Explaining Prefix Contributions in Russian Using Frame Semantics and RSA

Yulia Zinova(✉)

Heinrich Heine University, Düsseldorf, Germany
zinova@phil.hhu.de

Abstract. Variability in the interpretation of Russian verbal prefixes is traditionally regarded as an issue of lexical semantics. Grammars and dictionaries list different usages that are possible for each prefix without explaining when and why particular usages are realised. For a limited amount of prefixed verbs further information can be found in the dictionaries, but often even this is not enough for a precise interpretation. In Zinova (2017) I proposed a Frame semantic analysis that allows to compositionally construct the meaning of a complex verb. In this paper I make a further step towards a computational account of the pragmatic component of the system that would allow to predict the final interpretation of a given verb. I claim that the competition between various verbs derived from the same stem is an important part of the prefixation system that ensures its flexibility and leads to what on the surface looks like lexical ambiguity. The final interpretation of a verb depends on the availability of alternative expressions.

Keywords: Russian · Frame Semantics · Lexical semantics · Pragmatic competition · RSA · Verbal prefixation

1 Introduction

Russian verbal derivational morphology is extremely rich. One stem can serve as a base for deriving hundreds of verbs via prefixation and suffixation. This is due to the large number of prefixes (Švedova 1982, p. 353 lists 28, most of them have productive usages) as well as their polysemy (e.g., the prefix *pere-* has 10 usages according to Švedova 1982, pp. 363–364), and the possibility of stacking. In addition to this, at some stages of the derivation (once per derivation) the imperfective suffix can be attached to the verb. As only a small part of all possible complex verbs is present in the dictionaries, a computational approach is necessary in order to predict the existence and properties of complex verbs.

In Zinova (2017) I have proposed an account that provides a basis for such an approach. It is based on Frame Semantics (Fillmore 1982) in combination with Tree Adjoining Grammars (Joshi 1985, 1987; Joshi and Schabes 1997) as formalized in Kallmeyer and Osswald (2013). In this framework I model the derivation of complex verbs. The key feature of a Frame Semantics–TAG combination is that it allows for a semantically driven analysis of derivational morphology paired with a high decomposition level. An important property of the approach offered in Zinova (2017) is underspecification of prefix contributions. Most of it is then resolved when the prefix is combined

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with the verbal stem, but the resulting interpretation is often not as precise as the one listed in the dictionaries. In this paper I show some cases when such a mismatch is observed and propose how this gap can be put in place by using pragmatic competition between various verbs. In particular, I claim that whenever the general meaning of the prefix is underspecified, the interpretation of a particular verb gets settled in the optimal way. With respect to the prefixation system this means that for the range of the prefixed verbs derived form one root their interpretation is adjusted in a way that allows to most efficiently cover the range of meanings a speaker may want to express.

I propose to use underspecified semantics and probabilistic pragmatic modelling to explain the flexibility of prefix contributions in combination with distinct stems. The main idea behind this proposal is inspired by game theory and optimality theory principles: whenever the semantics of two or more lexical items (prefixed verbs formed from the same stem in our case) overlaps, their usage gets restricted in such a way that the uncertainty of the listener is minimized. This line of reasoning follows the recent research on vague language usage, see, e.g., van Deemter (2009) and references therein.

The rest of the paper is structured as follows: in Sect. 2 I provide data that evidences the competition in Russian verbal prefixation system in general. In Sect. 3 a particular example (four perfective verbs derived from the base verb *zimovat'* 'to spend winter time') is considered: I provide frame representations for the respective components and show how they are combined in order to obtain the representations of the complex verbs. In Sect. 4 I show how pragmatic competition functions when the information from the frame representations is transferred to the pragmatic competition module.

2 Competition Within the Prefixation System

Let us start by considering three Russian verbal prefixes: *na-, po-*, and *pere-*. When a large enough set of data is analysed (as is done, e.g., in Kagan 2015 or Zinova 2017), one comes to the following conclusion with respect to the semantics of the verbs derived using these prefixes.

1. Verbs prefixed with *na-* or *po-* can refer to events that culminate when the expected/standard degree is reached.
2. Verbs prefixed with *na-* can denote events that culminate at the degree higher than the expected degree.
3. Verbs prefixed with *po-* may refer to events that culminate without reaching the standard degree.
4. Verbs prefixed with *pere-* denote events that culminate at or above the standard degree.

When a *pere*-prefixed verb denotes an event that culminates above the standard degree, the usage of the prefix is called *excessive*. Let us consider verbs that contain the prefix *pere-* in such a usage. It turns out that there is always another verb derived from the same base, that is used as a neutral perfective. Under *neutral perfective* I mean either a verb that refers to an action performed until the normal/standard/appropriate degree,[1]

[1] These verbs would constitute aspectual pairs with the imperfective source verbs on the pair-based accounts of Russian verbal system. Janda (2007) calls such verbs Natural Perfectives.

or a verb that denotes an action that lasted for some non-specified time.[2] For example, if the verb *gret'* 'to heat' is prefixed with *pere-*, the resulting verb *peregret'* means 'to overheat'. The same verb can be prefixed with *na-* and the resulting verb *nagret'* means 'to warm up (until the desired temperature)'. In addition, the verb *pogret'* 'to heat' means warming up without necessarily reaching some particular temperature. In this case both *nagret'* 'to warm up' and *pogret'* 'to heat' are neutral perfectives, only with respect to different scales. More pairs and triples are provided in the Table 1. Let us explore them.

Table 1. Distribution of excess-denoting and neutral perfectives across verbal bases and prefixes

Source verb	Translation	"Excess"	Neutral	Other competing verbs
zanimat'sja	'to study'	*perezanimat'sja*	*pozanimat'sja*	
platit'	'to pay'	*pereplatit'*	*zaplatit'*	*oplatit'*$_{trans}$ 'to pay for smth'
rabotat'	'to work'	*pererabotat'*	*porabotat'*	*otrabotat'*$_{trans}$ 'to work in compensation of smth'
xvalit'	'to praise'	*perexvalit'*	*poxvalit'*	
žarit'	'to fry'	*perežarit'*	*požarit'*	*prožarit'* 'to fry thoroughly,' *nažarit'* 'to fry a lot of'
gret'	'to heat'	*peregret'*	*nagret'*	*pogret'* 'to heat,' *progret'* 'to heat through'
kormit'	'to feed'	*perekormit'*	*nakormit'*	*pokormit'* 'to feed'
trenirovat'	'to train'	*peretrenirovat'*	*natrenirovat'*	*potrenirovat'* 'to train for some time'

The upper third of the table contains three intransitive verbs. The prefix that is used to form a neutral perfective depends on the scale lexicalized by the verb. If there is no scale except for the time scale, the prefix *po-* is used. If there is a scale that allows for the attachment of the resultative *za-*, it may be the option. The lines in the middle third of the table are occupied by two transitive verbs that denote events that are by default measured according to these verbs' internal scales and do not rely on the information coming from the verbal arguments. These verbs form neutral perfectives using the prefix *po-*. In the bottom third the other type of transitive verbs is represented: for them the standard is determined for the pairs of event types and undergoers. In such a case it is the *na*-prefixed verb that refers to the situation of reaching the standard. The attachment

[2] Such verbs fall in the Complex Act Perfectives class in the account by Janda (2007).

of the prefix *po-* is also possible, but now the *po*-prefixed verbs tend to refer to events in course of which the standard value is not reached.

What we see is that even if the range of prefixes that two verbs can attach is the same, as for the verbs *žarit'* 'to fry' and *gret'* 'to heat', the semantic contribution of these prefixes may be different. While both *perežarit'* 'to burn by frying' and *peregret'* 'to overheat' have the meaning of excess, the role of the prefix *na-* in the verbs *nažarit'* 'to fry a lot of' and *nagret'* 'to heat' seems to be not the same. In what follows we will explore and fully model a particular example that will allow to shed some light on how these differences in the final semantic contribution can be explained using pragmatic competition principles.

3 Proposal

3.1 Data

Let us discuss and model a rather simple and clear example. Consider the verb *zimovat'* 'to spend winter time'. The OSLIN database[3] of verbal aspect provides the following list of the verbs derived from it: *vyzimovat'* 'to survive the winter' (usually about the plants), *dozimovat'* 'to spend the rest of the winter', *zazimovat'* 'to stay for the winter', *otzimovat'* 'to finish spending the winter', *perezimovat'* 'to spend the winter', *pozimovat'* 'to spend some winter time', *prozimovat'* 'to spend the winter time'.

However, out of these seven verbs only four are commonly used in contemporary texts, as evidenced by the data in Russian National Corpora[4]. These are (1) *pozimovat'* 'to spend some winter time' that describes a finished event of staying in some particular place without imposing further restrictions on the start and the end of the stay, ex. (1); (2) *zazimovat'* 'to stay for the winter' that establishes a connection between the start of staying somewhere and the beginning of the winter, ex. (2); (3) *dozimovat'* 'to spend the rest of the winter' that fixes the end point of the stay to be the end of the winter, ex. (3); and (4) *perezimovat'* 'to spend the winter' that relates both the start and the end points of the stay to the beginning and the end of the winter, respectively, ex. (4).

(1) Ix by k nam na severa, čtoby pozimovali v svoix kartočnyx
they to us on north.PL.PREP, that po.winter.PST.PL in their card
domikax.
house.PL.PREP
'I would like to see them spending winter time here in the north in their houses of cards.' (doskapozorakomi.ru)

(2) Èkspedicija zazimovala na Novoj Zemle.
expedition.SG.NOM za.winter.PST.SG.F on Novaya Zemlya
'The expedition stayed on the Novaya Zemlya for the winter.' (Ušakov 1940)

[3] Open Source Lexical Information Network, available online at http://ru.oslin.org/index.php?action=aspect.

[4] Available online at ruscorpora.ru.

(3) Dozimuem na korable vo l'dax.
do.winter.PRES.PL.1 on ship in ice.PL.PREP
'We will spend the rest of the winter on a ship in the ices.' (Ušakov 1940)

(4) Perezimovat' v derevne.
pere.winter.INF in village.SG.PREP
'To spend the winter in a village.' (Ušakov 1940)

What is special about the verb *zimovat'* 'to spend winter time' and makes this case more transparent than the others is that it (1) refers to a specific scale – the scale of spending winter time and that (2) this scale has a clear structure: it is a closed scale with two distinguished points (winter start and winter end). Due to this, a natural set of situations that one may want to refer to with respect to spending winter time contains four elements (Table 2):

1. spending one whole winter (t_1);
2. spending an initial part of the winter (t_2);
3. spending a final part of the winter (t_3);
4. spending some time of the winter without bounding the event duration to the duration of the winter (t_4).

Table 2. The domain of terminated events related to spending the winter

	event start = winter start	event end = winter end
t_1	+	+
t_2	+	–
t_3	–	+
t_4	–	–

Note that the four perfective verbs that are related to spending winter time situations cover the corresponding domain of the events. One possible explanation would be that selected prefixes refer exactly to the corresponding configurations. The other option that I argue for in this paper is that the contribution of prefixes is broader and gets restricted and shaped to cover the situations a speaker may naturally want to refer to.

3.2 Frame Semantic Representations

The idea of using frame representations in linguistic semantics and cognitive psychology has been put forward by Fillmore (1982) and Barsalou (1992), among others. The main ideas that motivate the use of frames as a general semantic and conceptual representation format can be summarized as follows (cf. Löbner 2014):

– conceptual-semantic entities can be described by types and attributes;
– attributes are functional relations, i.e., each attribute assigns a unique value to its carrier;

– attribute values can be also characterized by types and attributes (recursion);
– attribute values may be connected by additional relational constraints (Barsalou 1992) such as spatial configurations or ordering relations.

A number of recent studies offer further formalization of the frame theory (Petersen 2007; Petersen and Osswald 2009; Kallmeyer and Osswald 2012, 2013; Kallmeyer et al. 2015; Löebner 2014, among others). This paper is based on the formalization provided in Kallmeyer and Osswald 2013. Frames in the sense of Kallmeyer and Osswald (2013) are finite relational structures in which attributes correspond to functional relations. The members of the underlying set are referred to as the *nodes* of the frame.

$$\mathbf{e}\begin{bmatrix} \text{process} & \\ \text{MANNER} & [\text{spend-time} \wedge \text{winter}] \\ \text{ACTOR} & \\ \text{M-DIM} & \begin{bmatrix} \text{closed-scale} & \\ \text{MIN} & [\text{winter-start}] \\ \text{MAX} & [\text{winter-end}] \end{bmatrix} \end{bmatrix}$$

Fig. 1. Frame representation of the verb *zimovat'* 'to spend winter time'

An important restriction is that any frame must have a *functional backbone*. This means that every node has to be accessible via attributes from at least one of the *base nodes*: nodes that carry *base labels*. Importantly, feature structures may have multiple base nodes. In such a case often some nodes that are accessible from different base nodes are connected by a relation. Base labels serve as unique identifiers, that is, a given base label cannot be assigned to more than one node. Due to the functional backbone requirement, every node of the frame can be addressed by a base label plus a (possibly empty) finite sequence of attributes.

Let us start with a frame representation of the base verb *zimovat'* 'to spend winter time'. As shown on Fig. 1, this verb refers to a process (the type of the hole frame with the base node **e**). It has three attributes: MANNER that is of type *spend-time* $\wedge$ *winter*, ACTOR, and a measure dimension that is of type *closed-scale* and has the start of the winter as its minimum point and the end of the winter as its maximum point.[5]

Now we will explore the semantics of the four prefixes that are used to derive verbs from the *zimovat'* 'to spend winter time' stem: *po-*, *pere-*, *do-*, and *za-*. The contribution of the prefix *po-* can be represented by the frame on the left side of Fig. 2 (following Zinova 2017). This frame encodes the following information: first, the type of the frame

[5] Please note that representing the contribution of the base verb is not the primary goal of this paper and there may be better and more accurate solutions for this.

is *bounded-event*; second, the measure dimension of the event (M-DIM) is of type *scale*;[6] third, the event has an initial (INIT) and a final (FIN) stages that are associated with some degrees. It is left implicit that these degrees have to be degrees on the scale that is the measure dimension of the event. Overall, this is a highly underspecified representation that reflects that the prefix *po-* contributes a rather limited amount of information. While it is often considered that *po-* has an additional delimitative usage that allows to derive interpretations related to small quantity or time (Filip 2000; Kagan 2015), I claim that it is not necessary to postulate in in addition to the proposed semantic representation, as in what follows we will derive such a contribution via pragmatic competition.

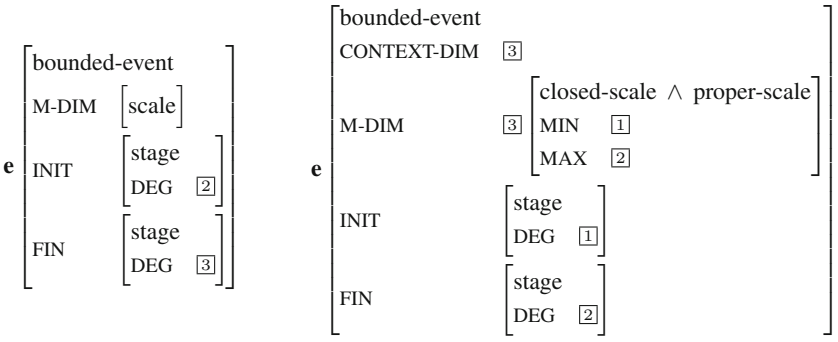

Fig. 2. Frame representations of the prefixes *po-* (left) and *pere-* (right) following Zinova 2017

At the same time, most verbs can attach prefixes that are more restrictive with respect to the identification of the initial and final stages of the event than *po-*. For example, the prefix *pere-*, as shown on right side of Fig. 2, provides information about both endpoints of the event. First, it states that the degree associated with the initial stage of the event (INIT.DEG) is the minimum degree on the relevant scale (M-DIM.MIN). Second, the degree associated with the final stage (FIN.DEG) is the maximum degree on the same scale (M-DIM.MAX). In addition to this, the prefix *pere-* limits the type of the measure dimension to proper scales. According to Zinova (2017, p. 223), proper scales are scales that impose an additional restriction on the event: if the measure dimension of the event is of type *proper-scale*, for each point of the scale there must be an event stage that is characterized exactly by this point (injection between stages and degrees on the scale). When such a requirement is absent, the scale may also be of type *measure of change*. This notion is adopted from Kennedy and Levin (2008) and Kennedy (2012).

The representation of the prefix *do-* is more complex. According to Kagan (2015), the prefix *do-* has completive or additive semantics: it can refer to the terminal part of

[6] Note that in Zinova (Zinova 2017) the frame for the prefix *po-* is associated with an additional restriction that the measure dimension (M-DIM) is the verbal dimension (VERB-DIM). This restriction is removed here.

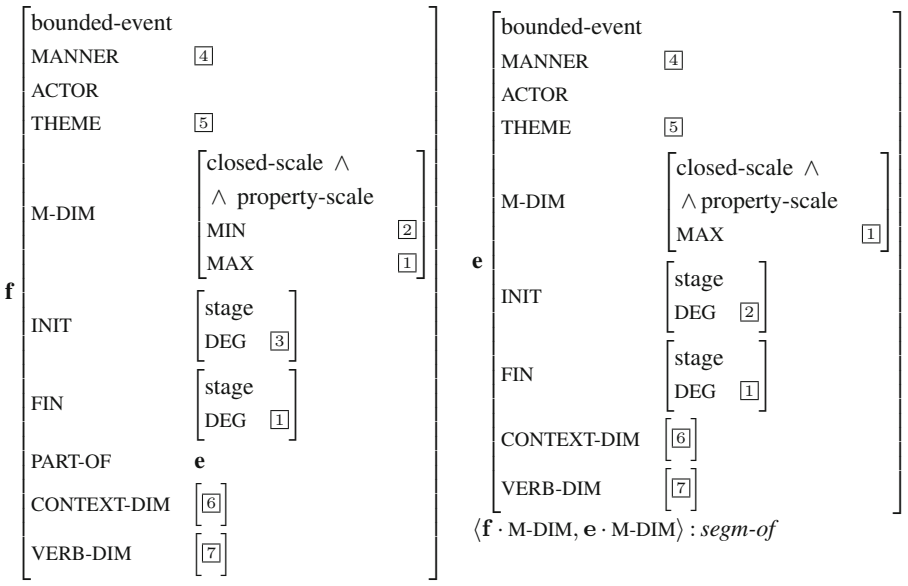

Fig. 3. Frame representation of the prefix *do-*

the event or to an event that can be seen as a continuation of another event. The frame that implements this semantic contribution is shown on Fig. 3.

In essence, the prefix *do-* introduces a new event that is a part of an event referred to by the base verb (the frame with the base label **e** will be unified with the frame representation of the base verb). This new event copies the MANNER and the THEME of the old one as well as the types of all the measure dimensions. The new measure dimension is defined on the basis of the old initial and final stages: for the base verb, the degree of the final stage (**e**.FIN.DEG) is the MAX of the M-DIM and this is also true for the new event. At the same time the MIN of the new event measure dimension is the degree of the initial stage of the base event (**e**.INIT.DEG). This is often (in case the derivation base verb does not contain further prefixes, as in the example considered in this paper) the minimum of the measure dimension of the event. Last, but not least, the degree of the initial stage of the new event is some degree on the corresponding measure dimension scale, but not necessarily its minimum. This ensures that the new event refers to some final segment of the old one, not excluding the possibility of the two events being equal.

Note that attributes in Frame semantics are functional, so the attribute PART-OF has to satisfy this restriction as well, that is why the value of this attribute is defined as the maximum event that the event in question is part of. In particular, it would be an event that proceeds from the minimum to the maximum degree on the relevant scale (provided by the M-DIM attribute). The scale has to be closed in order for the value of the PART-OF attribute to be defined.

The last prefix that is relevant for the discussed case is *za-*. The basic frame that I propose in order to represent its general semantic contribution is provided on Fig. 4. Informally it can be read in the following way: suppose the derivational base denotes some event **e** that has as its measure dimension a scale of type *proper-scale*. Then the verb prefixed with *za-* denotes another event of type *transition*. A transition is in general characterized by its anterior and posterior states. In this case we are interested in the posterior state that has to be a segment of the event denoted by the derivation base. What we also know is that the scale in the measure dimension of the posterior state of the transition event corresponds to some initial segment of the scale in the measure dimension of the event denoted by the derivational base. The identity of two attributes VERB-DIM and M-DIM of the event frame on Fig. 4 ensures that the measure dimension of the event is determined by the verb.

3.3 Representations of Prefixed Verbs

The next step is combining the representation of the base verb with the representations of the prefixes. This is done via the unification of the corresponding frames. When the frame for the verb (Fig. 1) is unified with the frame for the prefix *po-* (left side of Fig. 2), the frame on the left side of Fig. 5 is obtained. This resulting frame description refers to a bounded process of spending winter time that starts at some degree of the closed scale referring to winter time and ends at some other degree on the same scale. No further information is provided, so it is not excluded that these degrees can also be the minimum and the maximum of the scale.

$$\mathbf{f}\begin{bmatrix}\text{transition} & \\ \text{POST} & \begin{bmatrix}\text{event} & \\ \text{M-DIM} & \begin{bmatrix}\text{proper-scale} & \\ \text{MIN} & \text{deg}\end{bmatrix}\end{bmatrix}\end{bmatrix} \quad \mathbf{e}\begin{bmatrix}\text{event} & \\ \text{VERB-DIM} & \boxed{1} \\ \text{M-DIM} & \boxed{1}\begin{bmatrix}\text{proper-scale}\end{bmatrix}\end{bmatrix}$$

$$\langle \mathbf{f} \cdot \text{POST}, \mathbf{e}\rangle : \textit{esegm-of}$$

$$\langle \mathbf{f} \cdot \text{POST} \cdot \text{M-DIM}, \mathbf{e} \cdot \text{M-DIM}\rangle : \textit{segm-of}$$

Fig. 4. Representation of the contribution of the prefix *za-*

The second prefix we were considering is *pere-*. When its representation (see right side of Fig. 2) is unified with the representation of the verb *zimovat'* 'to spend winter time' (Fig. 1), the resulting frame (right side of Fig. 5) refers to a bounded event of spending winter time with the degree of the initial stage of the event being the minimum of the measure dimension scale (winter start) and the degree of the final stage of the event being the maximum of the measure dimension scale (winter end). Simply put, the obtained representation of the prefixed verb *perezimovat'* denotes an event of spending the whole winter (from the winter start to the winter end).

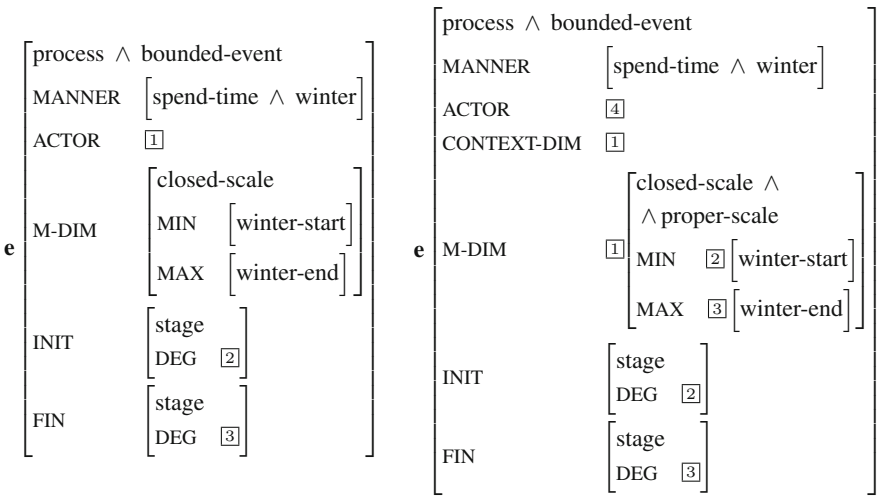

Fig. 5. Frame representations of the verb *pozimovat'* 'to spend some winter time' (left) and of the verb *perezimovat'* 'to spend the winter' (right)

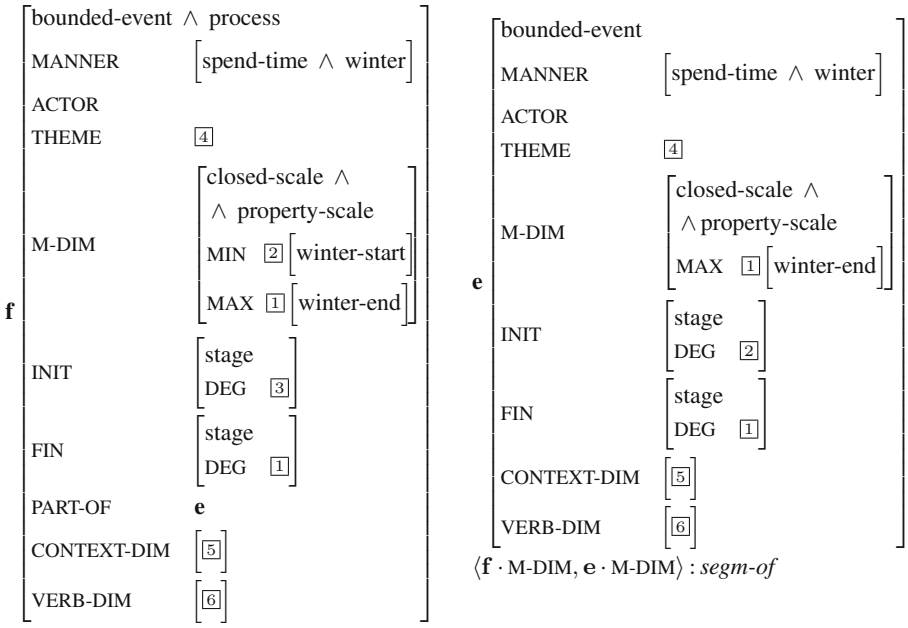

Fig. 6. Frame representation of the verb *dozimovat'* 'to finish spending the winter'

The next prefix is *do-*. To obtain the representation of the prefixed verb *dozimovat'* 'to finish spending winter time', the frame for the base verb (Fig. 1) has to be unified with the frame for the event with the base label **e** on Fig. 3. The resulting frame is shown on Fig. 6, whereby the prefixed verb refers to the event labelled by **f**. It is again a bounded process of spending winter time such that the degree of the final stage is the maximum of the measure dimension (winter end), but the degree of the initial stage may be any point on the same scale.

The last combination is that of the prefix *za-* (Fig. 4) with the same base verb (Fig. 1). The resulting frame, shown on Fig. 7, refers to a transition event such that its posterior stage is an event of spending winter time that necessarily includes the start of the winter. There is no information about how the situation developed apart from that.

4 Pragmatic Competition

Now, given the situations specified in Table 2 and the restrictions imposed by particular prefixes, possible interpretations of prefixed verbs are shown on Fig. 8: the verb *pozimovat'* 'to spend some winter time' can refer to any of the situations t_1–t_4, the verb *zazimovat'* 'to stay for the winter' can refer to t_1 and t_2, *dozimovat'* 'to spend the rest of the winter' – to t_1 and t_3, and *perezimovat'* 'to spend the winter' – only to t_1. In such a configuration, however, it follows from basic pragmatic and game-theoretic principles that the usage of the *za-*, *do-*, and *po-*prefixed verbs would be restricted to the situations t_2, t_3, and t_4, respectively: one can use, e.g., Gricean principles (Grice 1975), Game theory (Benz *et al.* 2006; Jäger 2008), or Optimality Theory (Blutner 2000; Dekker and Van Rooy 2000; Franke and Jäger 2012).

As a further step, I propose to implement such an approach using the Rational Speech Act model (RSA, Goodman and Frank 2016, Goodman and Tenenbaum 2016). The RSA model is an implementation of a social cognition approach to the understanding of utterances. It is based on Gricean ideas that speakers are cooperative and aim to produce utterances balancing between being informative and yet saving effort. A (pragmatic) listener then interprets the utterance by inferring what a speaker must have meant, given the expression they uttered (Bayesian inference). An advantage of this approach is that its output is a probability distribution that can be experimentally tested.

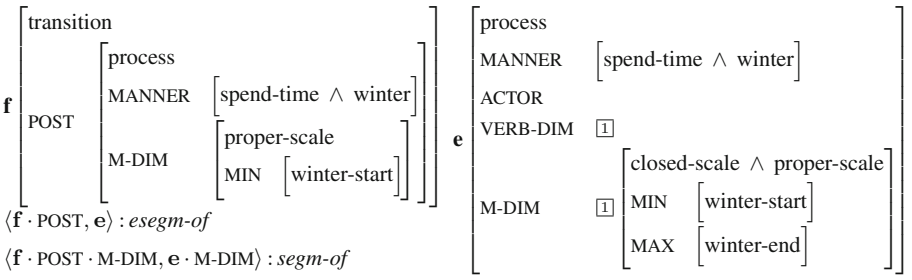

Fig. 7. Representation of the prefixed verb *zazimovat'* 'to stay for the winter'

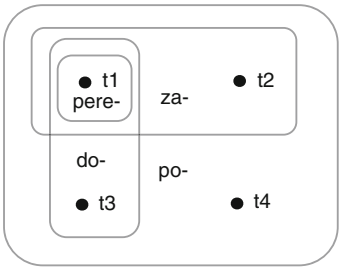

Fig. 8. Possible interpretations of the verbs derived from *zimovat'* 'to spend the winter', see also Table 2

For the implementation I use a probabilistic programming language (WebPPL[7]) with a basic three-layered RSA model. This model includes (i) a literal listener that interprets the utterance according to the provided literal semantics; (ii) a pragmatic speaker that selects an utterance from the available options based on the probability of the literal listener inferring the desired state of the world; (iii) a pragmatic speaker that interprets the utterance by reasoning about the pragmatic speaker. Six things need to be provided as an input to the model:

1. the world model;
2. probability distribution over possible world states;
3. set of alternative utterances;
4. their probabilities;
5. a meaning function from utterances to states;
6. a value of the optimality parameter.

Let us go through the list. First is the world model that in our case it contains four states that are shown in Table 2. This is a motivated by the structure of the scale the event relates to.

Next is the probability distribution over different states. In the implementation provided here I have assumed a flat prior over four world states which means that they are supposed to be equally likely. In order to later test the predictions of the model against speakers' intuitions the prior has to be either estimated from the data or the experimental design should allow for a prior setup.

I assume that the set of alternative utterances in case of a context-free setup is the set of all prefixed verbs formed from the same stem.[8] Such a set, however, can be very large, so an additional assumption I adopt here is to limit the set of alternatives to the verbs that have the same or smaller degree of morphological complexity with respect to the target verb. If more complex verbs are to be added, they would probably be associated with higher cost and thus lower prior probability. For the verbs of the same complexity (like in our example) I assume a flat probability distribution.

[7] https://probmods.org/.

[8] The question of competition between verbs that have different stems but are semantically close is left for future work.

Manipulating both priors (state prior and utterance prior) will lead to different probability distributions with respect to the interpretation of the individual prefixed verbs. For this reason the output of the model I show in this paper is not yet suitable for a comparison with experimental data for speakers' beliefs about the world after they have heard the utterance.

The next important piece of information is the meaning function that maps utterances to states. It comes more or less directly from the frame representations. Two parameters are set up: event start and event end. Both of them can get as a value any point other than winter start and winter end (value *some* in the code) or the respective endpoint of the scale (*winter_start* or *winter_end*).

The last parameter that has to be set is alpha, the optimality parameter. In the current implementation, the value of alpha is 1[9].

The graph on the left side of Fig. 9 represents the literal listener's probability distributions over the four possible situations (left to right: spending some winter time, spending time from winter start until some point, spending time from some point until the winter end, spending the whole winter). As the *po*-prefixed verb can refer to any of the situations, the distribution that the literal listener obtains corresponds to the prior distribution (in this case a uniform one).

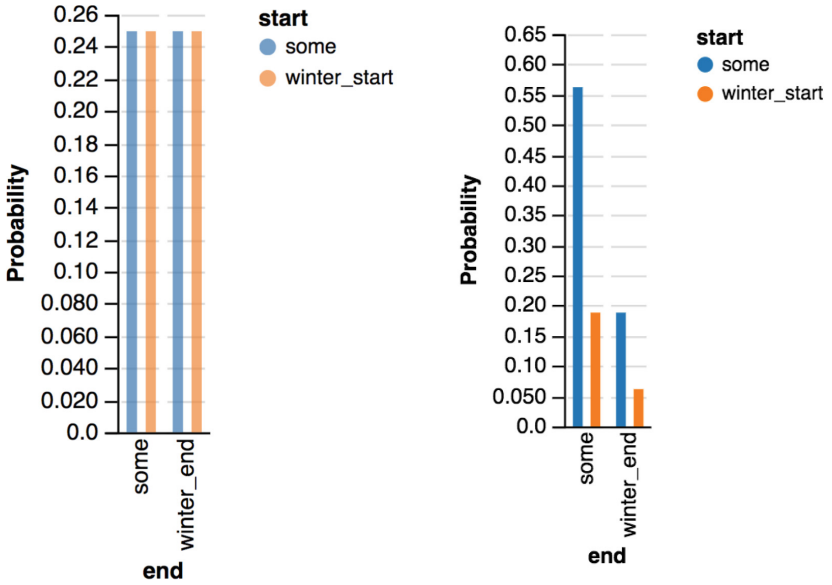

Fig. 9. RSA model output

[9] This is an arbitrary selected value. By varying this parameter one can model different behaviour: more or less dependent on the rational considerations. If alpha equals zero, pragmatic listener's behaviour will not differ from that of a literal listener.

Given this model the verb *pozimovat'* is interpreted by a pragmatic listener as 'spend some but not all winter time' with the probability almost 0.55, as shown on the right side of Fig. 8. The same verb can still be used to refer to the situations t_2 and t_3 (with probability a bit below 0.2) or t_4 (very low probability).

5 Results and Future Work

In sum, in this paper I have shown how underspecified semantics coordinated with pragmatic competition allows to explain the observed inference of 'low intensity' or 'short duration' of the *po*-prefixed verbs by the competition between various perfective verbs derived from the same derivational base. Simply put, when the semantics of several prefixed verbs overlaps, the usage of the *po*-prefixed verb gets restricted to the 'low degree' situations.

In future work I plan continue implementation within the RSA framework parallel to the experimental work that would allow to verify not only the qualitative, but also the quantitative predictions of the proposed approach. In course of this work, not only the final interpretations, but also the priors have to be tested and acquired from the data.

Another question that has to be addressed is whether the competition I have outlined here takes place every time a speaker produces and a listener hears an utterance (as shown above) or it is an evolutionary process.

A RSA code

```
// possible states of the world //
var worldPrior = function() {
  return categorical({ps: [1, 2, 4, 2],
  vs: [{start: "winter_start", end: "winter_end"},
       {start: "some", end: "winter_end"},
       {start: "some", end: "some"},
       {start: "winter_start", end: "some"},]})}

// possible one-word utterances //
var utterances = ["zazimovat","pozimovat","perezimovat","dozimovat"]
// possible preferences of utterances//
var utterancePrior = function() {
  return categorical({ps: [1, 1, 1, 1], vs: utterances})}
// meaning function to interpret the utterances//
var meaning = function(utterance, world){
  return utterance == "zazimovat" ? "winter_start"==world.start :
  utterance == "perezimovat" ? "winter_start"==world.start
  && "winter_end"==world.end :
  utterance == "dozimovat" ? "winter_end"==world.end : true}

// literal listener //
var literalListener = function(utterance){
  Infer({method:"enumerate"}, function(){
    var world = worldPrior();
    var uttTruthVal = meaning(utterance, world);
```

```
    condition(uttTruthVal == true)
    return world})}

// define speaker optimality //
var alpha = 1
// pragmatic speaker //
var speaker = function(world){
  Infer({method:"enumerate"}, function(){
    var utterance = utterancePrior();
    factor(alpha * literalListener(utterance).score(world))
    return utterance})}

// pragmatic listener //
var pragmaticListener = function(utterance){
  Infer({method:"enumerate"}, function(){
    var world = worldPrior();
    observe(speaker(world), utterance)
    return world})}
```

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