role: Some cases convey a greater number of possible thematic roles than others. In English, word order provides the syntactic information provided by case in Serbian. In spite of these differences, both languages behaved similarly with regard to ambiguity in thematic role as well as with regard to ambiguity in word meaning (polysemy). Lexical decisions were facilitated by increased polysemy. In contrast, thematic role ambiguity strongly slowed lexical decisions.

As ancillary experiments, we had also provided experimental support, by means of non-speeded choice paradigms, for the psychological reality of the particular categories of thematic role that formed the basis for our theoretical analysis of thematic role ambiguity. In order to claim that RT had been slowed because subjects had been uncertain as to which of several possible thematic roles were intended by an isolated Serbian noun in a particular case or by an English noun in a prepositional phrase, we had to show that subjects can actually differentiate the various roles. By demonstrating the psychological reality of several roles, we bolstered the likelihood that the results of thematic ambiguity manipulations in the lexical decision experiments were, in fact, due to the perceived ambiguity in the thematic roles of the target words.

The effect of thematic ambiguity that we demonstrated may, perhaps, be similar to a general comprehension effect, like that reported by Colombo and Williams (1990). That is, the process by which case thematic role or prepositional thematic role is resolved may be no different than the presumably high level cognitive processing that uses non-syntactic pragmatic knowledge and other world knowledge to understand a message in ordinary discourse.

On the other hand, it may be that the processing of thematic role is not the same as a general comprehension process. There is some evidence to suggest that certain kinds of syntactic information, at least, are processed independently of semantics. Gurjanov, Lukatela, Moskovljević, Savić, and Turvey (1985) and Katz et al. (1987) demonstrated that a pseudonoun (a nonword stem with a legitimate inflection) will show an effect of nominative case superiority: It is more quickly rejected as a word when it has an unmistakably nominative case inflection than when it carries another case's inflection. This is an example of a syntactic effect in the apparent absence of semantic content. Note that the nominative case inflection does not make the pseudoword seem more "wordlike"—a characteristic that would slow down its rejection instead of speeding it; instead, nonword responses are faster when the nonword is in the nominative case. Moreover, if a pseudonoun is primed by an adjective that agrees with it inflectionally (in case and number), it is also rejected faster. The inflections on the adjective and noun/pseudonoun are not identical, in general; therefore, the priming effect is not a simple form repetition effect but is truly syntactic in nature. These results suggest that the language system evaluates the morphological information carried by the suffix inflection independently from the semantic information carried by the word stem. Thus, there is some reason to

consider the possibility that not only the inflectional message itself but also its implications for thematic role may be processed in a different manner than the semantics of the stem. In the introduction to our Serbian experiments, we discussed the satellite model of inflectional organization. This model was proposed in order to explain the well-known phenomenon that words are recognized fastest in their nominative case form. Various explanations based on the physical characteristics of the word (e.g., its orthographic or phonologic characteristics) or its frequency of occurrence have been ruled out (Katz et al., 1987; Katz, Rexer, & Lukatela, 1991); the phenomenon seems to be caused purely by the cognitive syntactic meaning carried by the word.

Lukatela and his associates (e.g., Lukatela, Gligorijević, Kostić, & Turvey, 1980) proposed that the superiority of the nominative case reflected its central position in lexical organization: the satellite model. The present results suggest a different explanation of nominative case superiority. In line with the theoretical insight and data presented by A. Kostić (1989, 1991, this volume), we suggest that isolated words in the nominative case are recognized faster because they have fewer alternative thematic roles. Words in the nominative case are faster because there are fewer thematic alternatives to choose among.

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