Symbolic Rule versus Analogy in the Processing of Complex Verbal Morphology

Kira Gor

Department of Asian and East European Languages and Cultures
School of Languages, Literatures, and Cultures
University of Maryland
College Park, MD 20742, USA
kirao@wam.umd.edu

ABSTRACT: This paper will challenge the simple notion of analogy, which relies entirely on phonological associations, and the assumption that frequency effects are incompatible with symbolic rules as they are applied in research on morphological processing. It will propose and test against the experimental data the Rules and Probabilities Model of the processing of complex inflectional morphology, which incorporates the revised notion of the interrelationship between probabilities, rules, and analogies in linguistic processing. It will discuss the results of three experiments investigating the processing of Russian complex verbal morphology by adult native speakers of Russian, and American learners of Russian—two experiments on novel verb generation, and a lexical decision task.

KEY WORDS: rule, analogy, frequency, probability, processing, morphology

1. Background

The distinction between symbolic rule-based and analogy-based mechanisms lies at the core of the on-going debates concerning the architecture of human mind, modularity of language, and the structure of the mental lexicon. And indeed, the mechanisms of morphological processing, and in particular, English past-tense inflection, have been addressed in the framework of two opposite theoretical positions. The dual-system approach views it as a combination of two distinct mechanisms: regular morphology is processed by symbolic rule application, while irregular morphology is processed by analogy-based associative patterning in memory (Marcus et al., 1992, Pinker 1991, 1999, Pinker and Prince 1994, Prasada and Pinker 1993, Ullman 1999). According to the single-system approach, there exists only one mechanism for processing both regular and irregular morphology, which relies on associative memory (Bybee 1995, Langacker 1988, MacWhinney and Leinbach 1991, Plunkett and Marchman 1993, Rumelhart and McClelland 1986). There also exists an “intermediate” position, the dual-access theory, which
postulates that symbolic rule application and search in associative memory proceed in parallel, and the fastest route wins the competition (Baayen et al., 1997). The main difference between rule-based and analogy-based mechanisms is that symbolic rule application does not depend on any conditions external to linguistic constraints, while processing by analogy depends on input frequencies and the statistical probabilities derived from them. Therefore, the debates focus on the juxtaposition of abstract symbolic rules, which operate on any defined class of linguistic items regardless of any considerations of phonological similarity or linguistic probabilities, and processing by analogy. In the latter, associations between linguistic items are established based on similarity between them, and the strength of these associations depends on the frequency of the word-forms (token frequency), as well as the frequency of the pattern (type frequency). The two positions differ in that the dual-system approach claims that both kinds of mechanisms participate in morphological processing, while the single-system approach claims that only one analogy-based mechanism does. These theoretical positions and the experimental paradigm used to support them rely on one strong assumption, namely, that the existence of frequency effects in morphological processing is an indicator that it is analogical in nature. Since the argumentation involves a frequency-based distinction between rule and analogy, if one does not find an additional external criterion, one becomes engaged in circular argumentation: what is frequency-sensitive has to be analogy and cannot be a rule.

Yang’s Rule Competition Model, which accounts for child L1 acquisition of English past-tense morphology, is a radical departure both from the dual- and single-system approaches (Yang 2002). Crucial to the understanding of the Rule Competition Model is the differentiation between rules and analogies, since it operates with rules and not analogies. While the notion of analogy is built on phonological similarity, rules operate on abstract linguistic concepts. According to the Rule Competition Model, in child L1 acquisition, rules have weights, these weights being adjusted with more input. The Rule Competition Model replaces the absolute blocking principle assumed in the Words and Rules Model (Pinker 1999) with a stochastic version of the blocking principle, which states that a more specific rule overrides the default rule with a probability. Thus, the probability that a certain pattern will be applied is a function of the individual weight of the verb and of the weight of the rule. The verb weight is defined by its token frequency, while the rule weight is determined by the number of uses of all the verbs belonging to a particular class in the input to the child. The competition takes place between the irregular and the default rule. Yang proposes the Free-Rider Effect to explain how the frequency of the rule affects the rates of correct use for irregular verbs in child L1 acquisition of English. The Free-Rider Effect refers to a situation when high type frequency enhances the probability that a certain rule will be chosen to inflect a certain word.

The juxtaposition of regular and irregular morphological processing is well justified for English, however, it is much less meaningful for languages with complex morphology, in which regularity can become a gradual parameter, and the
opposition of default and non-default processing is more relevant. Thus, several studies report that the dual-system approach cannot be readily applied to languages such as Italian, Norwegian, Icelandic, and Russian (Chernigovskaya, Gor 2000, Gor 2002, Gor, Chernigovskaya 2001, 2003, Matcovich 1998, Orsolini, Marslen-Wilson 1997, Orsolini et al., 1998, Ragnasdóttir et al., 1997, Simonsen 2000). At the same time, the German data show a sharp dichotomy between default and non-default processing of morphologically complex words, which is understandably not the same as the regular/irregular dichotomy (Clahsen 1999).

A usage-based perspective on language acquisition distinguishes between exemplar-based and prototype-based models, with prototypes being the exemplars most typical of the category (Bybee 2002, Ellis 2002). “Exemplar-based models have multiple instances in memory, one for each exemplar. Prototype models count features and derive statistical abstractions of the central tendencies” (Ellis 2002, 147). In other words, while exemplars resemble the nodes in connectionist networks with phonologically-organized mappings between them, prototypes rather resemble the products of complex analogical processes involving a certain level of abstraction. Thus, the notion of analogy in language processing is not uniform, and it is possible to distinguish between a “simple” analogy, a result of direct mapping, and an analogy, which has an abstraction as a component. This latter “complex” analogy is close to a symbolic rule in that it includes an abstract level. However, there is one major difference between this prototype-based “complex” analogy and a “classical” symbolic rule—by definition, symbolic rules are immune to frequency effects, while “complex” analogies emerge from categorizations over statistically-organized groups of units. It is not surprising that this focus on the mechanisms of human categorization has led to the growing interest in categorization models affected by type rather than token frequency (Ellis 2002, 148).

This paper will challenge the simple notion of analogy, which relies entirely on phonological associations, and the assumption that frequency effects are incompatible with symbolic rules as they are applied in research on morphological processing. It will propose and test against the experimental data the Rules and Probabilities Model of the processing of complex inflectional morphology, which incorporates the revised notion of the interrelationship between probabilities, rules, and analogies in linguistic processing. It will discuss the results of three experiments investigating the processing of Russian complex verbal morphology by adult native speakers of Russian, and American learners of Russian—two experiments on novel verb generation (Chernigovskaya, Gor 2000, Gor 2002, Gor, Chernigovskaya 2002, 2003), and a lexical decision task (LDT)\(^2\). The Rules and Probabilities Model extends the Rule Computation Model (Yang 2002) to adult L2 processing. But more importantly, it claims that rules are affected by statistical probabilities emerging from input frequencies also in adult native processing when the linguistic system is

\(^2\) The paper will reanalyze and reinterpret the published data on verb generation, and discuss the new data on reaction times in a LDT.
stabilized, and there are no more competing grammars. The Rules and Probabilities Model develops the ideas, which are in the vein of the new strand of linguistics, Probabilistic Linguistics (Bod, Hay, and Jannedy 2003). Probabilistic Linguistics believes in a probabilistic language faculty and sees the integration of formal linguistics with research on language acquisition, psycholinguistics, and cognitive science as its aim. What is remarkable, however, is that this model was put forward independently of the claims of Probabilistic Linguistics\(^2\). The main point in common between the Rules and Probabilities Model’s position and the one espoused by Probabilistic Linguistics, which is reflected in the respective names, is the hypothesis that symbolic rule processing is probability-based.

The paper will rely on the understanding of the differences between adult L1 and L2 morphological processing outlined in the previous publications (Chernigovskaya, Gor 2000, Gor 2002, Gor, Chernigovskaya 2002, 2003). According to this understanding, the differences between L2 and L1 processing are to a large extent due to the differences in the input frequencies to native speakers, who have full access to the language system, and L2 learners, who have limited access to native input frequencies, only insofar as they are reflected in L2 input frequencies. Generally speaking, L2 input is characterized by the leveling of differences between type frequencies. Two features of L2 processing that impact generalization rates include (a) uncertainty about the probabilities of association of a certain conjugational pattern with the suffix vowel, which is due to the fact that the interlanguage system is not stabilized; and (b) a small lexicon, which constrains the use of analogies based on phonological associations. All this should potentially lead to non-native rule weights in L2 processing.

Several claims will be tested:

1. Type frequency influences generalization rates in native language (L1) novel verb production.
2. Type frequency and the number of uses influence generalization rates in second language (L2) novel verb production.
3. The influence of type frequency is constrained by the rule complexity factor, which refers to stem allomorphy.
4. The number of uses parameter affects reaction times in L1 perception of visually presented stimuli in a lexical decision task.
5. The frequency effects refer to rules or “complex” analogies, but not to “simple” analogies emerging from direct phonological mappings.

\(^2\) The absence of references to Probabilistic Linguistics in Yang’s book (Yang 2002) suggests that his Rule Competition Model was also developed without the influence of thereof.
2. Russian Verb System

This section will briefly review some basic facts about the Russian verb system with focus on the features and verb classes, which will be relevant for the actual data analysis and interpretation. According to the one-stem verb system (Jakobson 1948), Russian has 11 verb classes, each with its own suffix, or verbal classifier. The eleventh class has a zero suffix, and is subdivided into smaller subclasses depending on the quality of the root-final consonant. This is a small class, especially given the variety of conjugational patterns it includes, and there are well under 100 basic stems in it (Townsend 1975). The conjugational patterns of some of the subclass-classes of the non-suffixed stems have idiosyncratic features in their stem allomorphy, and thus form verb clusters, which can be compared to the neighborhoods of English irregular verbs and characterized by the minor rules. The remaining 10 suffixed classes are identified by the suffix: -aj-, -ej-, -a-, -e-, -i-, -o-, -ova-, -avaj, -nu- (including the “disappearing –nu”), and -zh-. The suffix determines all the parameters of the conjugational paradigm, including the choice of the thematic vowel in the inflections (1st or 2nd conjugation), and different types of stem changes (see Table 1). When the endings are added to the stem (which includes the optional prefix, the root, and the suffix), an automatic truncation rule works at the juncture of the stem and the ending.

Overall, the Russian verb system possesses the following features:

- Numerous verb classes;
- Developed conjugational paradigm;
- No sharp division between regular and irregular classes;
- Several regular classes in addition to default;
- Infinitives of many verb classes have unrecoverable stems due to the truncation of the stem-final consonant before consonantal endings.

Table 1 lists the morphological processes shaping the conjugational patterns of the stems chosen for Experiments 1 and 2. It does not include automatic consonant or vowel truncation, which occurs at the juncture of the stem and the ending. In Experiment 3, only five stems were used: the -aj-, -a-, -i-, -e-, and -ova-. The table also provides the information on stem productivity.

Figure 1 represents two kinds of data, type frequencies of all the verb stems included in the experiments (based on Zalizniak 1980), and the number of uses for these verb stems in L2 input. This L2 input was computed specifically for the

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1 The consonant “zh” represents any palatal consonant—a hushing or “j”—and is not part of the suffix.

2 The observed L2 type frequencies were so small compared to the native type frequencies that they could not be represented on the same chart. The ranking of verb classes based on L2 type frequency is the same as in the presented number of uses data. Importantly, however, the
American students taking part in Experiment 2 based on the instructional materials used in the classroom. With regard to type frequencies in Russian language, one can see that the productive classes –aj-, -i-, and –ova are the largest ones. The productive -ej- class has a much lower type frequency, and it is bypassed by the unproductive –a- class. If the Free-Rider Effect is operational in Russian verbal morphology, and the “Vowel+j” pattern indeed represents an abstract rule, then the generalization rates for the –ej- stem can be expected to be higher than the type frequency of the –ej- class predicts that.

<table>
<thead>
<tr>
<th>Verb classes and sub-classes</th>
<th>-aj- Prod.</th>
<th>-a- Prod.</th>
<th>-ej- Prod.</th>
<th>-e- Prod.</th>
<th>(i)j- Prod.</th>
<th>-i- Prod.</th>
<th>-ova- Prod.</th>
<th>-avaj- (o)j-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consonant</td>
<td>√</td>
<td>√</td>
<td></td>
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<tr>
<td>Mutation</td>
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<tr>
<td>Stress shift&lt;sup&gt;5&lt;/sup&gt;</td>
<td>√</td>
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<td></td>
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<tr>
<td>Suffix alteration</td>
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<tr>
<td>Vowel alteration</td>
<td>√</td>
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<tr>
<td>Vowel deletion</td>
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</tbody>
</table>

Table 1. Non-automatic processes in the stems included in the experiments

The chart shows that in general the ranking of the number of uses for different verb classes in the L2 input corresponds to the type frequencies in Russian. At the same time, in the L2 input one observes the leveling of differences between the verb classes, and also the fact that some classes were poorly represented, e.g., there were no –ej- verbs and very few –ova- verbs in the L2 input. One can predict that the leveling of differences between the verb classes will lead to less pronounced frequency effects and less reliance on the default in L2 processing.

<sup>5</sup>The (i)j- and (o)j- stems are the sub-classes of zero-suffixed stems, each of them has an idiosyncratic (“irregular”) feature in the conjugational pattern.

<sup>6</sup>This paper does not discuss stress shifts in the obtained data. Unlike all the other morphological processes that can be predicted given the verb stem, stress shifts need to be lexically encoded. However, the pattern of stress shift within the paradigm is fixed.
What will follow outlines a processing-based analysis of the Russian verb system, which represents an attempt to integrate the one-stem verb system approach with a psycholinguistic mechanism underlying verbal processing. Given that the -ova- suffix mutates to -uj- in the non-past tense, the 9 stems can be divided in two types—those that have the “Vowel+j” pattern (-aj-, -ej-, (i)j-, -ova-, -avaj-, and (o)j-), and those that use the “Vowel+ø” pattern (-a-, -e-, and -i-). The verbs chosen for the verb generation tasks include 6 “paired” stems differing by the absence or presence of the final “j”. Among those, the -aj- and -ej- stems belong to the productive, regular, default conjugational pattern, while the -a- and -e- stems belong to the small unproductive patterns characterized by a developed stem allomorphy. The situation is reversed in the -i-/(i)j- pair, where the -i- class is productive, while the (i)j- sub-class of non-suffixed verbs has only 7 basic stems in it. Therefore, one can represent the Russian verb system as two major conjugation types, the “Vowel+j” and the “Vowel+ø”, plus several additional conjugation types, including one productive class, the -ova-. In this view, the probability of the individual verb belonging to one or the other major conjugation type is defined by the suffix vowel. This ultimately means that depending on whether the unit of storage is the basic stem and/or the infinitive, the vowel either appears as part of the suffix (or the root

Figure 1. Type frequencies for the Russian verbs and the number of uses in the L2 input
in non-suffixed stems) in the basic stem, or as the rhyme vowel in the infinitive. This happens because of the automatic consonant truncation in the infinitive:

-aj-: chit-aj- + -t' = chit' (“to read”)

-a-: pis-a- + -t' = pisat' (“to write”)

In the above examples, the infinitives of two verbs belonging to different verb classes and major conjugation types, the default “Vowel+j” -aj- class and the small unproductive “Vowel+ø” -a- class, both end in -at’, but the underlying basic stems are different. This prompts the hypothesis that a Russian speaker when dealing with a novel infinitive ending in -at’ will process it as an -aj- stem with a much higher probability than an -a- stem. Thus, in the “paired” stems, the probability that a certain pattern will be selected can be predicted as follows:

<table>
<thead>
<tr>
<th>Infinitive Rhyme</th>
<th>Verb Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>-at’</td>
<td>Very likely –aj-, unlikely –a-</td>
</tr>
<tr>
<td>-et’</td>
<td>Likely –ej-, unlikely –e-</td>
</tr>
<tr>
<td>-it’</td>
<td>Very unlikely (i)j-, very likely –i-</td>
</tr>
</tbody>
</table>

At the same time, for the last pair of stems, we can expect the Free-Rider Effect to enhance the chances that the unproductive (ij)- pattern, which mirrors the default pattern, will be selected for the novel infinitive ending in -it’. Moreover, the competing -i- pattern involves stem allomorphy and potential lexicalized processes, such as stress shifts, and therefore, more complex processing rules than the default “Vowel+j” pattern. If stem allomorphy were to influence the choice of the conjugational pattern, then the -i- stem would be at a disadvantage. For the non-suffixed (oj)- stem whose infinitive ends in -yt’, the prediction based on its low type frequency (only 5 basic stems) is that the pattern using the basic (o)j- stem allomorph would not be applied. Therefore, for this stem the likely choice would be the default “Vowel+j” pattern. However, the *-yj- pattern with the “y” vowel in the infinitive is illegal in Russian. If it were used by Russian speakers when processing novel verbs, then this would support the claim that the default pattern in Russian is indeed the “Vowel+j” pattern, and more importantly, that the use of the pattern relies on an abstract category “Vowel” and thus is symbolic rule-based rather than simple analogy-based.

Experiments 1 and 2 tested these predictions and addressed the issue whether novel verb generation shows type frequency effects. Experiment 3 tested a different prediction, namely, that the higher the frequency of the inflectional rule, the faster the inflected form is accessed/decomposed in a lexical decision task with visually presented stimuli. Experiment 3 was based on the existing notion that the number of uses of the 2nd person singular in Russian oral and written speech is lower than the
use of the 3rd person singular. The following sections will briefly report the findings of the three experiments.

3. Experiment 1: Verb generation by adult L1 speakers

Since both Experiments 1 and 2 are described in detail in a previous publication (Chernigovskaya, Gor 2000), for the lack of space we will provide a short summary of the material and methods, and focus mostly on the reanalysis of the obtained results. The experiment was conducted at St. Petersburg State University, Russia, with 27 adult native speakers. It was conducted orally and individually with each subject, and recorded on audiotape. The testing material included 48 nonce verbs that were created by manipulating the initial segments, in most cases, the initial consonants in 48 existing Russian verbs. The existing 48 verbs belonged to 9 classes and sub-classes based on Jakobson’s one-stem verb system: -aj-, -ej-, (i)j-, (o)j-, -a-, -e-, -i-, -ova-, -avaj- (see Table 1). All the verb classes included in the testing material, except for two, belong to the suffixed stems. Two stems, (i)j- and (o)j-, belong to non-suffixed stems ending in –j and differing by the root vowel (these are the subclasses of non-suffixed stems). The number of verbs in each class varied from 2 for very small (i)j- and (o)j- subclasses to 6-8 in other classes. The verbal stimuli were in the past tense plural form. Subjects were asked to generate the non-past 3rd person plural and 1st person singular forms of the verbal stimuli. All the verbs were embedded in simple carrying sentences, which together with follow-up questions formed a quasi-dialogue:

Experiment: Yesterday they ______. And what are they doing today?

Subject: Today they ______.

Experiment: And you?

Subject: Today I ______.

The percentages of stem recognition show the effect of type frequency on the rates of stem recognition:

• The rates of stem recognition were very high for the –aj- and –ej- stems.
• The –aj- and –ej- patterns were generalized to the –a- and –e- stems.
• However, for the last pair of stems, the (i)j- and –i-, the prediction based on the high type frequency of the –i- pattern is not borne out—both the (i)j- and –i-

7 This elicitation technique is based on the adaptation of the instrument developed by Bybee and Slobin (1982) used in the studies of child L1 acquisition of Norwegian, Icelandic (Ragnasdóttir, Simonsen and Plunkett, 1997), and Italian (Matcovich 1998).
patterns get rather low rates of stem recognition and both patterns are used equally often in response to each stem.

- The productive high-frequency –ova- stem had higher rates of stem recognition than the low-frequency unproductive –avaj- stem.
- The low-frequency unproductive (o)j- stem was not recognized as such, in half of the responses it was conjugated using the *-yj- pattern illegal in Russian.

All these results, which evoke the effect of type frequency defined for the verb stems, support the claim that rules or "complex" analogies have probabilities in native processing. The facts that the “Vowel+j” pattern shows the Free-Rider Effect, predicted by Yang, for the –ej- and (i)j- stems, and that native Russians use the *-yj- pattern illegal in Russian in their responses indicate that it is indeed an abstract rule or "complex" analogy that is at works. “Simple” analogy-based processing would have produced a different effect—lower generalization rates for the –ej- stem, practically zero generalization rates for the (i)j- stem⁹, and no responses using the illegal *-yj- pattern.

4. Experiment 2: Verb generation by L2 learners

Experiment 2 sought to demonstrate that L2 processing, similarly to adult L1 processing, is rule-governed rather than analogy-based and it is influenced by the frequency of the rule. At the same time, it hypothesized a fundamental difference between native and L2 morphological processing, namely, that for native speakers the probability of a certain inflectional pattern for an existing word is close to either 100% or 0%, depending on whether it is correct or not. For L2 learners, however, these probabilities are not set and fluctuate between 100% and 0%. In this respect, L2 processing is comparable to child L1 processing. The experimental procedure was exactly the same as in Experiment 1. 15 volunteer students, who had completed one year of intensive Russian at the University of Maryland, took part in Experiment 2. The material consisted of 48 real Russian verbs, which were manipulated to create the set of nonce verbs for Experiment 1 with Russian speakers.

The experiment compared two sets of data on input frequencies to our L2 learners, type frequency and the number of uses, with the collapsed data on their rates of stem recognition and generalization. Given the leveling of differences in class size in the non-native input, one could expect less generalizations of high type frequency classes to small classes and less reliance on the default pattern in L2 processing. And indeed, the results obtained for beginning adult American learners

⁹Note that the (i)j- pattern involves a rare feature—root vowel deletion—in the non-past paradigm. If the generalization of this pattern to the –i- stem were analogy-based, one could expect this feature to carry over to the verb forms generated using the (i)j- pattern. However, such vowel deletion was never present, which is another argument in support of rule-based processing.
of Russian were similar to the ones obtained for native Russians; e.g., in the “paired” –aj/-a- stems, the “Vowel+j” pattern is dominant. At the same time, a closer comparison of the native and L2 sets of data reveal significant differences. Several aspects of L2 processing are less dominated by the default pattern: First, L2 stem recognition rates for the –aj- and –ej- stems are lower, and for the –a- and –e- stems higher than in native speakers. Second, the high rates of stem recognition for the –i- stem show that L2 speakers were less dominated by the default in their choice of the “Vowel+ø” pattern as were the native speakers. And finally, the rates of the use of the *-yj- pattern are lower in L2 speakers. One can hypothesize that the reduced role of the default pattern is due to the less pronounced differences between class sizes and the resulting diminished role of default in L2 input. L2 processing showed a strong Free-Rider Effect that manifested itself in the high stem recognition and generalization rates for the (ij)–, and especially, the –ej- stem despite the fact that there were no –ej- verbs in their active vocabulary.

Therefore, we have observed two important features of L2 processing. First, the leveling of type frequencies in the reduced L2 input leads to the weakening of the role of the default. And second, L2 processing is characterized by insufficient control of the probability that a conjugational pattern will be used with a particular rhyme vowel, which leads to a strong Free-Rider Effect. If we apply the same arguments to the L2 data as the ones we applied above to the L1 data, then we need to admit that L2 processing relied on rules rather than analogies. An additional argument in favor of rule-based processing is the fact that beginning learners know so few L2 verbs that it is less likely that they would be influenced by phonological similarity to other verbs.

And finally, Experiment 2 with adult American learners of Russian explored the applicability of the Rule Competition Model (Yang 2002) to L2 acquisition. It tested whether L2 learners have a variational system of inflectional rules, which is shaped by the input frequencies to L2 learner. In this understanding, conjugational patterns have weights, which reflect their frequency of use in the input to L2 learner. And indeed, the experimental data support this hypothesis. At the same time, the Rules and Probabilities mechanism that we have observed in native adults is not fully developed in L2 learners.

5. Experiment 3: Lexical Decision Task with adult native speakers of Russian

This experiment aimed to test the hypothesis that the frequency of the rule required to generate the particular verb form in the conjugational paradigm influences the speed of access/decomposition of the inflected verb forms and, consequently, reaction times (RTs) in a Lexical Decision Task (LDT). It compares the RTs to three verb forms—the infinitive, 2nd person singular, and 3rd person singular non-past tense. All the three forms including the infinitive are inflected in Russian. The infinitive is a citation form, while the 2nd person singular and 3rd
person plural involve the same morphological processes, and differ only in the inflection. However, the 2nd person singular has a lower frequency in Russian speech, oral or written, than the 3rd person plural and infinitive. It should be noted, that the number of uses or the frequency of use (Yang’s term) is more accurate in reference to the verb form frequency within the conjugational paradigm than the type frequency parameter.

5.1. Experimental procedure and material

The experiment used the PsyScope software on a Macintosh platform. The stimuli were visually presented to the subjects, and appeared on the monitor in random order. The task of the subject was to press the red or green button on the button-box depending on whether they thought the stimulus was a word or non-word. 8 adult native Russian participants, unpaid volunteers, took part in the experiment. The material (N=480) consisted of:

- Real Russian verbs belonging to 5 classes (N=150): -aj-, -a-, -i-, -e-, -ova-
  In each of the 5 classes—5 frequent (10-25 per million) and 5 rare (less than 1 per million) verbs
  Each verb in 3 forms: Infinitive, 2nd person singular, 3rd person plural
- Matching nonce verbs (N=150)
- Fillers—real Russian nouns (N=90)
  15 frequent (10-25 per million), 15 rare (less than 1 per million)
  Each noun in 3 forms: Nominative singular, Dative plural, Instrumental singular
- Matching nonce nouns (N=90)

The verb frequency was determined based on the Online Queryable Tuebingen Russian Corpora, which contain the Uppsala Corpus of modern Russian texts with 1 million word forms.

5.2. Results of Experiment 3

The first result of this experiment is in conformity with the general understanding that high-frequency lexical items are easier and/or faster to retrieve than low-frequency items. And indeed, for all the stems the RTs to the real frequent verbs were shorter than to the real rare verbs, with RTs to the nonce verbs closer to
the real rare verbs (see Figure 2). At the same time, the obtained results indicate that the frequency data on the stimuli used in the experiment were accurate.

![Bar chart showing reaction times (RTs) for frequent, rare, and nonce verbs in the LDT experiment.](chart.png)

**Figure 2.** Reaction times to the frequent, rare, and nonce verbs in the LDT experiment

The main goal of Experiment 3, however, was to demonstrate that the speed of access/decomposition of an inflected verb form in a LDT depends on the frequency of the inflectional pattern. Figure 3 demonstrates that indeed the RTs to the 2nd person singular verbs are longer than to the infinitives in both frequent and rare verbs, and longer than to the 3rd person singular in frequent verbs. In frequent verbs, all the three types of verb forms, infinitives, 3rd and 2nd person singular, are differentiated by the reaction times. Therefore, the results of the experiment confirm the initial hypothesis that the number of uses of a verb form in a conjugational pattern, or in other words, the frequency of the rule or “complex” analogy involved in the generation of the inflected verb form, has an effect on the speed of access/decomposition of the verb form. In our case, the (de)composition of the 2nd and 3rd person singular non-past tense forms of the verb require exactly the same morphological processes, such as possible vowel truncation, consonant mutation, stress shift, and suffix or vowel alternation. The only difference between them is the inflection itself.
6. Discussion and conclusions

The results of the three experiments discussed above suggest that the frequency of the pattern exerted an influence both on adult L1 generation of novel verbs and on reaction times in a lexical decision task. Therefore, one can conclude that input frequencies played a role both on the level of production and of perception. The data on L2 generation of novel verbs also showed the effect of input frequencies on generalization rates. This section will discuss the reported findings with focus on the issue of whether the patterns that showed frequency effects in L1 and L2 morphological processing are rule- or analogy-based. If we recur to the previously used argumentation, the one-dimensional dichotomy of rule versus analogy may in
fact be less meaningful than the juxtaposition of rules and complex analogies on the one hand, and simple analogies on the other.

Experiment 1 demonstrated the role of type frequency in native generation of novel verbs. Its results highlight the importance of a psycholinguistically valid description of the Russian verb system, and more generally, of research into the psycholinguistic reality of linguistic descriptions. Overall, the obtained results are more compatible with the description of Russian verbal morphology, which organizes verb classes into rule-based conjugational patterns. Thus, the fact that the high-frequency productive –aj- pattern was generalized to the low-frequency unproductive –a- class can be accommodated both by the description in terms of 11 verb classes (the one-stem verb system approach), and by the one proposed in this paper. This latter description combines the stems into the broader “Vowel+j” and “Vowel+ø” patterns and consequently eliminates the phonologically-justified distinctions between some classes, e.g., the distinction between the –aj- and –ej- classes both belonging to the “Vowel+j” pattern. At the same time, the relatively high generalization rates for the –ej- stem and even for the (i)j- stem fit better within the rule-based “Vowel+j” description. If we apply the Rule Competition Model (Yang 2002) to these data, the Free-Rider Effect will account for the observed response pattern. However, the Rule Competition Model, which handles the competing grammars in a linguistically developing child, does not deal with a stabilized native adult grammar. Consequently, it cannot handle the fact that in native adult novel verb generation the probability that a certain rule-based pattern will be applied depends on its frequency. This is why the Rules and Probabilities Model proposed in this paper is more appropriate in dealing with adult native data. Since the “Vowel+j” and “Vowel+ø” conjugational patterns do not depend on phonological associations, because the potential source of phonological associations, the vowel of the suffix, is not specified, one can claim that it is the probability of the abstract rule that is at work. The generalization rates for the (i)j/-i- pair of stems also support the argument that the frequency of phonological mappings alone cannot account for the obtained responses. Indeed, based solely on the high frequency and productivity of the –i- stem, one could expect a considerably higher generalization rate than the one actually obtained in the experiment. This relatively low generalization rate combined with a high generalization rate for the (i)j- stem indicates that the probabilities of the abstract rules “Vowel+j” and “Vowel+ø” take precedence over the simple analogy-based probabilities9.

9 For Russian verbs, the role of input frequency is not limited to the frequency of the major conjugational patterns, the “Vowel+j” and “Vowel+ø”, but also includes the probabilities of the association of each pattern with the particular suffix vowel, which appears as the rhyme vowel of the infinitive. In this sense, the probabilities of phonological associations interact with the rule-based probabilities. It remains to be seen whether the vowel of the suffix is part of rule-based or analogical processes. As always, this evokes the controversial status of morphology versus phonology in linguistic processing.
The results of Experiment 2 extend the Rule Competition Model (Yang 2002) to adult L2 verbal processing. The good fit of the Rule Competition Model to the L2 data was to be expected, since child L1 and adult L2 linguistic processing have several important features in common. Thus, both child L1 and adult L2 acquisition are dynamic in nature, are characterized by the limited input, and as a result, by the absence of direct access to native linguistic probabilities, and limited control of the rules. However, it may be the case that L2 verb generation, in fact, shows two different kinds of rule variability. The first kind is of the same nature as variability in child L1 processing, and has to do with the (a) linguistic system in the process of development with several co-existing grammars leading to a competition among different rules. The second kind of rule variability is a reflection of the rule probabilities observed in native adult verbal processing, which were discussed above in reference to Experiment 1. One major difference between native and L2 processing arises from the leveling of differences between the probabilities of the conjugational rules associated with verb classes resulting from the limited L2 input. This leveling of differences leads to a reduced role of the default pattern and a stronger Free-Rider Effect in L2 processing. Additional research is needed to disentangle these two aspects of rule probabilities in L2 speakers and to establish whether both the Rules and Probabilities Model and the Rule Competition Model have separate roles in accounting for the L2 data, or the Rule Competition Model can handle all the observed effects.

Experiment 3 demonstrated that the frequency of the conjugational pattern affects the speed of access and/or decomposition in a lexical decision task performed by adult native speakers. The differences in RTs to 2nd and 3rd person singular and infinitive verb forms reflected the frequency of these forms in speech: the more frequent the form, the less time was needed to decide whether it was a word or non-word. This effect remained relatively stable across the different verb classes, which suggests that it was the frequency of the inflectional rule that affected the latencies. If we compare the status of the three tested inflections with the status of the past-tense –ed inflection in English, they show even stronger properties of rule-based processing. The use of these inflections occurs almost without exceptions and does not depend on any phonological associations. Therefore, one can hypothesize that we are dealing with rule-based or complex analogy-based frequency effects, and not simple analogy-based ones.

Finally, in conclusion, the reported results found support for the claim that input frequencies affect both adult L1 and L2 processing of complex verbal morphology. The study addressed the issue of whether the observed role of probabilities refers to rule-based or analogical processing. It introduced a distinction between simple and complex analogies with the latter including an abstract level and thus having the properties of rules. The analysis of the data on the processing of Russian verbal

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10 In the non-past tense, the 2nd and 3rd person inflections appear in two allomorphs with different thematic vowels, which correspond to the 1st and 2nd conjugational types.
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morphology suggests that the response pattern in different experiments fits better with the interpretation in terms of rules or complex analogies. Simple analogies based on phonological similarity did not affect the response pattern. Thus, the study demonstrated that rules are applied with probabilities based on the input frequencies. It further extended the Rule Competition Model (Yang 2002) to L2 verbal processing and proposed the Rules and Probabilities Model to account for the results obtained for adult native speakers.

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