PROCESSING OF VERB TENSE

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Processing of Serbian inflected verbs was investigated in two lexical decision experiments. In the first experiment subjects were presented with five forms of future tense, while in the second experiment the same verbs were presented in three forms of present and future tense. The outcome of the first experiment indicates that processing of inflected verb is determined by the amount of information derived from the average probability per congruent personal pronoun of a particular verb form. This implies that the cognitive system is not sensitive to verb person per se, nor to the gender of congruent personal pronoun. Results of the second experiment show that for verb forms of different tenses, presented in the same experiment, the amount of information has to be additionally modulated by tense probability. Such an outcome speaks in favor of cognitive relevance of verb tense.

Key words: psycholinguistics, inflectional morphology, verb tense, lexical decision

In the present study we investigate processing of verb forms in Serbian which is a highly inflected, free word order language. Specifically, we are interested in processing of verb person with respect to tense. This issue will be discussed from the perspective of the Information-theoretic Approach which assumes that the cognitive system is sensitive to the amount of information carried by an inflected word form (Kostić, A. 1991; 1995; 2003 submitted). Since the Information-theoretic Approach has been evaluated only on Serbian noun forms, this study is aimed to investigate whether it could be extended to inflected Serbian verbs as well. The attempt is twofold. On the one hand we wish to evaluate whether some of the standard verb attributes like person and tense influence processing of inflected

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verbs, while on the other hand we intend to investigate whether the same general formalism could be applied to word types other than nouns.

This study is also an attempt to establish criteria for cognitive relevance (i.e. psychological reality) of standard grammatical categories, as described by linguists. In number of studies with Serbian inflected noun forms it was demonstrated that formal linguistic description does not map directly into the cognitive domain, suggesting that some of the standard linguistic attributes may not be cognitively relevant (cf. Kostič, A. & Katz, 1987; Kostič, A. 1991; 1995; 2003 submitted). The criteria for cognitive relevance will be evaluated through formalisms that provide numerical predictors of processing latency to various forms of the same inflected word.

**MORPHOLOGICAL PROPERTIES OF SERBIAN VERBS**

In Serbian language morphology plays central role in establishing relational aspects among sentence constituents. Syntactic attributes of nouns, verbs, adjectives, and sometimes pronouns, are indicated by inflectional suffices. Each open class word type is characterised by a fixed set of suffix transformations (declensions and conjugations) which specify their grammatical attributes.

Serbian verbs have distinct grammatical attributes such as person (first, second and third), grammatical number (singular and plural), tense (e.g. present, future, etc.), aspect, and sometimes gender. Each verb can appear in all persons, grammatical numbers, tenses and genders which are marked by an inflectional suffix. There are three persons singular and plural which cross all tenses. Verb tense is formed either by adding a suffix to the base morpheme (e.g. present tense), or by means of the preceding auxiliary verb and specific set of suffixes attached to the base morpheme (e.g. past tense). Unlike other tenses, future tense can be formed by both procedures - by adding an inflectional suffix, or by an auxiliary verb preceding the infinitive form (see Table 1). While in most cases suffix uniquely specifies person, number and tense, there are some exceptions like, for example, third person future tense where the same suffix (e) specifies both singular and plural (see Table 1).

Unlike person, tense and aspect which are intrinsic properties of verbs, verb gender derives from the complementing noun and is determined by its gender. The first and the second person singular and plural are contextually modified for gender with respect to communicational frame of reference (gender being assumed and therefore in most cases not marked). In contrast, the third person singular and plural are either marked for gender (e.g. past tense) and/or specified by preceding personal pronoun (e.g. present tense).

In contrast to noun declension, which is in most cases tied to grammatical gender, conjugation is not related to any particular grammatical attribute. In Serbian there are seven types of conjugations which could be reduced to three verb types with respect to suffix in the third person plural present tense. Thus, for example, the verb *videti* (*to see*) will have suffix *e* (*vid-e*) attached to the third person plural
present tense, the verb *plakati* (to cry) will have suffix *u* (*plač-u*), while the verb *pevati* (to sing) will have suffix *ju* (*peva-ju*). These differences are due to phonological properties of a verb and are not related in any obvious way to other verb attributes.

Like in all inflected languages agreement among different word types in Serbian is accomplished through morphological rules which require suffix coordination. Thus, for example, an adjective has to agree with a noun in case, grammatical number and gender, this agreement being marked by inflectional suffixes. Likewise, a preposition has to agree with the case of noun and adjective, and sometimes pronoun. Verb person, on the other hand, is modified by personal pronoun which in most cases precedes verb\(^2\). If there is a preceding pronoun, it has to agree with verb person and number. In Table 1 different forms of verbs in present and future tense are presented, as well as their congruent pronouns.

The agreement among different word types in Serbian is guided by strict morphological rules. Any violation of these rules will produce an ungrammatical combination.

<table>
<thead>
<tr>
<th>Table 1: Serbian present and future tense verb forms in singular and plural and their preceding pronouns</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Person</strong></td>
</tr>
<tr>
<td>Sing. 1.</td>
</tr>
<tr>
<td>Sing. 2.</td>
</tr>
<tr>
<td>Sing. 3.</td>
</tr>
<tr>
<td>Plur. 1.</td>
</tr>
<tr>
<td>Plur. 2.</td>
</tr>
<tr>
<td>Plur. 3.</td>
</tr>
</tbody>
</table>

\(^*\) *pevam* - (I sing)

(m) - masculine, (f) - feminine, (n) - neuter

MODELS OF PROCESSING AFFIXED WORDS

Models dealing with representation and processing of morphologically complex words could be categorized into two distinct groups. On the one hand it is assumed that affixed words are represented in the lexicon as a whole (Rubin, Becker and Freeman, 1979; Kempley & Morton, 1982; Butterworth, 1983; Cutler, 1983; 2 The preceding pronoun is not an obligatory modifier. Verb can also appear without a pronoun.
Fowler, Napps & Feldman, 1985; Henderson, 1985; Feldman & Fowler, 1987; Katz, Boyce, Goldstein & Lukatela, 1987). On the other hand, the opponents of such approach assume that morphologically complex words are represented through their constituents, therefore, processing of an affixed word should imply some sort of decomposition into a base form and affix (Mackay, 1978; Taft, 1979a; 1979b; 1981; Jarvella & Meijers, 1983, Allen & Badecker, 1999, Badecker & Allen, 2002). There are also intermediate stands based on the assumption that representation and processing of affixed words may depend on type of affixation (Bergman, Hudson & Eling, 1988; Marslen-Wilson, Komisarjevsky, Tyler, Waksler & Older, 1994). In spite of divergent attitudes with respect to type of representation and access to the lexicon, there seems to be a consensus that suffix probability is one of the pivotal factors that influence processing latency of an inflected word. Proponents of the decomposition stand, for example, advocate probability dependent lexical search of the decomposed constituents, while researches that advocate the "whole representation" assume that processing difference between affixed and non-affixed words are due to their respective probabilities of occurrence.

The difference between the two approaches, as instantiated in the Decomposition Hypothesis on the one hand, and the Single Unit Hypothesis on the other hand, is primarily based on the assumed status of polymorphemic words and mechanisms of their processing. Thus, for example, the Decomposition Hypothesis postulates several processing stages which consist of: (a) decomposition of a word into an affix and the base form, (b) search for an affix and the base form in the lexicon, this search being probability dependent, and (c) postlexical evaluation of affix/base combination validity. If extended to inflective languages where the same word can appear in number of inflected forms, the model would imply that processing time variation for different forms of the same word is due to suffix probability.

Manelis and Tharp, on the other hand, found no evidence for decomposition. The model they propose (the Single Unit Hypothesis) assumes that affixed words are represented as a whole in the lexicon, while eventual processing differences between the two are due to their probability of occurrence. Therefore, other things being equal, there should be no difference between affixed and non-affixed words (Manelis & Tharp, 1977). Extension of the model to inflected languages implies that processing time variation for different inflected forms of the same word should be due to suffix probability.

Experiments on Serbian nouns showed that neither Single Unit Hypothesis nor Decomposition Hypothesis can account for the observed processing differences because suffix probability proved not to correlate with processing time for various inflected forms of the same noun (Kostić, A. 1991; 1995; 2003 submitted). The absence of systematic relations between suffix probability and processing time suggests that any explanation of processing variability for the inflected Serbian noun forms based on suffix probability per se has to be rejected.
THE INFORMATION-THEORETIC APPROACH TO PROCESSING OF INFLECTED MORPHOLOGY

The models discussed so far assume that processing time variation to inflected forms of the same word is either due to lexical organization (e.g. probability dependent search), or to some aspects of processing mechanisms which are time consuming (e.g. decomposition). As already noted, these premises proved not to be fruitful in predicting processing time variation observed with inflected Serbian noun forms.

Instead of searching for the alternative processing mechanisms which may account for the observed effects, the Information-theoretic Approach emphasized the proper stimulus specification (Kostić, A., 1991; 1995; 2003 - submitted). According to this approach, stimulus specification should include cognitively relevant aspects of morphology in order to make proper prediction of processing time variation of inflected word forms. Suffix probability (i.e. frequency), which intuitively seemed to be the most plausible candidate, proved not to be a proper descriptor since in regression analyses it did not account for a significant proportion of processing time variability of inflected Serbian noun forms (Kostić, A., 1991). The absence of significant proportion of explained variance may imply that form frequency is cognitively irrelevant, or that in addition to form probability, there has to be some other factor which influences processing time to inflected Serbian nouns. The additional factor proved to be the number of syntactic functions and meanings carried by a particular noun form. Each case of Serbian nouns encompasses number of syntactic functions and meanings. Thus, for example, noun in the nominative case can take the subject or predicate role, in the accusative case it can take the object role or can denote place, in instrumental its syntactic meaning will be that of an instrument or accompaniment etc. (cf. Kostić, Đ., 1965b). All these potential functions/meanings are realized in a sentence context and are not overtly marked. Since inflected noun form rather than noun case has to be a unit of description, the number of syntactic functions/meanings should also be summed for cases that share the same form.

Form frequency and number of syntactic functions/meanings have inverse processing effects. While form probability is inversely proportional to processing speed, the number of syntactic functions/meanings is directly proportional. The increase of number of syntactic functions and meanings is paralleled by form complexity increase and, consequently, processing time has to be longer. Proper relation between the two parameters proved to be the ratio of form probability and number of syntactic functions/meanings. If form probability is divided by the number of syntactic functions/meanings modified by a particular noun form, the derived unit is the average probability per syntactic function/meaning modified by a particular noun form. An additional modification has been made by applying the

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3 These are just two out of fifty eight functions and meanings encompassed by the accusative case (cf. Kostić, Đ., 1965b).
log transform to the proportion of probability by number of functions/meanings ratio relative to ratios of other noun forms, which allowed the morphological aspects of stimulation to be expressed in terms of the amount of information (bits) (Equation 1) (Kostič, A. 1991; 1995; 2003 submitted).

\[
\bar{RT}_m = f \left[ -\log_2 \left( \frac{F_m}{R_m} \cdot \frac{M}{\sum_{m=1}^{M} \frac{F_m}{R_m}} \right) \right]
\]

In Equation 1 \(F\) stands for form frequency, \(R\) for the number of syntactic functions/meanings, while index \(m\) denotes morpheme (i.e. form rather than case). The equation states that the basic unit of subject's sensitivity when processing inflected nouns is the amount of information derived from the average probability per syntactic function/meaning modified by a particular noun form. The evaluation of this descriptor indicated that it accounts for almost all processing variability of inflected noun forms (Kostič, A. 1995, 2003, submitted).

The implication of Equation 1 is that subjects when processing inflected Serbian noun forms are not sensitive to some of the standard linguistic attributes like case and grammatical number. In spite of the fact that Equation 1 has no case and grammatical number terms, values derived from the equation provide almost perfect prediction of processing time variation. By virtue of not being terms in the equation, these grammatical attributes do not correspond to any cognitively relevant aspect of stimulation. Extending this rationale it could be stated that the status of cognitive relevance (i.e. psychological reality) could be attributed only to those grammatical categories which prove to be obligatory terms in the equation which specifies values that highly correlate with processing latency. In other words, an equation that provides a satisfactory prediction of processing time variability is also a description of the principal processing unit derived from cognitively relevant aspects of stimulation.

Since case and grammatical number are not terms in Equation 1, according to the above criterion they may be considered as cognitively irrelevant aspects of a noun.

**PROCESSING OF SERBIAN INFLECTED VERB FORMS**

Evaluation of the Information-theoretic Approach with inflected noun forms indicated that the amount of information, as specified by Equation 1, accounts for almost all processing variability. The question is whether the same metrics (i.e. bits) could be applied to inflected forms of other word types as well, and if so, what may be the relation among relevant grammatical attributes to provide a proper prediction of processing time variability. As already noted, verbs in Serbian are characterized
by person, number, tense, aspect and sometimes gender. With these morphological properties in mind, the question is how does the Serbian native speaker processes inflected verb forms.

Several studies addressed this question. In the experiment reported by Ognjenović and his associates subjects were presented with verbs in four persons present tense (first, second and third person singular, and third person plural) (Ognjenović, Knežević & Mandić, 1984). Results indicated that response latency roughly corresponds to probability of verb person - persons with higher probability were processed faster, although subsequent analysis did not show a significant proportion of variance explained by person's probability (cf. Havelka, 1993). A somewhat different outcome was observed for the results reported by Kostić and Katz (1987) who presented verbs in three persons singular and plural present tense. This time processing latencies significantly correlated with person's probability (Havelka, 1993), suggesting that processing of suffixed verbs may be influenced by suffix frequency, in spite of the fact that the third person singular and plural exhibited significant deviations which caused substantial proportions of unexplained variance. It could be assumed that large amount of unexplained variance is due to improper specification of person probability, or that an additional parameter may also influence processing verb forms. The analogy with the way the amount of information for inflected noun forms had been specified suggests that the term which would refer to pure grammatical aspects of a word (R in Equation 1) may also be obligatory for verbs. The question is what this grammatical term might be since verbs, unlike nouns, are not characterized by syntactic functions and meanings realized in a sentence context.

In order to extend the Information-theoretic Approach to processing of verb forms, A. Kostić suggested that probability of verb person should be divided by the number of congruent personal pronouns. The first and the second person singular and plural are modified by one pronoun only, while the third person (singular and plural) is modified by three (one for each gender) (see Table 1). It could be assumed that the third person is more complex compared to the first and the second person, since it has an implicit gender realized through pronominal agreement. In that respect, the number of congruent pronouns could be treated as formally analogous to the number of syntactic functions/meanings in the case of nouns. In order to parallel the way the predictor for noun forms has been specified, form probability by number of congruent pronouns ratio could be expressed as proportion relative to ratios for other verb persons, subsequently transformed into the amount of information (Equation 2).

$$\overline{RT}_m = f \left( \sqrt{\frac{F_m}{P_m}} \right)$$

\[\text{(2)}\]
In Equation 2 $F$ stands for form frequency, $P$ for the number of congruent personal pronouns, while index $m$ denotes morpheme (i.e. form rather than verb person). Equation 2 states that subjects when processing inflected verb forms are sensitive to the amount of information derived from the average probability per congruent pronoun of a particular verb form. Inspection of Table 1 shows that the denominator value for the first and the second person singular and plural is 1, while for the third person singular and plural it is 3. In other words, the amount of information for the first and the second person singular and plural is derived form probability only, which is not the case for the third persons singular and plural. When regressed on response latencies from the Kostić and Katz (1987) experiment, values derived from Equation 2 account for a significant proportion of processing variability. For the data reported by Ognjenović et al. (1984) 89% of variability has been accounted for by values obtained from Equation 2, which is close to statistical significance ($p<.056$). In both cases form probabilities were specified relative to probabilities of other forms of present tense.

In spite of the fact that values obtained from Equation 2 provide somewhat better prediction than non-transformed form probability, there was still a significant proportion of unexplained variability. Havelka assumed that this may be due to idiosyncracies of the sample from which verb form probabilities have been estimated (Havelka, 1993). Probabilities of Serbian grammatical forms were estimated on samples of daily press and contemporary poetry (Kostić, Đ, 1965a). In calculating the amount of information carried by inflected noun forms the average probability values ($F$) for the two samples were used. While noun forms proved not to be sample sensitive, this was not the case with verb forms. Conspicuous differences were observed for the first and the second person singular present tense between daily press and contemporary poetry. In order to explore factors that might additionally influence processing of inflected verbs, Havelka presented subjects with three persons singular and plural present tense verbs, ballanced for type (U, E and JU). While there was no significant effect of verb type, the proportion of explained variance was numerically (but not statistically) higher for values derived from contemporary poetry (86%), compared to those averaged for daily press and contemporary poetry (76%). Findings reported by Havelka suggest that probability of verb person is influenced by social contex which, on the other hand, may be an insurmountable obstacle to make stable and reliable estimates of verb person probability based on a sample of written language.

In experiments with verbs discussed so far only present tense verbs were presented. The question is whether values obtained from Equation 2 will provide satisfactory prediction for other tenses as well and if so, will there be a requirement for an additional term when verbs of different tenses are presented in the same experiment. The second part of the question addresses the problem of cognitive relevance of verb tense. If a tense term proves to be obligatory it could be stated that tense is a cognitively relevant attribute of verb. In order to evaluate whether Equation 2 has sufficient generality, two experiments will be conducted. In the first experiment we ask whether Equation 2 can be applied to tenses other than present tense.
tense, while the second experiment is aimed to investigate the cognitive status of verb tense.

**EXPERIMENT 1**

In this experiment we evaluate the generality of the Information-theoretic Approach asking whether the procedure of specifying the amount of information for present tense forms could also be applied to future tense forms. Another objective is to investigate whether the cognitive system is sensitive to *verb person* or *verb form*. Note that the number of future tense forms does not coincide with the number of persons due to the fact that the third person singular and plural are morphologically identical (see Table 1). Therefore, the probability of third person has to be specified as a cumulative probability of the third person singular and plural. By the same token, the number of congruent pronouns should also be specified as the sum of pronouns modifying the third person singular and plural. The cognitive status of verb person may be challenged if the mean response latency for that form does not deviate from the informational value specified in terms of cumulative probability of the third person singular/plural. Such an outcome would imply that subjects are sensitive to verb form rather than verb person.

There are six personal pronouns congruent with the third person singular and plural (two for each gender, singular and plural) (see Table 1). However, the third person singular feminine pronoun is morphologically identical to the third person plural neuter pronoun (*ona*) (see Table 1). In other words, there are five distinct pronouns congruent with the form that includes third person singular and plural future tense. While collapsing the third person singular and plural into a single form implies exclusion of grammatical number, collapsing feminine singular and neuter plural pronoun into a single morpheme implies exclusion of pronominal gender. In the case of verb person the stimulus description has been shifted from *grammatical form* to more abstract level of *inflected form*. Likewise, in the case of a pronoun the specification has been shifted from personal pronoun to morpheme. The question is whether subjects, when processing the form that includes the third person singular and plural are sensitive to grammatical gender of a preceding pronoun. Empirically, this may be evaluated by contrasting values derived from two ways of specifying the denominator ($P_m$) in Equation 2. If subjects are sensitive to pronominal gender, better prediction should be obtained with denominator's value being six (i.e. pronouns of three genders singular and plural). If subjects are not sensitive to pronominal gender, better prediction should be obtained with the denominator being five (i.e. number of *distinct* congruent pronouns) (Equation 3).

\[
\overline{RT}_m = f\left(-\log_2\left(\frac{F_m}{\sum_{m=1}^{M} F_m} \frac{Q_m}{\sum_{m=1}^{M} Q_m}\right)\right)
\]
Equation 3 is equivalent to Equation 2, the only difference being term $Q_m$ which refers to the number of congruent modifiers, rather than to the number of congruent personal pronouns.

If subjects prove not to be sensitive to pronominal gender, somewhat neutral term like "congruent modifier" may be more suitable to describe the nature of the denominator (see Appendix 1 - bit(a)).

**Method**

**Participants:** Fifty first-year undergraduates from the Department of Psychology, University of Belgrade, participated in the experiment. Each subject was assigned to one of five subgroups according to the order of appearance to the experiment.

**Materials:** Sixty verbs and sixty pseudo-verbs were presented in five forms of future tense. The same verbs presented in Havelka (1993) experiment were presented in this experiment as well in order to enable a comparison with the results obtained on present tense verbs.

**Design and procedure:** Stimuli were presented on a computer screen and participants were asked to respond as quickly and as accurately as possible (by pressing the *yes* or *no* button) whether presented stimulus is a word or a pseudo-word. All 120 stimuli were presented to each subject. They were presented in such a way that participants saw all words and pseudo-words, and all forms of future tense, but they never saw the same stimulus twice.

**Results and discussion**

Mean reaction times and standard deviations to words are presented in Table 2. Analysis of variance showed significant effect of grammatical form: $F(4,196)=20.76, p<0.01$.

**Table 2: Mean reaction times and standard deviations for five forms of future tense verbs presented in Experiment 1**

<table>
<thead>
<tr>
<th>Number</th>
<th>Person</th>
<th>RT (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sing.</td>
<td>1.</td>
<td>681 (76.36)</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>705 (92.14)</td>
</tr>
<tr>
<td>Plural</td>
<td>1.</td>
<td>725 (92.93)</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>743 (91.06)</td>
</tr>
<tr>
<td>Sing./Plur.</td>
<td>3.</td>
<td>689 (92.28)</td>
</tr>
</tbody>
</table>

Values derived from Equation 2, denominator being five (see Appendix 1 – bit /a/), accounted for significant proportion of explained variance: $r^2=0.82$,
F(1,3)=13.282, p<0.05. Somewhat smaller proportion of explained variance was observed when the denominator was six: $r^2=0.789$, F(1,3)=11.249, p<0.05. The relation between the amount of information carried by five future tense forms and processing latency variability is presented in Figure 1. Inspection of the scattergram indicates conspicuous deviation for the first person plural. If we exclude this form from the analysis, almost all processing variability is accounted for by values derived from Equation 3: $r^2=0.999$, F(1,3)=2193, p<0.01. The reason for the observed deviation remains unclear.

Since no deviation has been observed for the form containing the third person singular and plural, there is good reason to assume that the pivotal processing unit is verb form rather than verb person. Contrast between the two showed that somewhat better prediction, although not statistically significant, is obtained when denominator referred to the number of congruent modifiers than to the number of personal pronouns. However, if the first person plural is excluded from the analysis, multiple regression indicated that values derived from denominator referring to the number of congruent modifiers (5) explains significant proportion of variance over and above values derived from the denominator referring to the number of personal pronouns (6): t(1,1)=20.823, p<0.05. Such an outcome, although on somewhat restricted number of forms, suggests that the denominator from Equation 2 may have to be specified in terms of number of distinct congruent modifiers (Equation 3).

**Figure 1: Relation between the amount of information carried by the future tense forms (bit/a/) and processing latency variability in Experiment 1 (in the right scattergram first person plural has been excluded).**

Applied to the present tense forms Equation 3 generates values equivalent to those derived from Equation 2, which is not the case for the future tense since denominator's value for the third person singular/plural will change. Equation 3 states that subjects when processing inflected Serbian verbs are sensitive to the amount of information derived from the average probability per congruent modifier of a particular verb form. In spite of the observed deviation of form equivalent to
the first person plural, Equation 3 seems to have sufficient generality to be applied to all verb tenses.

**EXPERIMENT 2**

In this experiment, by presenting verb forms of different tenses to the same subject we address the question whether verb tense is a cognitively relevant grammatical category. As noted earlier, only those attributes, which are obligatory terms in the equation should be considered as being cognitively relevant. There are two distinct ways of specifying probability of verb forms: (a) probability of a given form could be specified relative to probabilities of other forms of a *particular tense* (e.g. probability of the first person present tense relative to probabilities of other persons present tense (procedure a)) and, (b) probability of a given form (e.g. the first person singular present tense) could be specified relative to probabilities of *all verb forms* (procedure b) (see Appendix 1).

If values derived from the first procedure provide a satisfactory prediction of processing latency, verb tense could be treated as a cognitively relevant morphological attribute, since probabilities of verb forms are directly related to tense (see Appendix 1 – Fa/Q%). If, on the other hand, values derived from the second procedure provide better prediction, it could be concluded that verb tense is cognitively irrelevant, since form probability is specified irrespective of tense (see Appendix 1 – Fb/Q%).

There are good reasons to believe that the first procedure may not provide satisfactory prediction, since it does not take into consideration substantial differences in tense probability. Thus, for example, the probability of a Serbian verb to appear in the present tense is .61, while probability to appear in the future tense is only .013 (cf. Kostić, P, 1965a). This fact is to some extent captured by the procedure b, but not by the procedure a. If this assumption is correct, verb tense, being a subcategory of the verb system, could also be treated as an additional modulator of the amount of information carried by inflected verb forms (Equation 4).

\[
\bar{RT}_m = f\left\{-\ln T_m \left\{ -\log_2 \left( \frac{F_m}{Q_m} \right) \right\} \right\}
\]

At this point there are three possible ways of specifying the amount of information carried by inflected verb forms: (a) form probability can be specified relative to probabilities of other forms of the same subcategory (procedure a), (b) form probability can be specified relative to probabilities of other forms of the same word type (procedure b). The third procedure is based on Equation 4 with form probability being specified relative to probabilities of other forms of the same
subcategory - procedure \( a \), additionally modified by the \( \log n \) of tense probability. The above specifications will be empirically evaluated in the experiment with three forms of present and future tense verbs. Note that the denominator \( (Q_m) \) for the morphologically unique third person singular present tense is three (the number of distinct modifiers /i.e. personal pronouns/). In contrast, the denominator \( (Q_m) \) for the form that includes the third person singular and plural future tense is five, since there are five morphologically distinct modifiers, which include six personal pronouns. It is a matter of empirical evaluation which of the three procedures will provide better prediction.

**Method**

*Participants:* Forty eight first-year undergraduates from the Department of Psychology, University of Belgrade, participated in the experiment. Each of them was assigned to one of six subgroups according to the order of appearance to the experiment.

*Materials:* Seventy-two verbs and pseudoverbs (total 144 stimuli) were presented in three persons singular present and future tense. Forms were equivalent to first, second and third person singular present tense, and first and second person singular and third person singular/plural future tense (see Table 1).

*Design and procedure:* Identical to those from Experiment 1.

**Results and discussion**

Mean reaction times and standard deviations for responses to words are presented in Table 3.

<table>
<thead>
<tr>
<th>Tense</th>
<th>Present</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. sing.</td>
<td>658 (78.45)</td>
<td>691 (91.14)</td>
</tr>
<tr>
<td>2. sing.</td>
<td>673 (88.88)</td>
<td>745 (109.04)</td>
</tr>
<tr>
<td>3. sing.</td>
<td>661 (80.63)</td>
<td>704 (94.66)</td>
</tr>
</tbody>
</table>

The analysis of variance showed a significant effect of grammatical form: \( F(5,235)=35.24, p<.01 \). The first procedure takes into consideration probability of verb form relative to probabilities of other forms of the respective tense (procedure
The predictor specified in such a way did not account for a significant proportion of variance for response latencies. The second procedure (procedure b, Equation 3, see also Appendix 1, bit/b/) where form probability is specified irrespective of tense, accounted for a significant proportion of processing time variation: $r^2 = .827$, $F(1,4)=19.168$, $p<.01$. This suggests that verb tense may be cognitively irrelevant category since form probabilities do not refer to tense. Finally, values derived from the third procedure (Equation 4), where form probability has been specified in terms of procedure a, the amount of information being additionally modulated by the $\log_a$ of tense proportion (see Appendix 1 - bit*T), also accounted for significant proportion of processing time variability: $r^2 = .968$, $F(1,4)=120.939$, $p<.001$. Multiple regression indicated that values derived from Equation 4 explained a significant proportion of variance over and above values derived from Equation 3, procedure b: $t(1,3)=3.963$, $p<.05$. The two patternings of results are presented in Figure 2.

**Figure 2: Relation between the amount of information and response latencies in Experiment 2.**

(a) $RT$ vs the amount of information as specified by Equation 3, procedure b, (b) $RT$ vs the amount of information as specified by Equation 4, procedure a.

Inspection of scattergram 2a suggests a nonlinear increase of processing latency as a function of linear increase of the amount of information. If it could be demonstrated that transformed response latencies highly correlate with the amount of information as specified by Equation 3 (procedure b), no firm conclusions about the status of verb tense could be made since both procedures provide proper prediction, although with different theoretical implications. The implication of Equation 4 (procedure a) is that verb tense is cognitively relevant attribute since the tense term is part of the equation. On the other hand, Equation 3 (procedure b) states that verb tense is cognitively irrelevant, because form probability has been specified irrespective of tense. The question is what kind of function may provide the best description of the nonlinearity observed for values derived from Equation 3 (procedure b). The quadratic function was rejected since it did not provide the
significance that would exceed the one obtained with linear regression: $r^2=.921$, $F(1,3)=17.602$, $p>.05$. In addition, there was no significant contribution of the quadratic component. The observed nonlinearity could also be described in terms of log increase of response latency as a function of linear increase of the amount of information. If so, the log of latency values above the intercept should be regressed on values derived from Equation 3 (procedure $b$). By introducing the log transform of the response latencies the proportion of explained variability becomes highly significant: $r^2=.943$, $F(1,4)=66.405$, $p<.001$. With such an outcome in mind, there seem to be two procedures of specifying variables that provide satisfactory prediction of response latency variation. Note that the two procedures differ in way values for the two variables have been specified (i.e. RT and bit). Consequently, there is no legal statistical procedure to allow multiple regression, and no decisive conclusion could be made whether the observed difference of explained variance between the two predictors is sufficient to reject the latter. However, there are empirical and theoretical arguments in favour of Equation 4 (procedure $a$), that will be discussed in the forthcoming paragraphs.

**GENERAL DISCUSSION**

The outcome of the two experiments show that *verb form* (rather than verb person), *congruent modifier* and *verb tense* are cognitively relevant morphological properties of Serbian verbs. The criterion for cognitive relevance has been established with respect to presence of grammatical attribute in the equation which specifies the amount of information carried by inflected verb forms.

Results of the first experiment (five forms of the future tense) suggest that verb person is cognitively irrelevant since the proper stimulus description required collapsing third person singular and plural into a single form. Instead, form of a particular word type appears to be the pivotal unit to which our cognitive system is sensitive.\(^4\) In that respect, a parallel between nouns and verbs could be drawn, since for both word types inflected form (rather than grammatical form) appears to be the pivotal unit of cognitive sensitivity.

An additional parallel between processing of noun and verb forms comes from the fact that verb form probability has to be modulated by the number of congruent modifiers. Processing of four forms equivalent to the first and the second person singular and plural is determined by their respective probabilities since there is only one preceding congruent pronoun. In contrast, the two forms, which are morphologically identical to the third person singular and plural present tense, are modified by three distinct modifiers (equivalent to personal pronouns of the three genders). The form equivalent to the third person singular and plural future tense is modified by five congruent modifiers, due to the fact that the third person singular

\(^4\) Unlike the noun form which often includes number of cases, the verb form is most of the time morphologically equivalent to verb person.
and plural future tense are morphologically identical. Consequently, forms equivalent to the third person present and future tense are more complex compared to other forms because in a sentence context they are modified by greater number of modifiers. On the other hand, the value of the denominator for the form that includes the third person singular and plural has to be five rather than six, suggesting that the cognitive system is not sensitive to the actual number of personal pronouns (three for each gender, singular and plural), but to the number of morphologically distinct modifiers. The fact that better prediction is obtained when the denominator is specified in terms of number of morphologically distinct modifiers (rather than number of personal pronouns), indicates that the cognitive system is not sensitive to pronominal gender, since it can not disambiguate the third person pronoun (ona) for gender.

The cognitive relevance of verb tense appears to be less intuitive and less conclusive. There are two distinct ways of specifying the amount of information for verb forms of different tenses that provide almost equivalent predictions. Implications of the two, however, differ dramatically. While Equation 4 (procedure a) implies that verb tense is cognitively relevant, the alternative specification (Equation 3, procedure b) indicates cognitive irrelevance of verb tense, and a nonlinear increase of processing latency as a function of linear increase of uncertainty. In spite of the fact that it provides the numerically higher proportion of explained variability, the first way of specifying the amount of information can not be statistically confirmed as the better predictor since the variables are not of the same kind. This, on the other hand, suggests that additional empirical evidence may be required in order to make proper specification of the cognitive status of verb tense.

REFERENCES


APPENDIX 1

**Probability (expressed in percentages) and the amount of information for present and future tense verb forms**

<table>
<thead>
<tr>
<th>Present tense</th>
<th>Fa%</th>
<th>Fb%</th>
<th>Fa/Q%</th>
<th>Fb/Q%</th>
<th>bit(a)</th>
<th>bit(b)</th>
<th>bit*T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person</td>
<td>Fa%</td>
<td>Fb%</td>
<td>Fa/Q%</td>
<td>Fb/Q%</td>
<td>bit(a)</td>
<td>bit(b)</td>
<td>bit*T</td>
</tr>
<tr>
<td>Singular</td>
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<td>8.002</td>
<td>12.340</td>
<td>8.002</td>
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<td>3.974</td>
<td>2.577</td>
<td>3.532</td>
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<td>49.767</td>
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<td>10.757</td>
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<tr>
<td>Plural</td>
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<td>2.573</td>
<td>3.967</td>
<td>2.573</td>
<td>3.535</td>
<td>3.566</td>
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<td>1.327</td>
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<tr>
<th>Future tense</th>
<th>Fa%</th>
<th>Fb%</th>
<th>Fa/Q%</th>
<th>Fb/Q%</th>
<th>bit(a)</th>
<th>bit(b)</th>
<th>bit*T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person</td>
<td>Fa%</td>
<td>Fb%</td>
<td>Fa/Q%</td>
<td>Fb/Q%</td>
<td>bit(a)</td>
<td>bit(b)</td>
<td>bit*T</td>
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<td>8.004</td>
<td>0.111</td>
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<td>8.097</td>
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<td></td>
<td>1.344</td>
<td>0.019</td>
<td>1.344</td>
<td>0.019</td>
<td>5.133</td>
<td>10.671</td>
<td>22.127</td>
</tr>
</tbody>
</table>

* Frequency values are adopted from Kostić, D., 1965a.

Fa% - Form probability relative to probabilities of other forms of a particular tense (procedure a)

Fb% - Form probability relative to probabilities of all verb forms (procedure b)

Fa/Q% - Average probability per modifying pronoun relative to other form probabilities of a particular tense (procedure a)

Fb/Q% - Average probability per modifying pronoun relative to form probabilities of all verb forms (procedure b)

bit(a) - The amount of information derived from Fa/Q%

bit(b) - The amount of information derived from Fb/Q%

bit*T - The amount of information derived from Fa/Q%, multiplied by ln of tense proportion according to Equation 5.

Note: Values for the amount of information derived from Fb/Q%, multiplied by ln of tense proportion have been omitted since such procedure would imply that tense probability has been taken into consideration twice.