

# The source of nonfinite temporal interpretation

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**Introduction.** Which aspects of semantic interpretation are due to predicates’ denotations and which are due to the denotations of their arguments? This question has proven particularly difficult to answer in the context of the temporal interpretation of nonfinite embedded clauses (Stowell, 1982; Landau, 2001; Wurmbrand, 2001, 2014; Grano, 2012; Pearson, 2016): in (1), is it a fact about *regret* or its subordinate clause that explains why the leaving can be yesterday but not tomorrow? Is it the same for *want* in (2)?

- (1) a. #Jo regretted leaving tomorrow.                      (2) a. Jo wanted to leave tomorrow.  
      b. Jo will regret leaving yesterday.                    b. #Jo will want to leave yesterday.

One reason this question is difficult to answer is that a change in embedded clause structure sometimes alters the relevant pattern: in (3a), *remember* patterns like *regret* but in (3b), it patterns like *want*.

- (3) a. Jo will remember leaving yesterday.                      b. #Jo will remember to leave yesterday.

Is this an idiosyncratic fact about *remember* or a general fact about the composition of its complements?

**Contribution.** We investigate this question across the entire English clause-embedding verb lexicon by assessing the range of temporal interpretations a verb can have in a range of nonfinite complement types. To do this, we conduct a lexicon-scale study of temporal orientation in five constructions involving nonfinite embedded clauses and use the resulting dataset in conjunction with a computational model to induce the source of temporal interpretation in these structures. The resulting dataset—MegaOrientation—is available at [megaattitude.io](http://megaattitude.io). Consistent with prior work, our model’s optimal solution associates nonfinite clauses with three distinct semantic types relevant to temporal orientation and posits no systematic contribution from the predicate beyond selection.

**Background.** Approaches to temporal interpretation in nonfinite contexts fall into roughly two groups: ones positing covert embedded tense and/or aspect in a nonfinite complement selected by the predicate (*argumentive* approaches; Stowell, 1982; Landau, 2001; Wurmbrand, 2001, 2014; Grano, 2012) and ones positing temporal constraints imposed by the predicate (*predicative* approaches; Pearson, 2016). Which to prefer depends, at least in part, on the variability observed in temporal interpretation. Insofar as temporal interpretation remains constant across verbs for particular complement types, one has *prima facie* evidence for an argumentive approach; insofar as temporal interpretation remains constant across complement types for a particular verb (and many predicates show a similar pattern), one has *prima facie* evidence for a predicative approach. Insofar as both occur, one has evidence for a mixed approach.

Deciding on which approach best answers the question requires measuring temporal orientation across many verbs in different syntactic contexts. We do this using an acceptability judgment study that builds on the MegaAttitude dataset (White and Rawlins, 2016), which contains acceptability judgments for English clause-embedding verbs in 50 different subcategorization frames. To avoid typicality effects, frames were constructed to contain as little lexical content as possible besides the verb: all DP arguments were indefinite pronouns and all verbs besides the one being tested were either *do* or *happen*.

- (4) a. Someone thought something happened.                      b. Someone was told to do something.

We use the same method of constructing low content items to avoid typicality effects for our experiment.

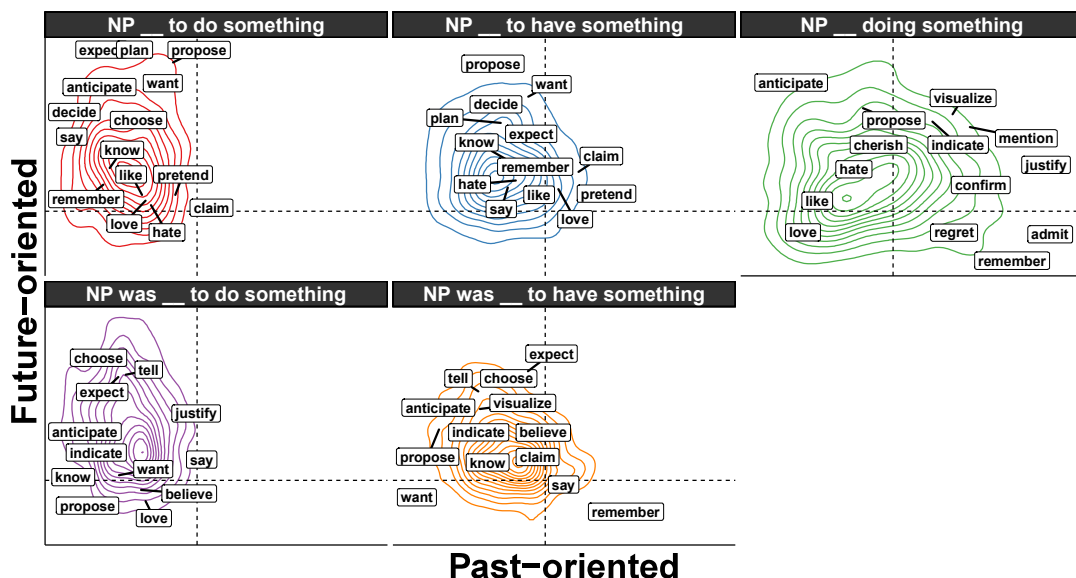
**Experiment.** We chose 887 verbs from the MegaAttitude dataset based on their acceptability—on average, a 4 or better—for the frames listed in (5). Following White and Rawlins (2016, 2018), we include the passive constructions (5b) to capture both object control and ECM structures—including both *believe* and *wager* class verbs (Pesetsky, 1991)—using the same frame.

- (5) a. Someone wanted to {do, have} something.                      [NP \_\_ to VP[+/-EV]]  
      b. Someone was known to {do, have} something.                      [NP \_\_ to VP[+/-EV]]  
      c. Someone regretted doing something.                                      [NP \_\_ VPing]

This yielded a total of 2,208 verb-frame pairs: 513 in the [NP \_\_ VPing] construction and 404 eventive active, 463 eventive passive, 364 stative active, and 464 stative passive infinitives. Two sentences were constructed with each verb-frame pair: one with a matrix past tense and embedded future adverb (6a), and another with a future modal in the matrix and an embedded past adverb (6b). A future interpretation is indicated by high acceptability in (6a) and past interpretation is indicated by high acceptability in (6b).

- (6) a. Someone wished to do something in the future.                      FUTURE-ORIENTED  
      b. Someone will deny doing something in the past.                      PAST-ORIENTED

Sentences were divided into lists of 48, with an even distribution of temporal constructions and as even of a distribution of syntactic frames as possible, with no verb appearing more than once. 869 participants were recruited through Amazon’s Mechanical Turk and asked to give acceptability judgments on a 7-point scale, with 1 being *terrible* and 7 being *perfect*. We gathered 10 such annotations per sentence.



**Results.** The figure plots the responses for the past-oriented construction (x-axis) against the future-oriented one (y-axis) after applying an ordinal model based normalizer (see White and Rawlins 2019). A verb located towards the top left means that it is more future-oriented while a verb towards the bottom right is past-oriented. Verbs falling into the other quadrants allow both orientations. Our method correctly captures that verbs such as *expect* and *anticipate* are future-oriented with infinitival complements, while *remember* and *regret* are past-oriented with *-ing* complements. Further, we see clear constraints on past interpretations: only the the [NP \_\_ VPing] frame allows them, while all frames allow future interpretations with some verbs. This is consistent with an argumentative approach. However, while overall the frame seems to impact a given verb’s orientation, individual verbs, such as *anticipate*, remain constant across frames. This is consistent with a predicative approach, though without assessing how many such predicates exist (adjusting for effects of the structure) it is unclear whether specifying, e.g., that *anticipate* requires future interpretation in its lexical entry as opposed to what it selects is necessary.

**Analysis.** To quantitatively assess how much to prefer an argumentative approach v. a predicative approach v. a mixture of the two, we construct a model in the vein of White and Rawlins’ (2016) model of semantic-selection. This model assumes (i) that frames can fall into different argument types based on the temporal orientations they allow; (ii) that verbs can fall into different predicate types based on the temporal orientations they allow; and (iii) that each of these two kinds of type are associated with constraints on allowable temporal orientations. This model allows us to specify purely argumentative approaches, by assuming there are multiple structure types but only a single predicate type, and purely predicative approaches, by assuming there are multiple predicate types but only a single argument type.

We implement this model using a form of non-negative tensor factorization, wherein each surface complement type  $c$  is associated with a probability  $\rho_{ci} \in [0, 1]$  that it has each of  $K_C$  argument types  $i$  and each predicate  $p$  is associated with a probability  $\nu_{pji} \in [0, 1]$  that it has each of  $K_P$  predicate types  $j$  and selects structure type  $i$  when it has that type. The argument types  $i$  and the predicate types  $j$  are linked to the acceptability of orientation  $o$  by  $r_{io}, n_{io} \in \mathbb{R}_+$ , respectively. The acceptability for a particular predicate  $p$  with a particular complement type  $c$  and a particular orientation  $o$  is then defined as  $a_{pco} = \sum_{i,j} \nu_{pji} \rho_{ci} r_{io} n_{io}$ . This value is then used as input to a mixed effects ordinal link with unconstrained cutpoints. The model is optimized against the likelihood of the data using this link.

We fit this model with varying numbers of predicate and argument types  $K_C, K_P \in \{1, 2, 3, 4\}$ , where  $K_C = 1$  is a purely predicative model and  $K_P = 1$  is a purely argumentative model. To select the optimal values of  $K_C, K_P$ , we compute the Akaike Information Criterion (AIC) for each model. The model with the minimum AIC is the one with one predicate type and three argument types. This finding is consistent with Wurmbrand’s (2014) proposal and suggests that information relevant to temporal interpretation is solely encoded in the embedded clause, with the predicate’s only role being selectional.

**Conclusion.** We presented a lexicon-scale study aimed at assessing the full range of temporal interpretations a verb can have in different nonfinite complement types. We used this dataset in conjunction with a computational model to induce predicate types, argument types, and their relationship to temporal interpretation, showing that the optimal model posits three argument types that predicates select.

**Selected References.** Grano, 2012. Control and Restructuring at the Syntax-Semantics Interface · Landau, 2001. *Elements of Control* · Pearson, 2016. The semantics of partial control · Stowell, 1982. The tense of infinitives · White and Rawlins, 2016. A computational model of S-selection · Wurmbrand, 2001. *Infinitives* · Wurmbrand, 2014. Tense and aspect in English infinitives