THE SOURCE OF NONFINITE TEMPORAL INTERPRETATION

ELLISE MOON AND AARON STEVEN WHITE, UNIVERSITY OF ROCHESTER

CENTRAL QUESTION

Which aspects of **semantic interpretation** are due to **predicates' denotations** and which are due to the **denotations of their arguments**?

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Focus: temporal interpretation in English nonfinite embedded clauses.

(Stowell, 1982; Landau, 2001; Wurmbrand, 2001, 2014; Grano, 2012, 2017; Pearson, 2016)

CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

1. Jo wanted to leave.

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CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

1. Jo wanted to leave.

2. Jo regretted leaving.

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CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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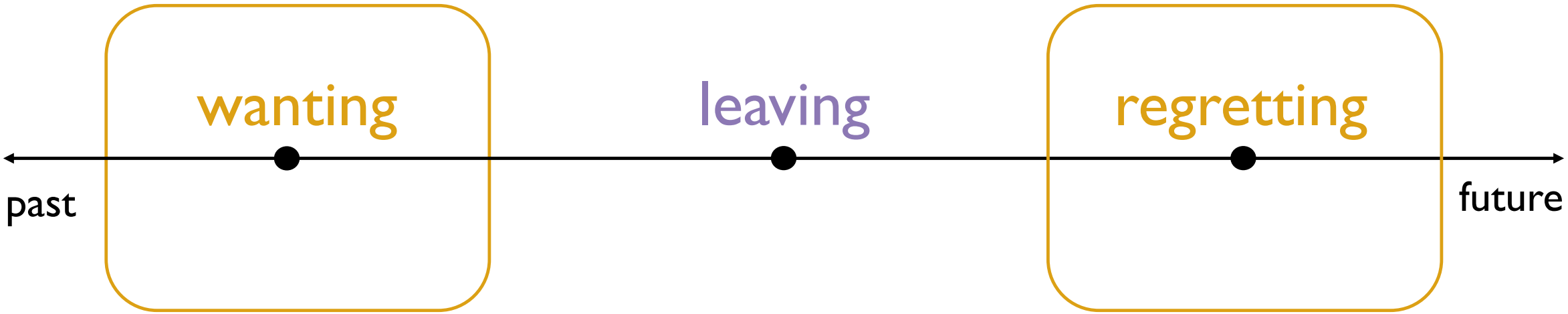

CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

3. Jo remembered leaving.

CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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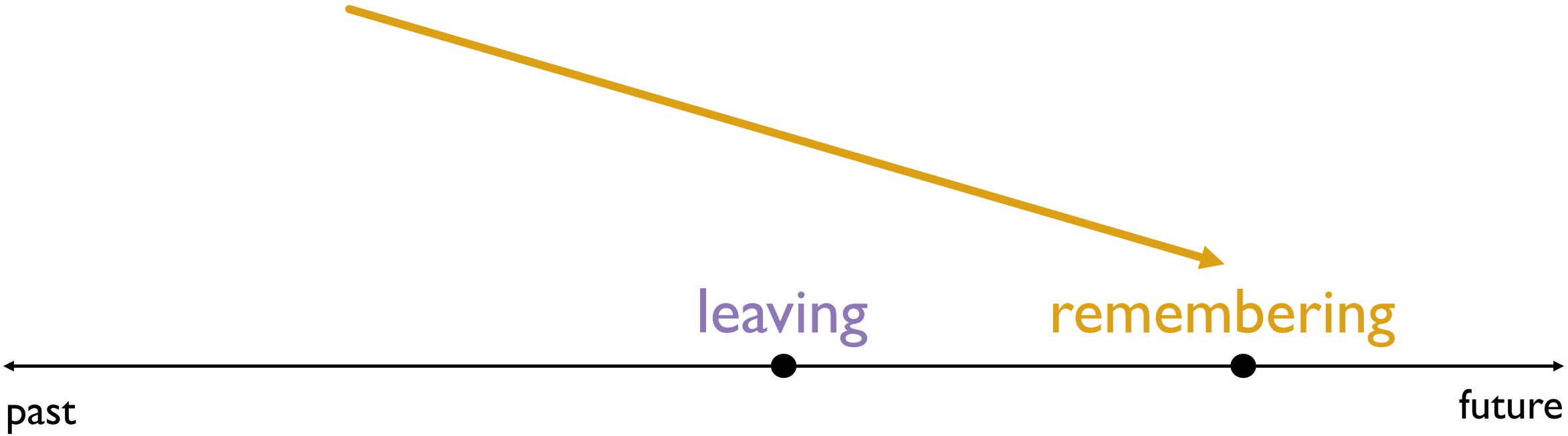
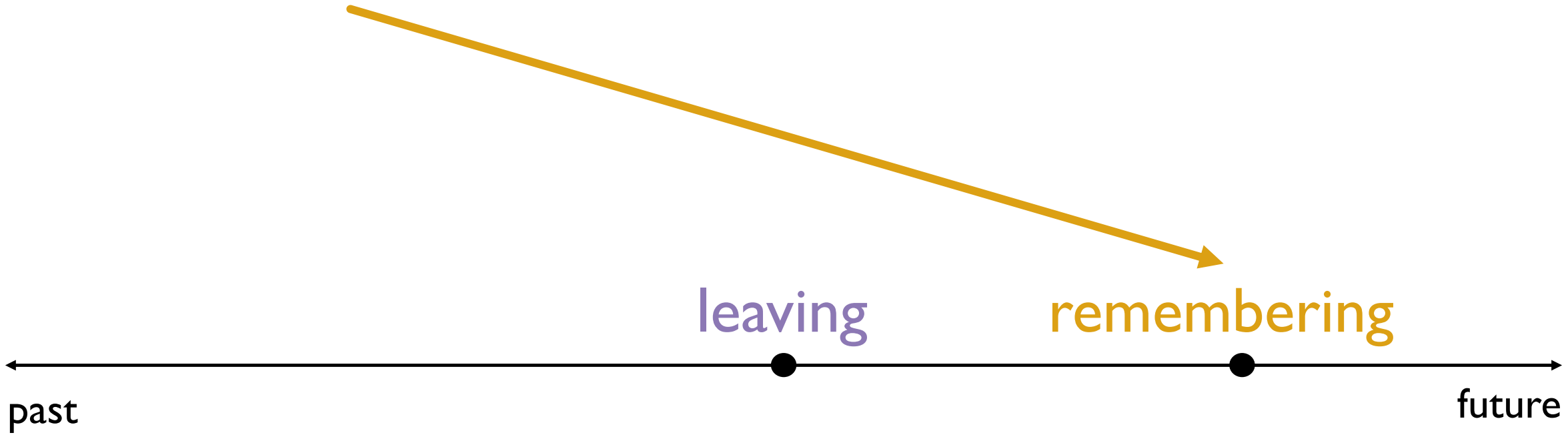


CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

3. Jo remembered leaving.

4. Jo remembered to leave.



CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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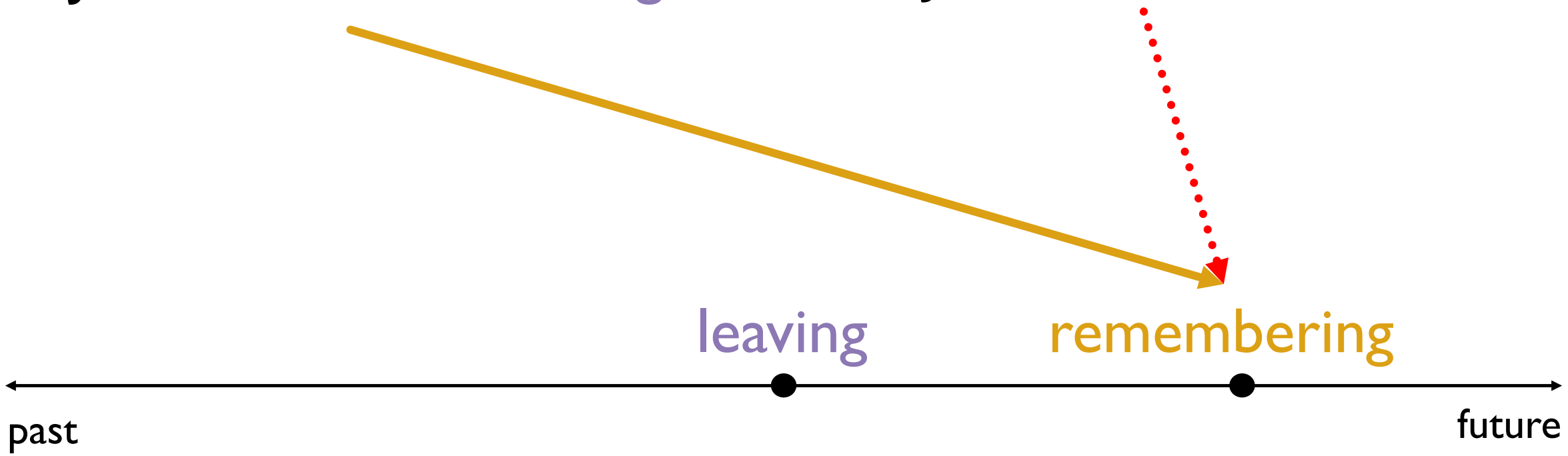

CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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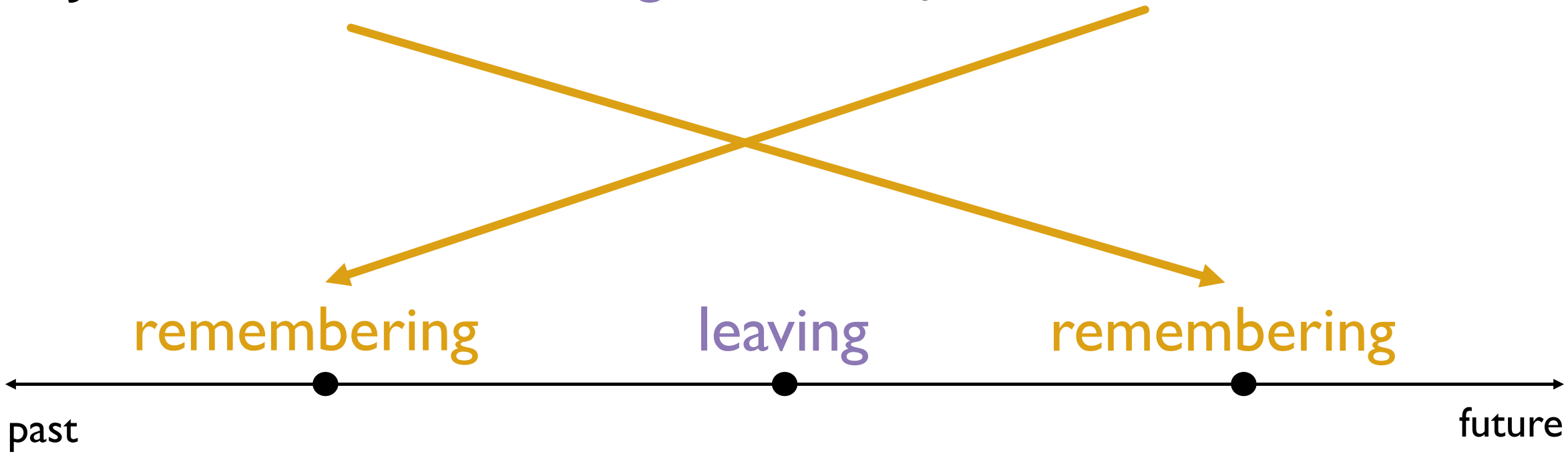

CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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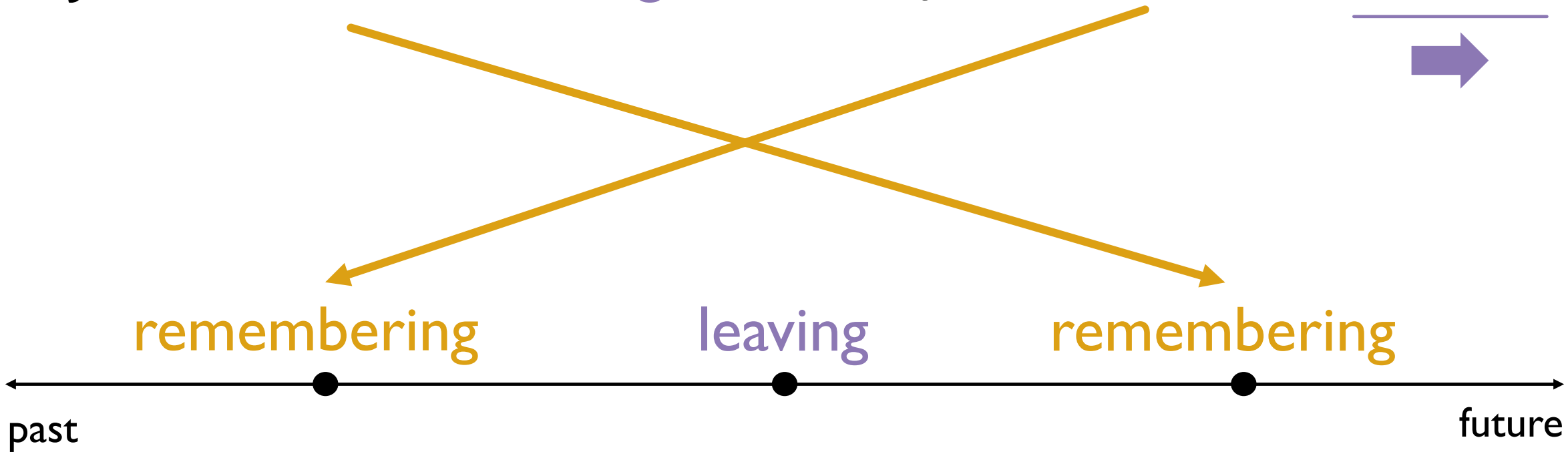

CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

4. Jo remembered to leave.

5. Jo claimed to leave.

CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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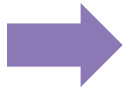

5. Jo claimed to leave.

CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

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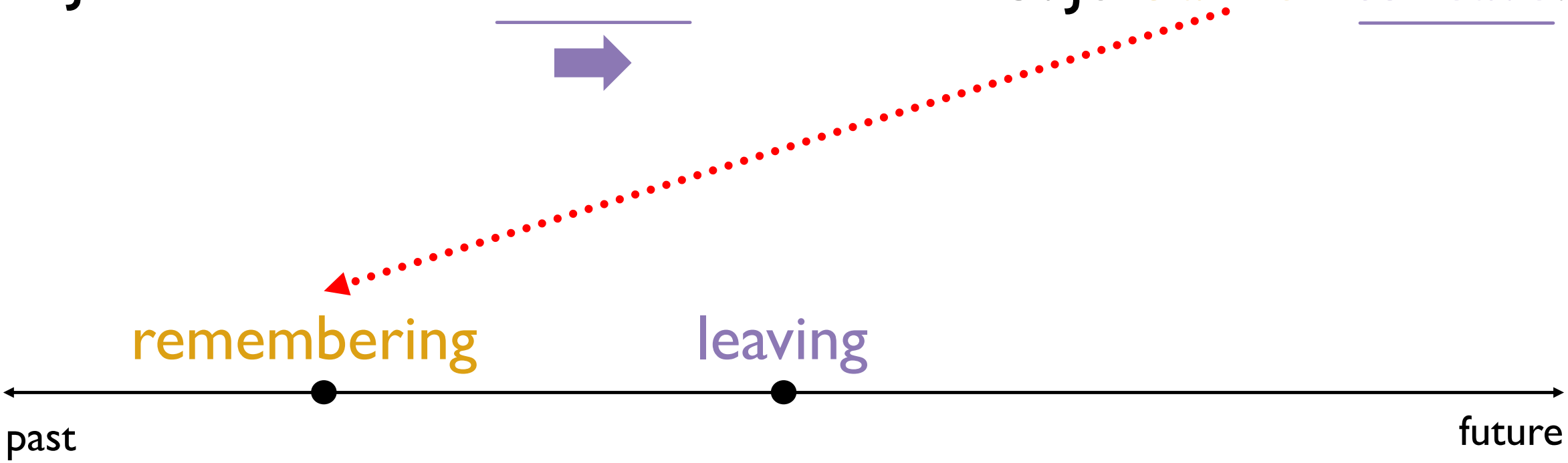

CLAUSE EMBEDDING AND TEMPORAL ORIENTATION

4. Jo remembered to leave.

5. Jo claimed to leave.

QUESTION

What is the source of this temporal orientation?

CHALLENGE

Are predicates like remember and claim just idiosyncratic?

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Are predicates like remember and claim just idiosyncratic?

Bird's-eye view of temporal orientation across the lexicon

APPROACH

- Collect a lexicon-scale dataset of **clause-embedding verbs** with different possible **embedded structures**

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- Collect a lexicon-scale dataset of **clause-embedding verbs** with different possible **embedded structures**
- Formalize possible theoretical frameworks as parameters in a computational model and test on data

TALK OUTLINE

- Introduction

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- Introduction
- Three Hypotheses

TALK OUTLINE

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- Data Collection

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- Model Design

TALK OUTLINE

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- Model Design
- Analysis and Results

HYPOTHESES

1. **Lexical:** Temporal orientation is due to the predicate

(Pearson, 2016)

HYPOTHESES

1. **Lexical:** Temporal orientation is due to the predicate

Jo regretted leaving $[\![\text{regret}]\!] \rightsquigarrow t_{(\text{regret})} < t_{(\text{leave})}$

(Pearson, 2016)

HYPOTHESES

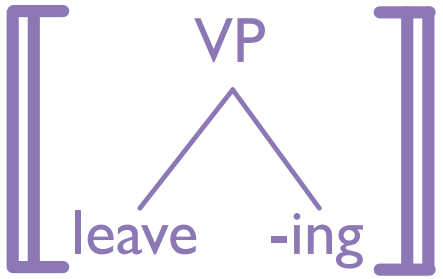
2. Structural: Temporal orientation is due to the structure of the argument selected by the predicate

(Stowell, 1982; Landau, 2001; Wurmbrand, 2001, 2014; Grano, 2012)

HYPOTHESES

2. Structural: Temporal orientation is due to the structure of the argument selected by the predicate

Jo regretted leaving



$\rightsquigarrow t_{(regret)} < t_{(leave)}$

(Stowell, 1982; Landau, 2001; Wurmbrand, 2001, 2014; Grano, 2012)

HYPOTHESES

3. Mixed: temporal orientation depends on both the predicate and argument type.

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Jo remembered leaving.

$[\![\textbf{remember}]\!] \rightsquigarrow t_{(remember)} < t_{(leave)}$

$[\![$ VP (leave, -ing) $]\!] \rightsquigarrow t_{(leave)} < t_{(remember)}$

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GOAL

A way to capture temporal orientation across different possible verb/structure pairings

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A way to capture temporal orientation across different possible verb/structure pairings

A bleaching method for acceptability judgements, following White and Rawlins 2016

DATA COLLECTION

Jo wanted to leave in the future.

*Jo will want to leave in the past.

DATA COLLECTION

Jo wanted to leave in the future.

*Jo will want to leave in the past.

DATA COLLECTION

tense manipulation | temporal adverb phrase

Jo wanted to leave in the future.

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DATA COLLECTION

tense manipulation

temporal adverb phrase

Jo wanted to leave in the future.

*Jo will want to leave in the past.

future-oriented

past-oriented

DATA COLLECTION

NP __ doing something

Someone regretted doing something.

DATA COLLECTION

NP ___ to do something

Someone <u>wanted</u> to do something.

DATA COLLECTION

NP __ to have something

Someone loved to have something.

DATA COLLECTION

NP was __ to do something

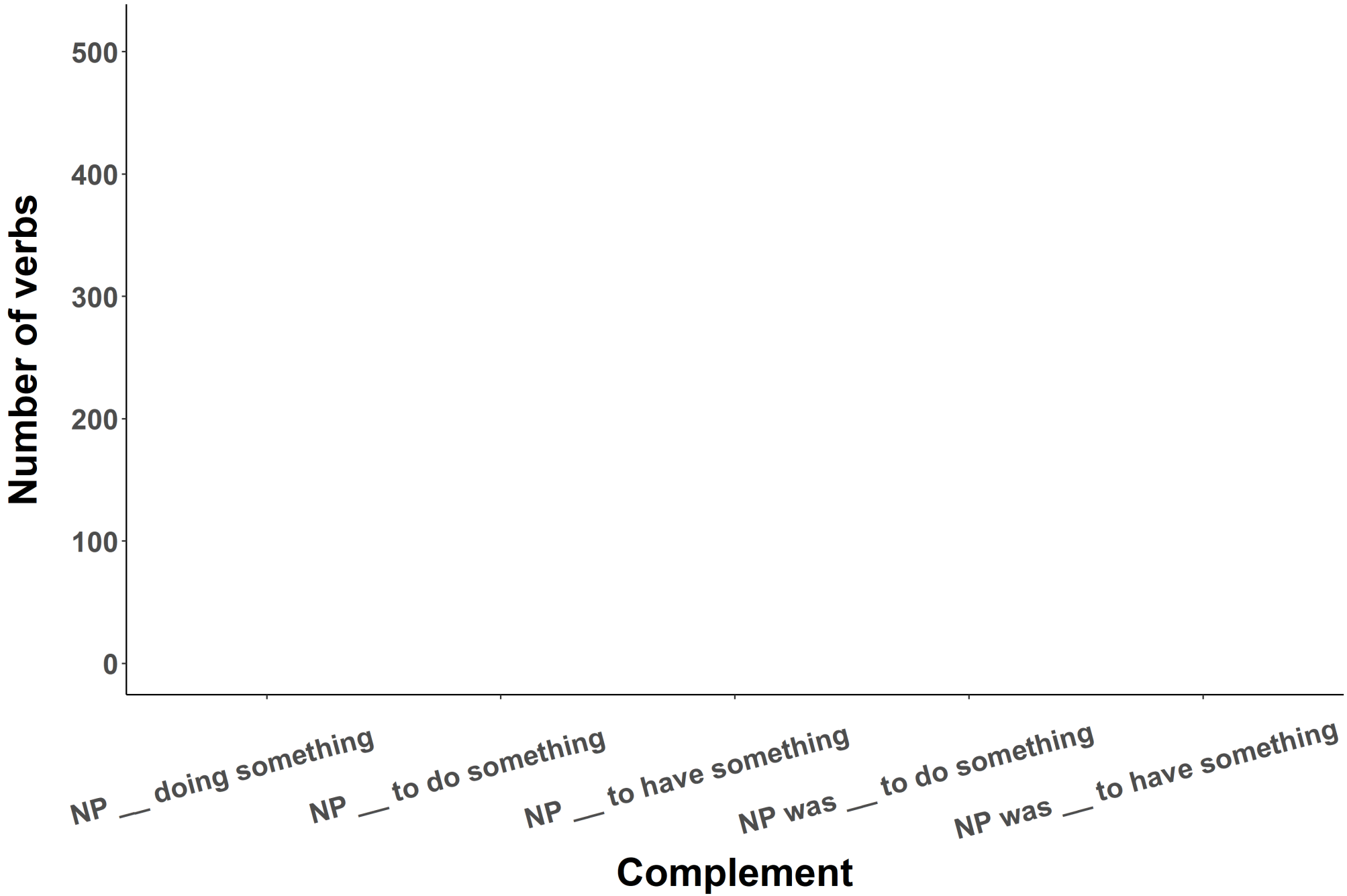
Someone was told to do something.

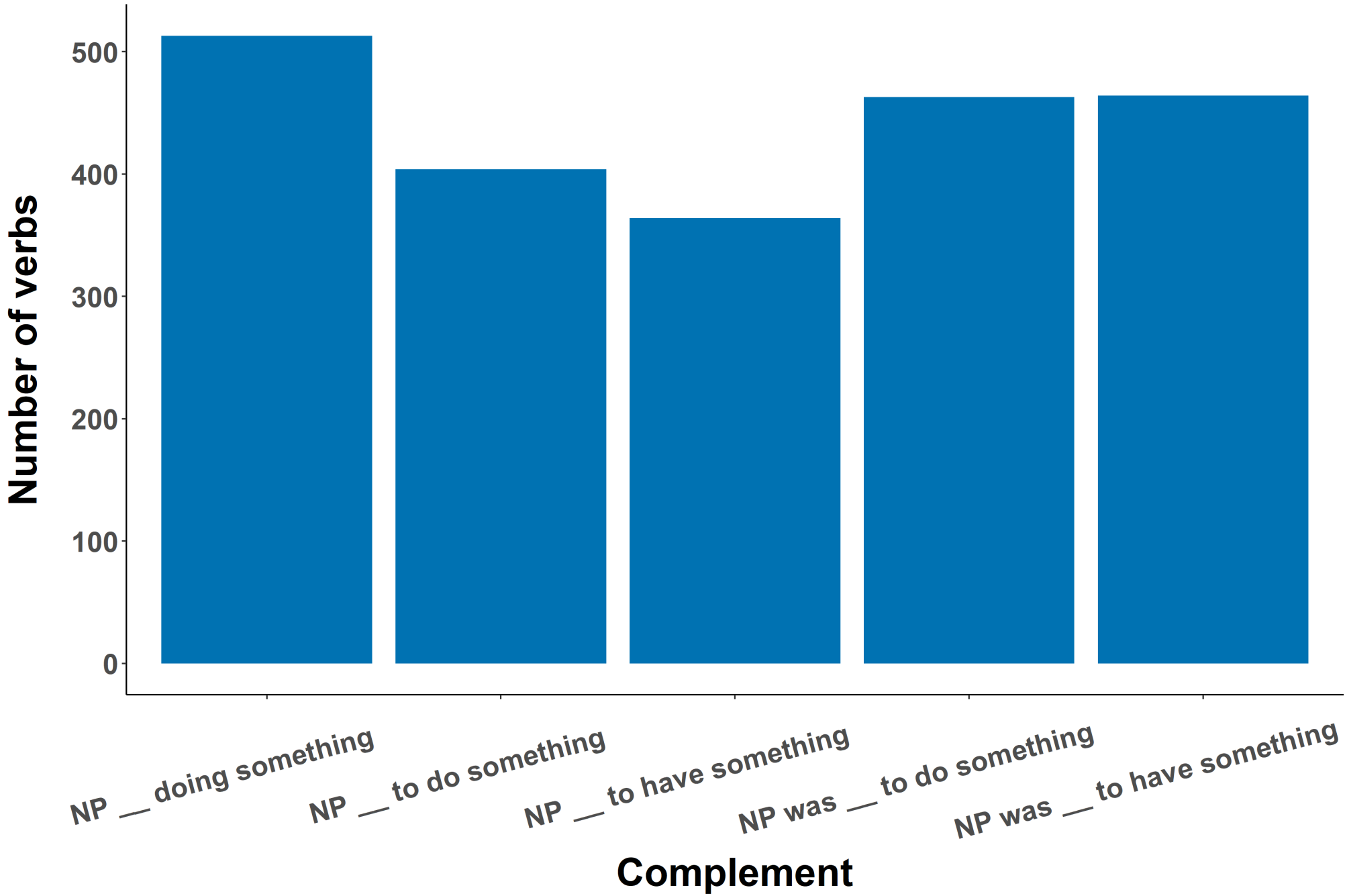
(Pesetsky 1991, Moulton 2009)

DATA COLLECTION

NP was ___ to have something

Someone was <u>believed</u> to have something.


Number of verbs
500
400
300
200
100
0
NP __ doing something
NP __ to do something
NP __ to have something
NP was __ to do something
NP was __ to have something
Complement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- 2208 verb/complement pairs in 2 orientations

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- Semantically bleached 3rd person singular subject

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- Lists of 48 sentences, with even distribution of orientations and randomized item order

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- 2208 verb/complement pairs in 2 orientations
- Semantically bleached 3rd person singular subject
- Lists of 48 sentences, with even distribution of orientations and randomized item order
- 10 acceptability judgements per sentence from 869 annotators on Mechanical Turk

DATA COLLECTION

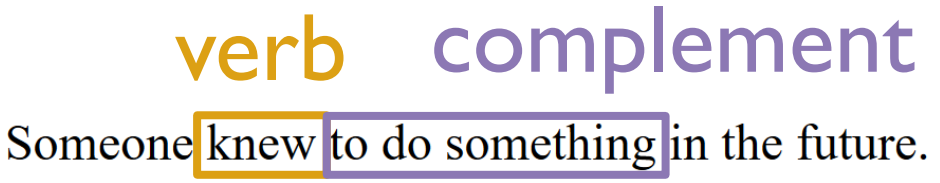
Someone knew to do something in the future.

DATA COLLECTION

verb

Someone knew to do something in the future.

DATA COLLECTION



DATA COLLECTION

verb complement

Someone knew to do something in the future.

How acceptable is this sentence?

terrible	1	2	3	4	5	6	7	*perfect*

DATA COLLECTION

verb complement

Someone knew to do something in the future.

future-oriented

How acceptable is this sentence?

terrible 1 2 3 4 5 6 7 *perfect*

DATA COLLECTION

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Someone knew to do something in the future.

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How acceptable is this sentence?

terrible 1 2 3 4 5 6 7 *perfect*

DATA COLLECTION

Someone will wish to have something in the past.

DATA COLLECTION

verb

Someone will wish to have something in the past.

DATA COLLECTION

verb complement

Someone will wish to have something in the past.

DATA COLLECTION

verb complement

Someone will wish to have something in the past.

How acceptable is this sentence?

terrible 1 2 3 4 5 6 7 *perfect*

DATA COLLECTION

verb complement

Someone will wish to have something in the past.

past-oriented

How acceptable is this sentence?

terrible 1 2 3 4 5 6 7 *perfect*

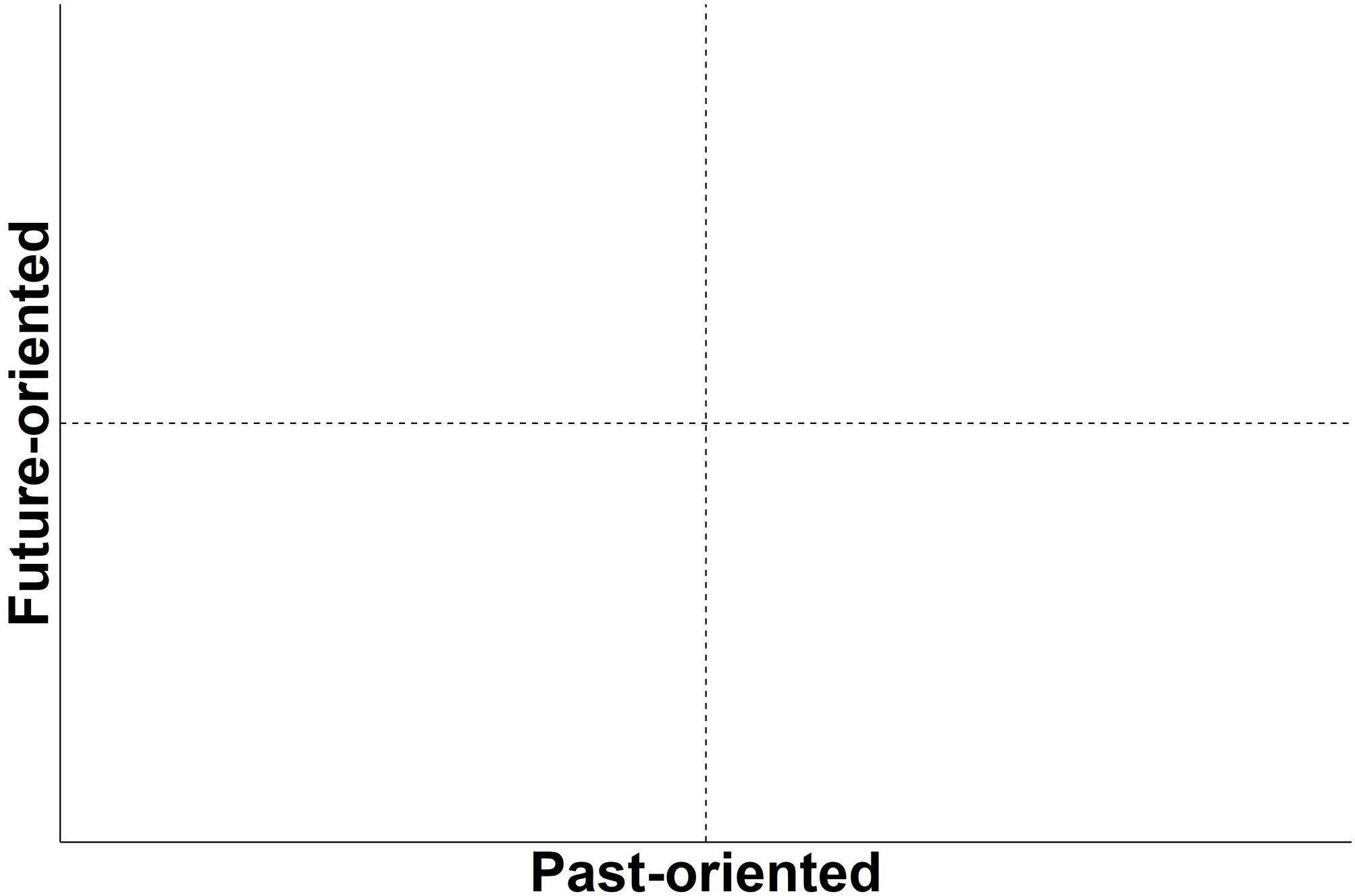
DATA COLLECTION

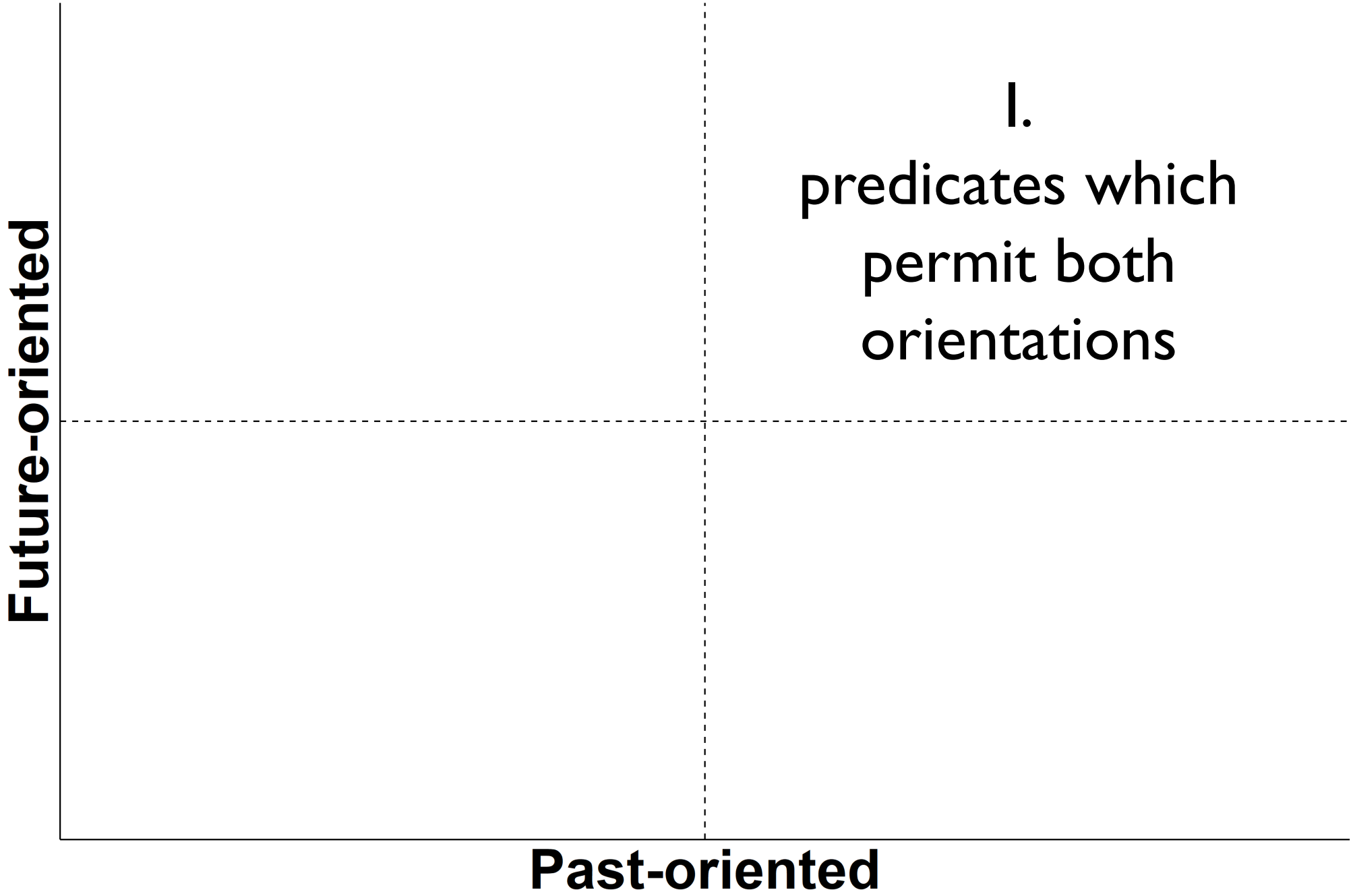
verb complement

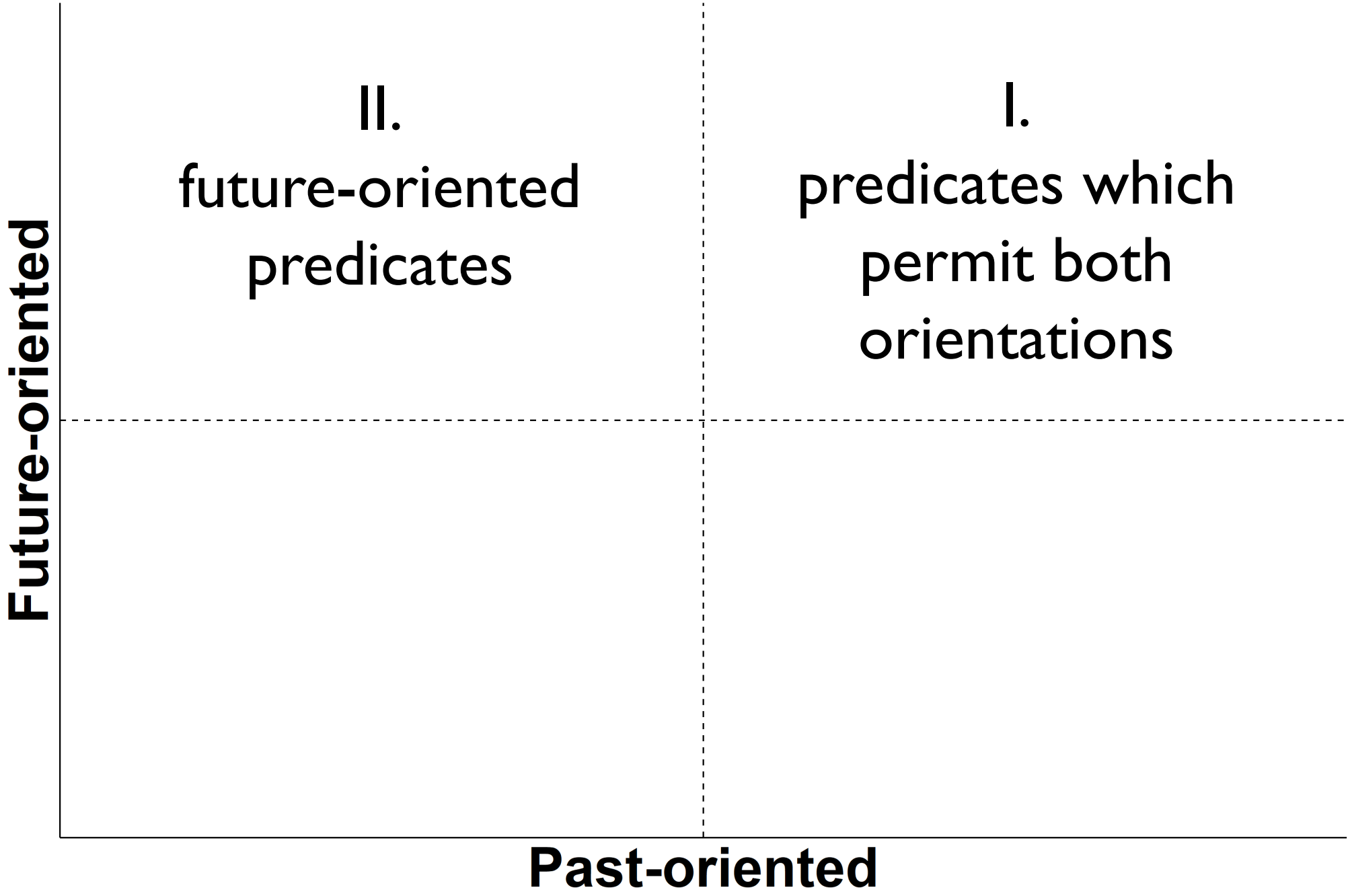
Someone will wish to have something in the past.

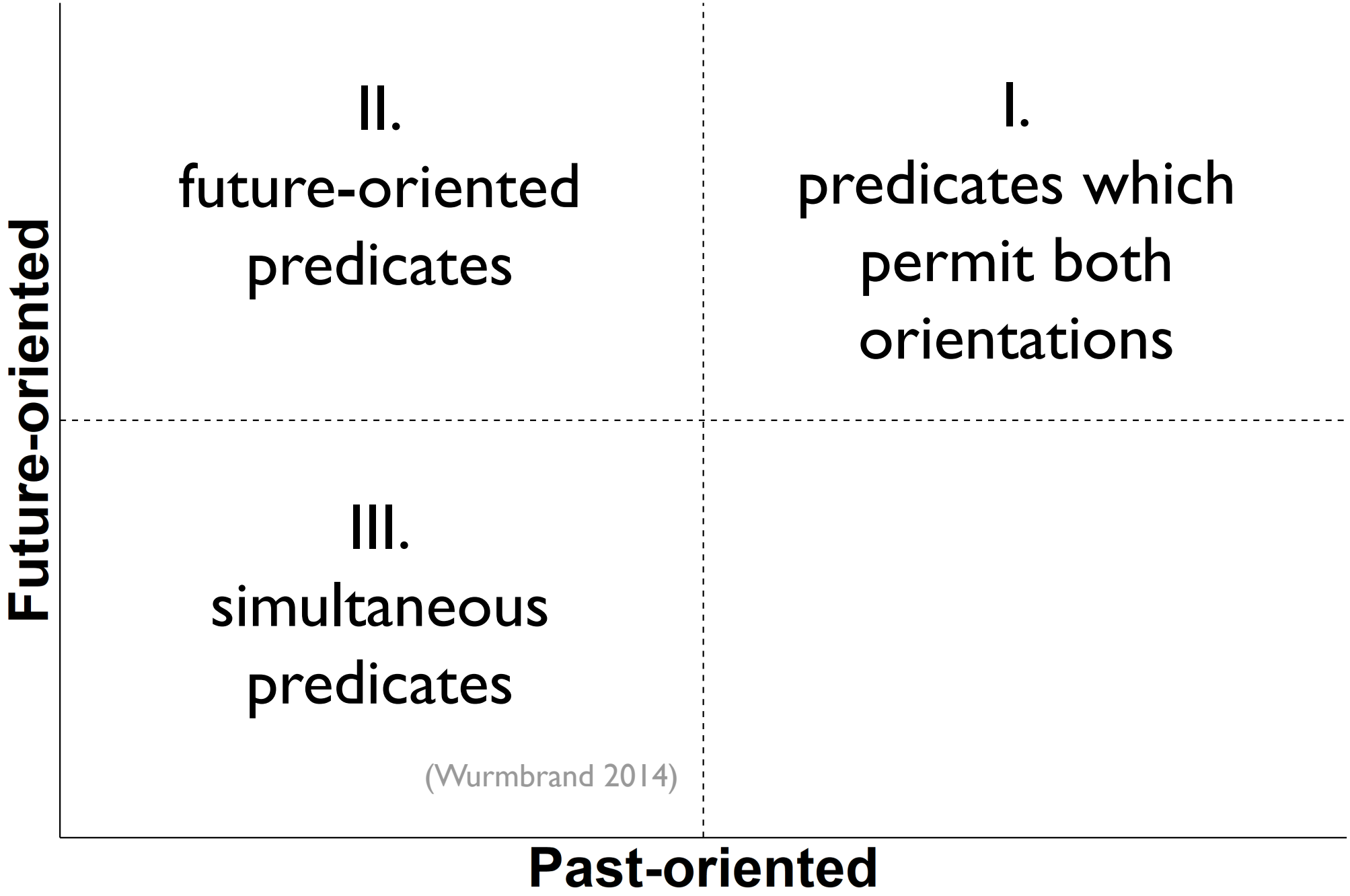
past-oriented

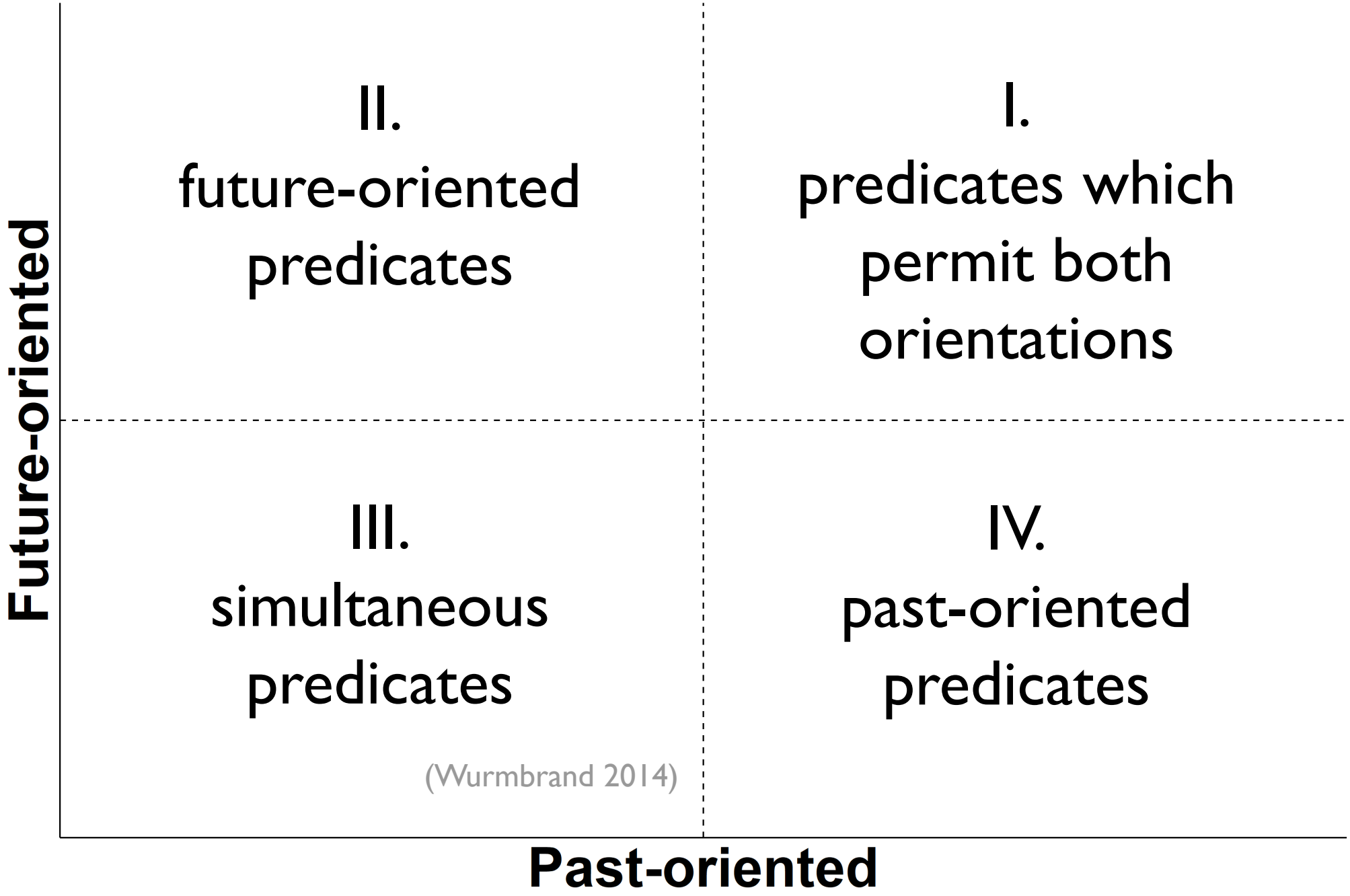
How acceptable is this sentence?


Future-oriented
Past-oriented


I.
predicates which
permit both
orientations
Future-oriented
Past-oriented


II.
future-oriented
predicates
I.
predicates which
permit both
orientations
Future-oriented
Past-oriented


II.
future-oriented
predicates
I.
predicates which
permit both
orientations
III.
simultaneous
predicates
(Wurmbrand 2014)
Future-oriented
Past-oriented


II.
future-oriented
predicates
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predicates which
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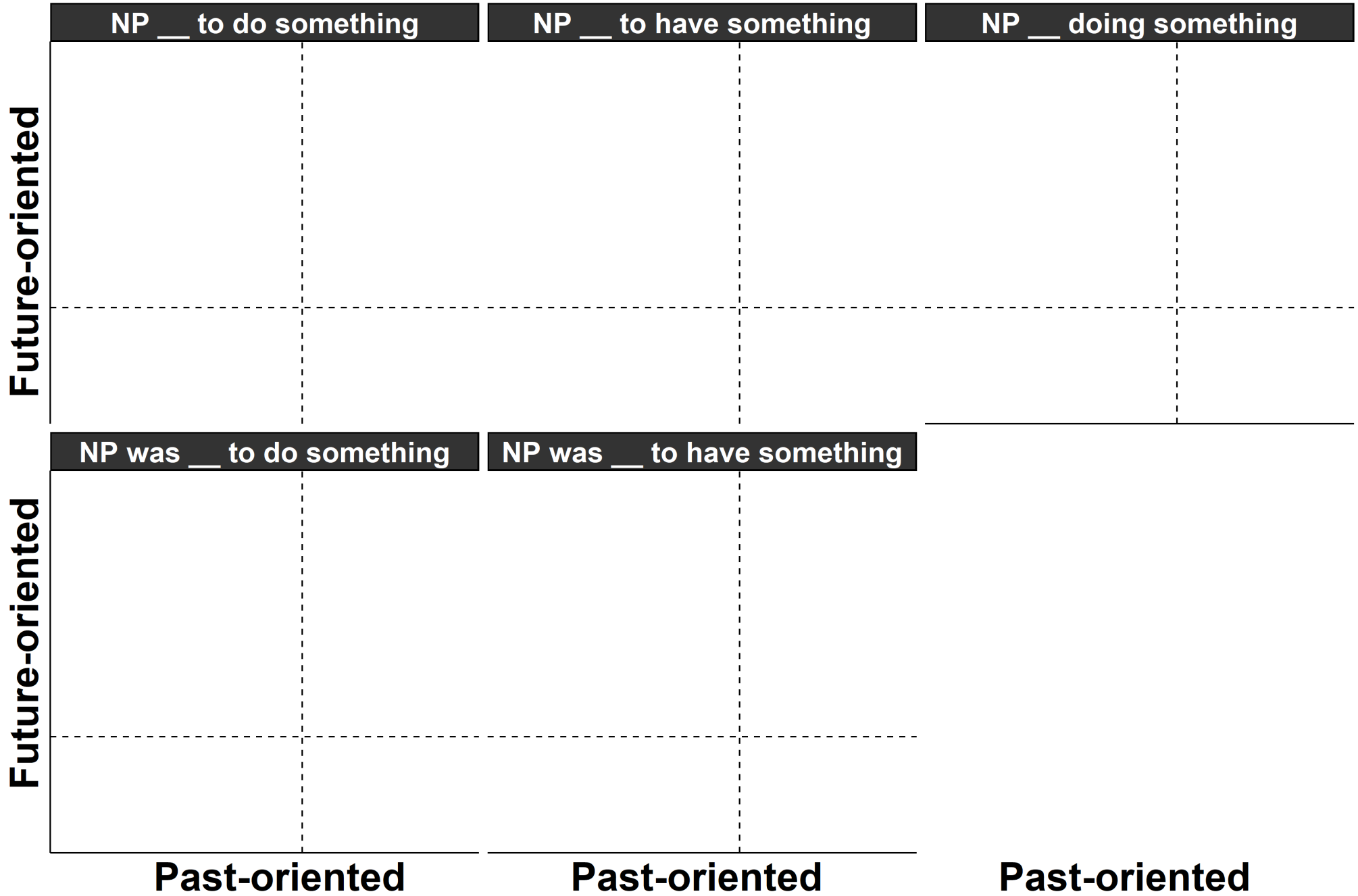
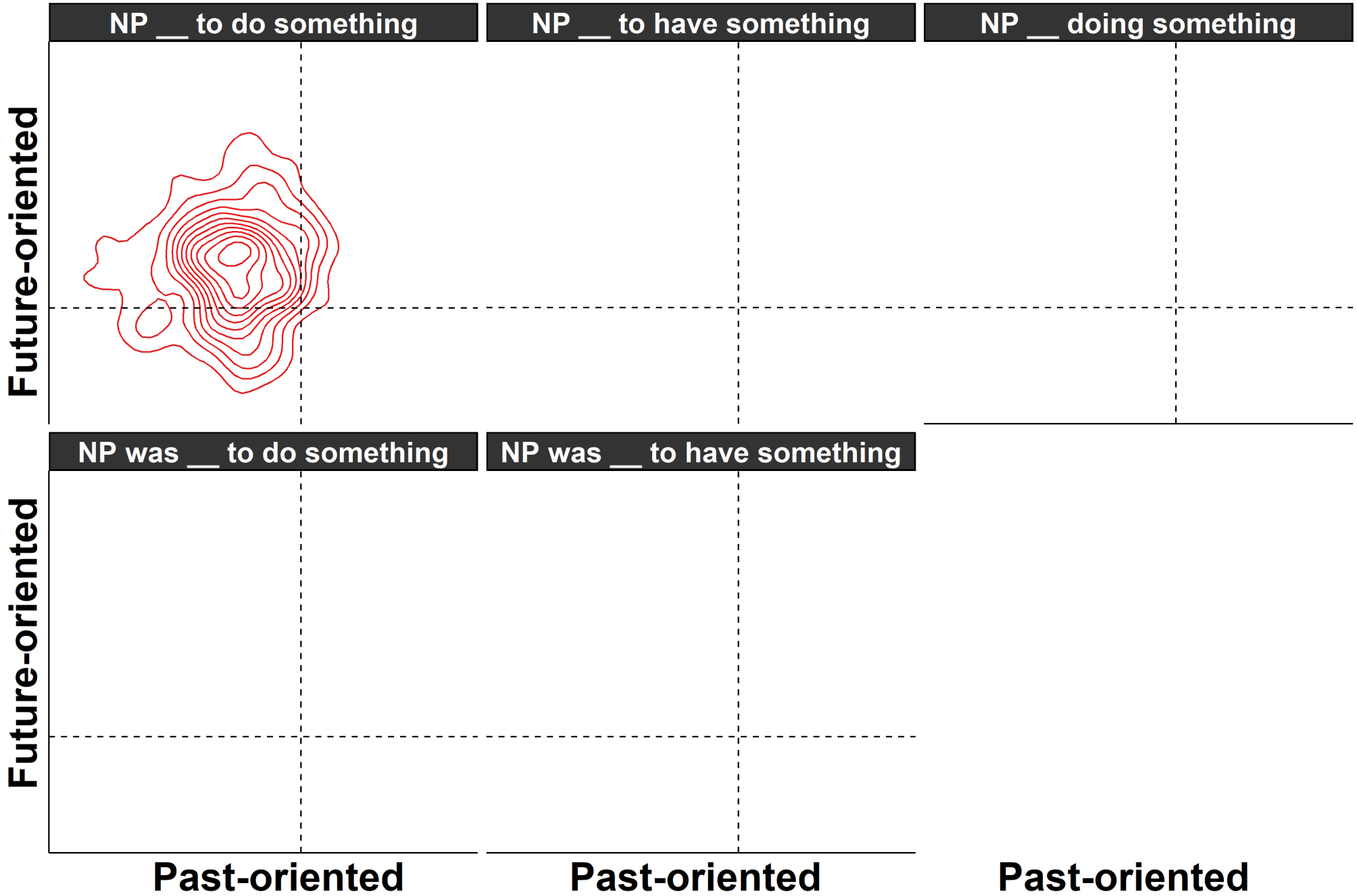
predicates
IV.
past-oriented
predicates
(Wurmbrand 2014)
Future-oriented
Past-oriented


NP __ to do something
NP __ to have something
NP __ doing something
NP was __ to do something
NP was __ to have something
Future-oriented
Future-oriented
Past-oriented
Past-oriented
Past-oriented


NP __ to do something
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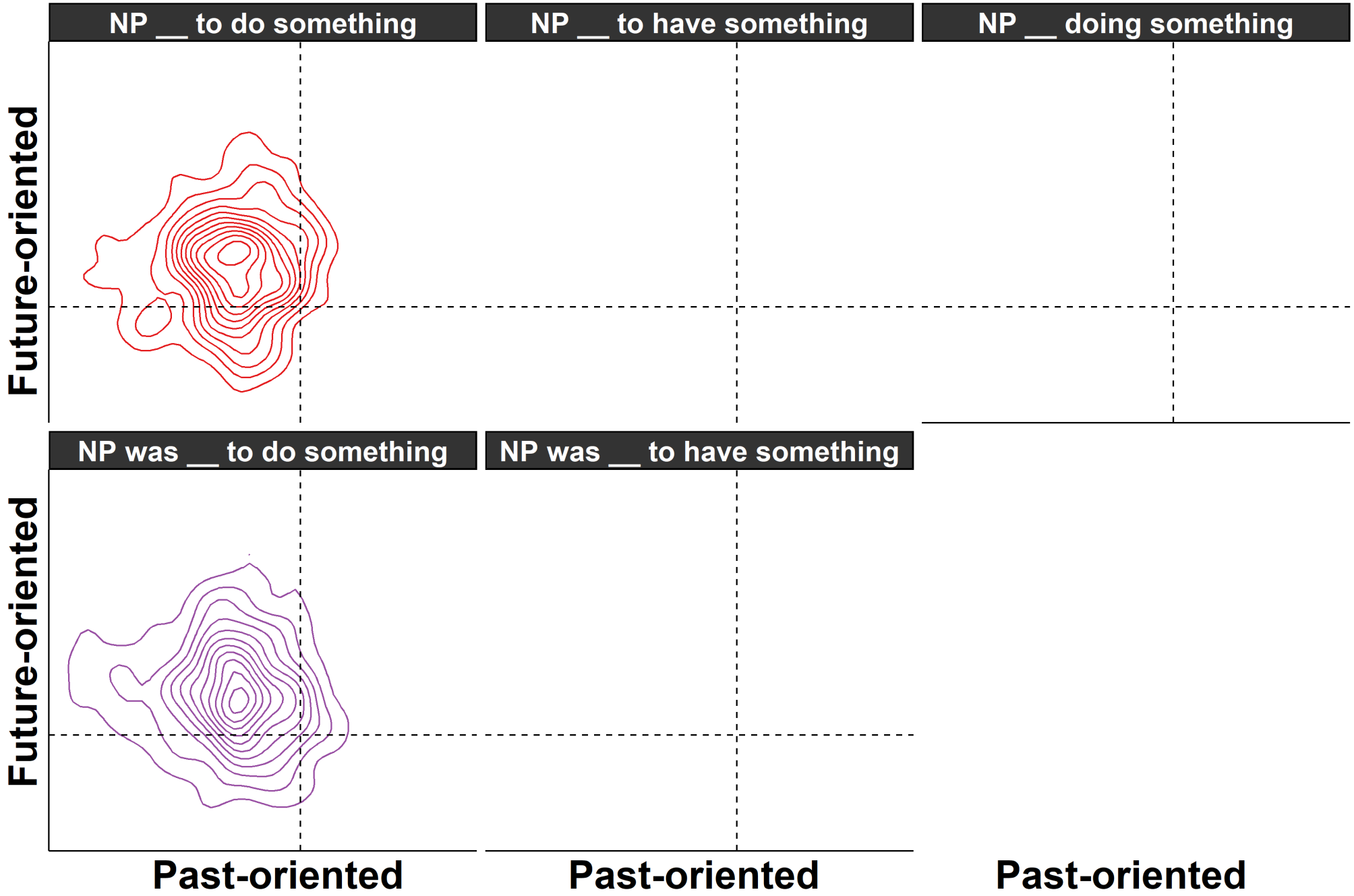
Future-oriented
Future-oriented
Past-oriented
Past-oriented
Past-oriented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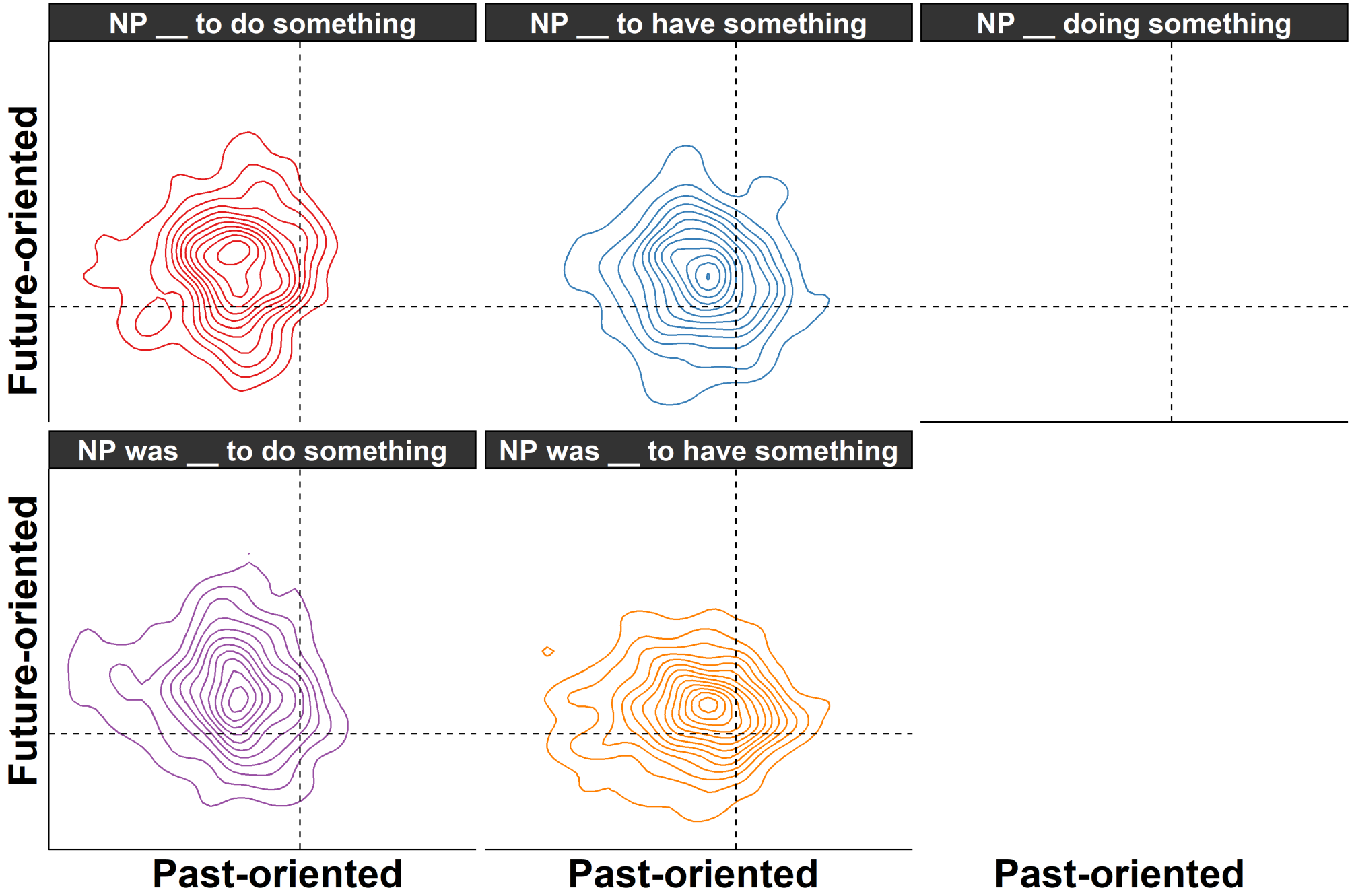
Future-oriented
Future-oriented
Past-oriented
Past-oriented
Past-oriented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NP __ doing something
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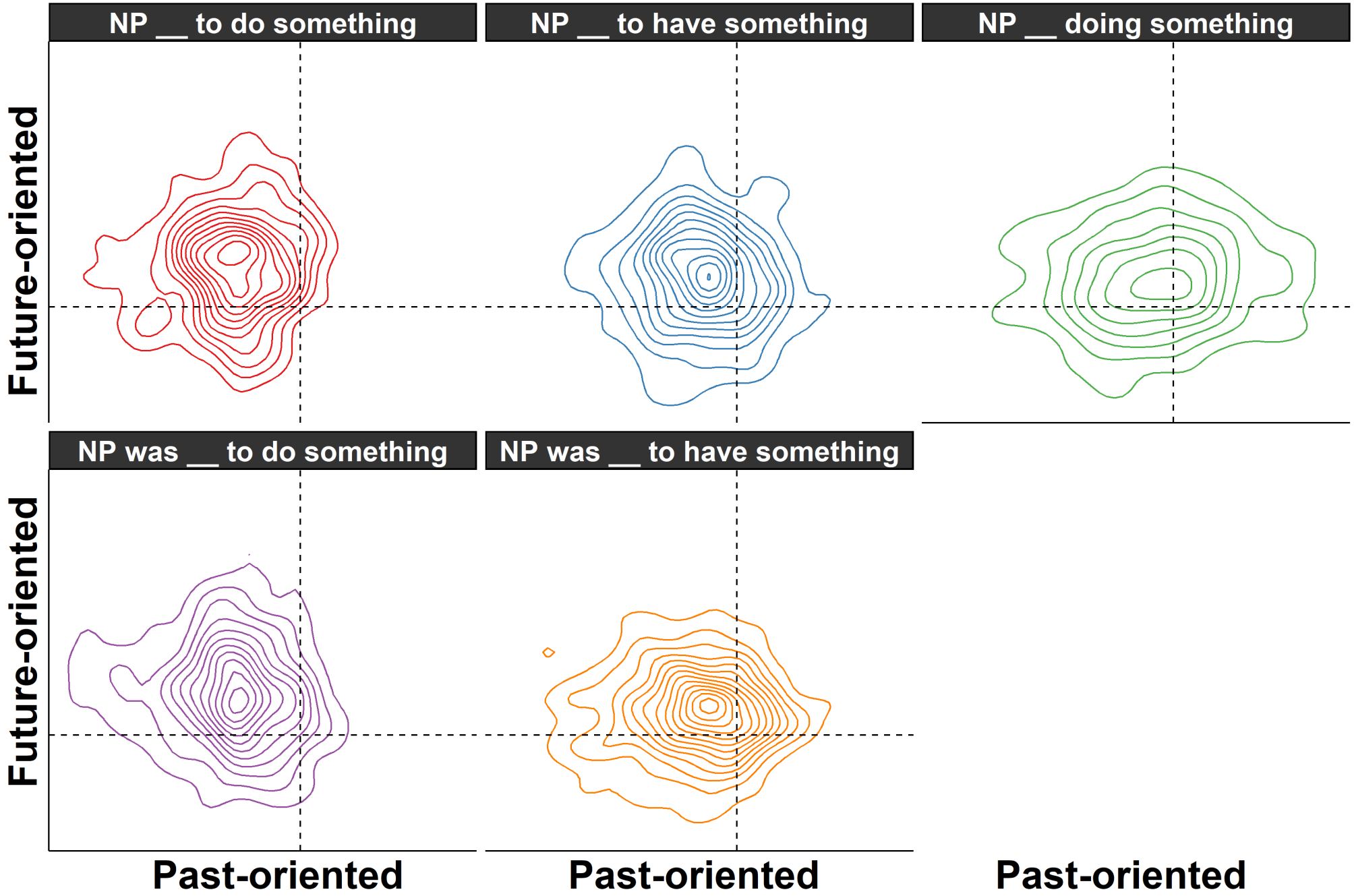
Future-oriented
Future-oriented
Past-oriented
Past-oriented
Past-oriented


NP __ to do something
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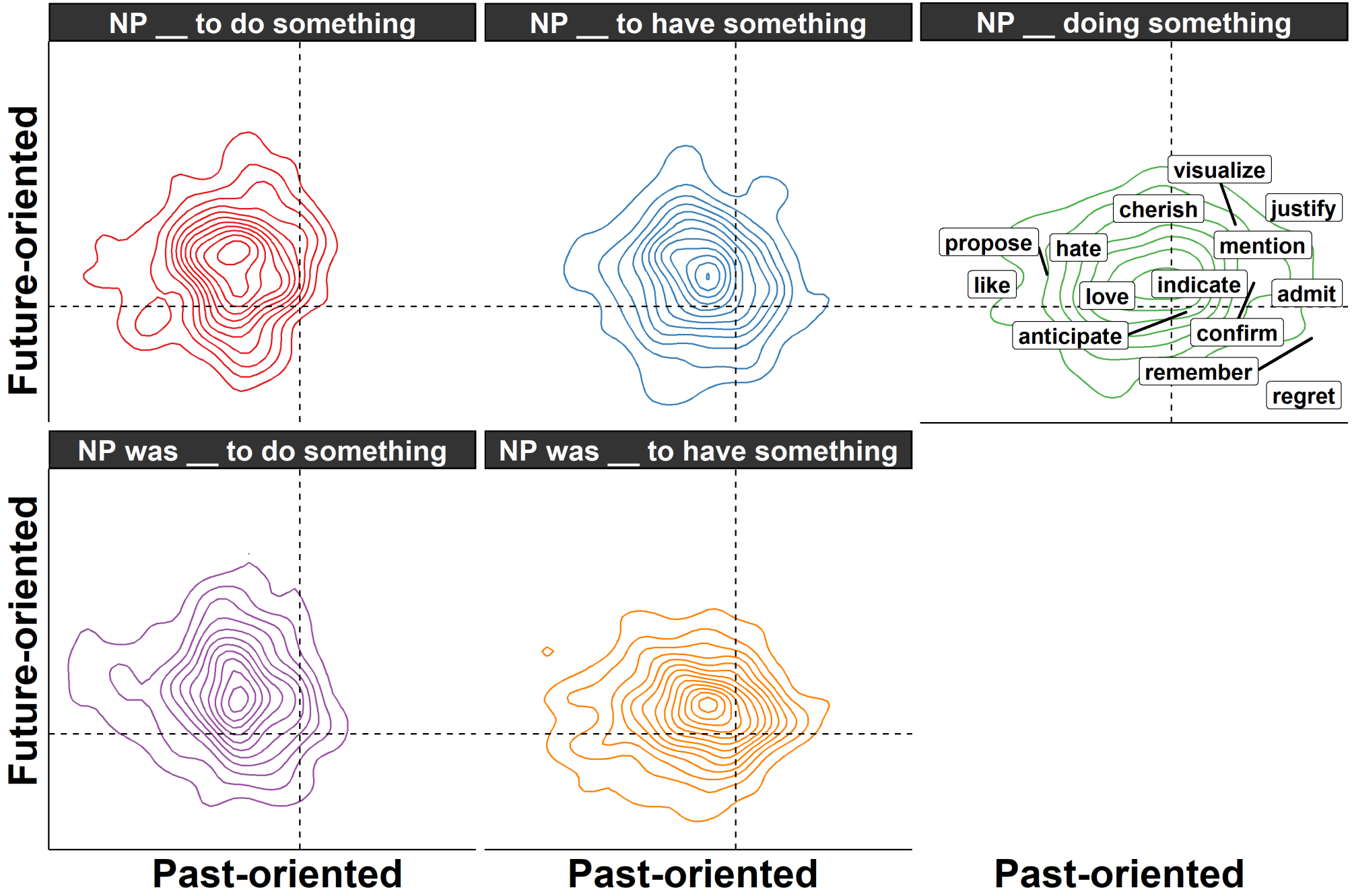
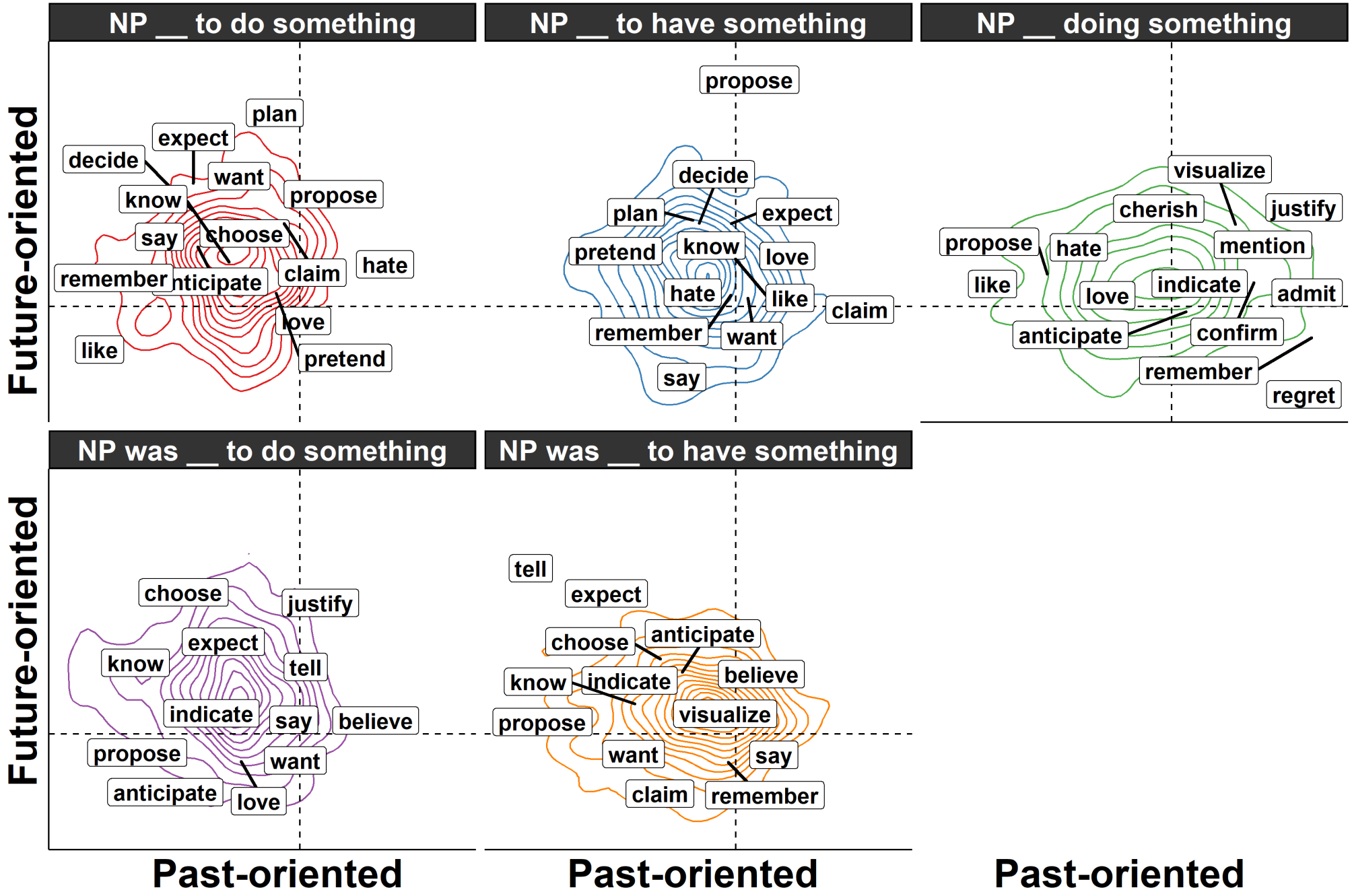
NP was __ to have something
Future-oriented
Future-oriented
Past-oriented
Past-oriented
Past-oriented


NP __ to do something
NP __ to have something
NP __ doing something
NP was __ to do something
NP was __ to have something
Future-oriented
Future-oriented
visualize
cherish
justify
propose
hate
mention
like
love
indicate
admit
anticipate
confirm
remember
regret
Past-oriented
Past-oriented
Past-oriented


NP __ to do something
NP __ to have something
NP __ doing something
NP was __ to do something
NP was __ to have something
Future-oriented
Future-oriented
plan
expect
decide
want
propose
know
say
choose
hate
remember
claim
like
love
pretend
propose
decide
plan
expect
pretend
know
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- **Model Design**

GOAL

- ✓ A way to capture temporal orientation across different possible verb/structure pairings

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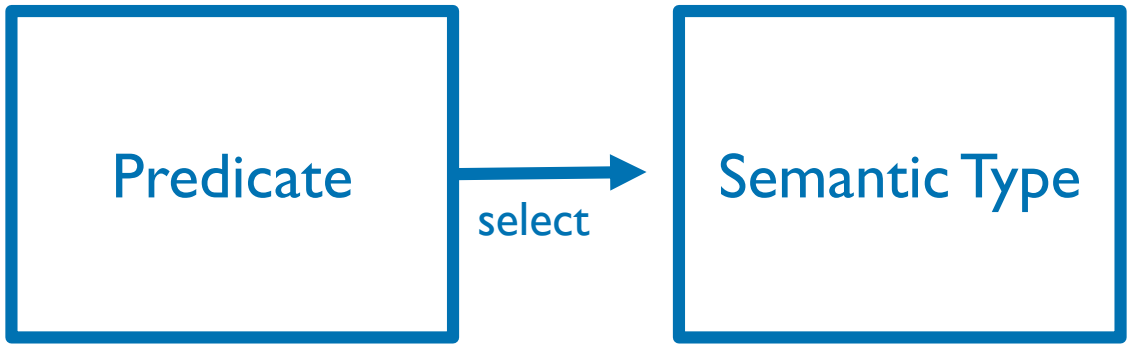
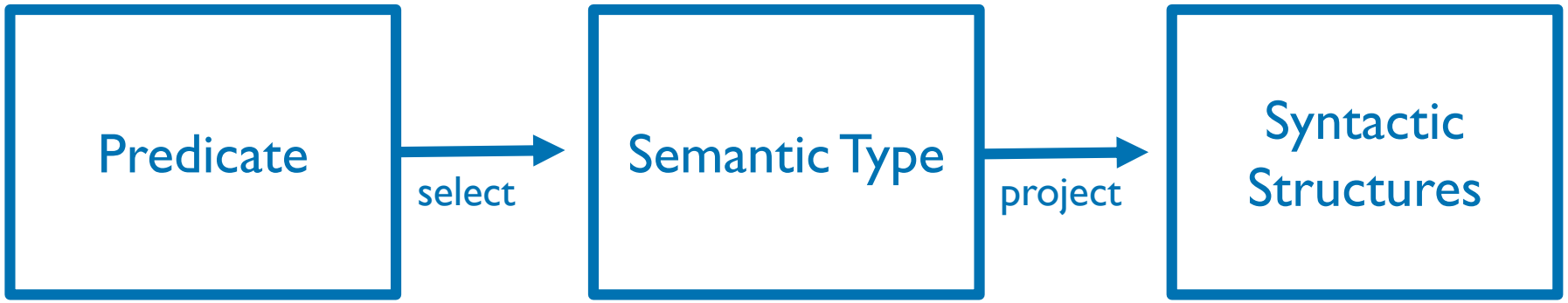
- ✓ A way to capture temporal orientation across different possible verb/structure pairings
- ▪ A way to model our hypotheses relative to this data

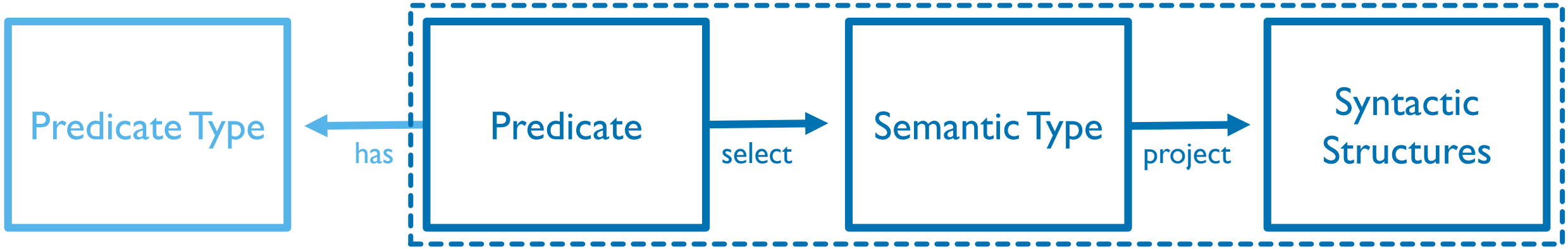
(White and Rawlins 2016)


Predicate


Predicate
select
Semantic Type


Predicate
select
Semantic Type
project
Syntactic Structures

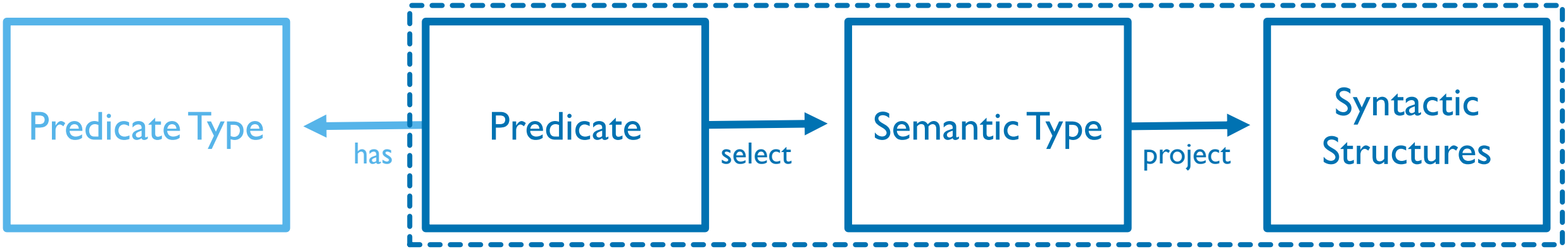
(White & Rawlins 2016)



(An & White 2020)

(White & Rawlins 2016)

Temporal Orientation



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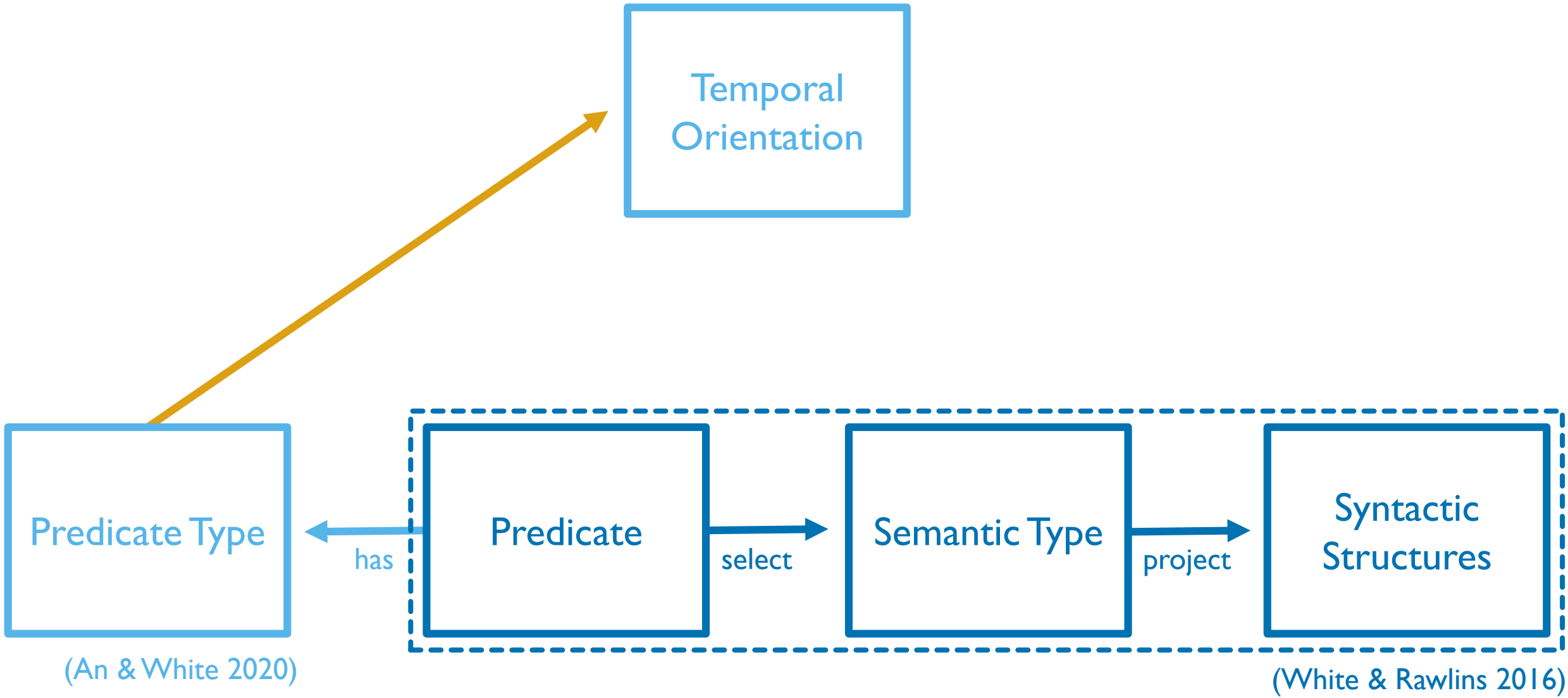
Temporal Orientation
Predicate Type
has
Predicate
select
Semantic Type
project
Syntactic Structures
(An & White 2020)
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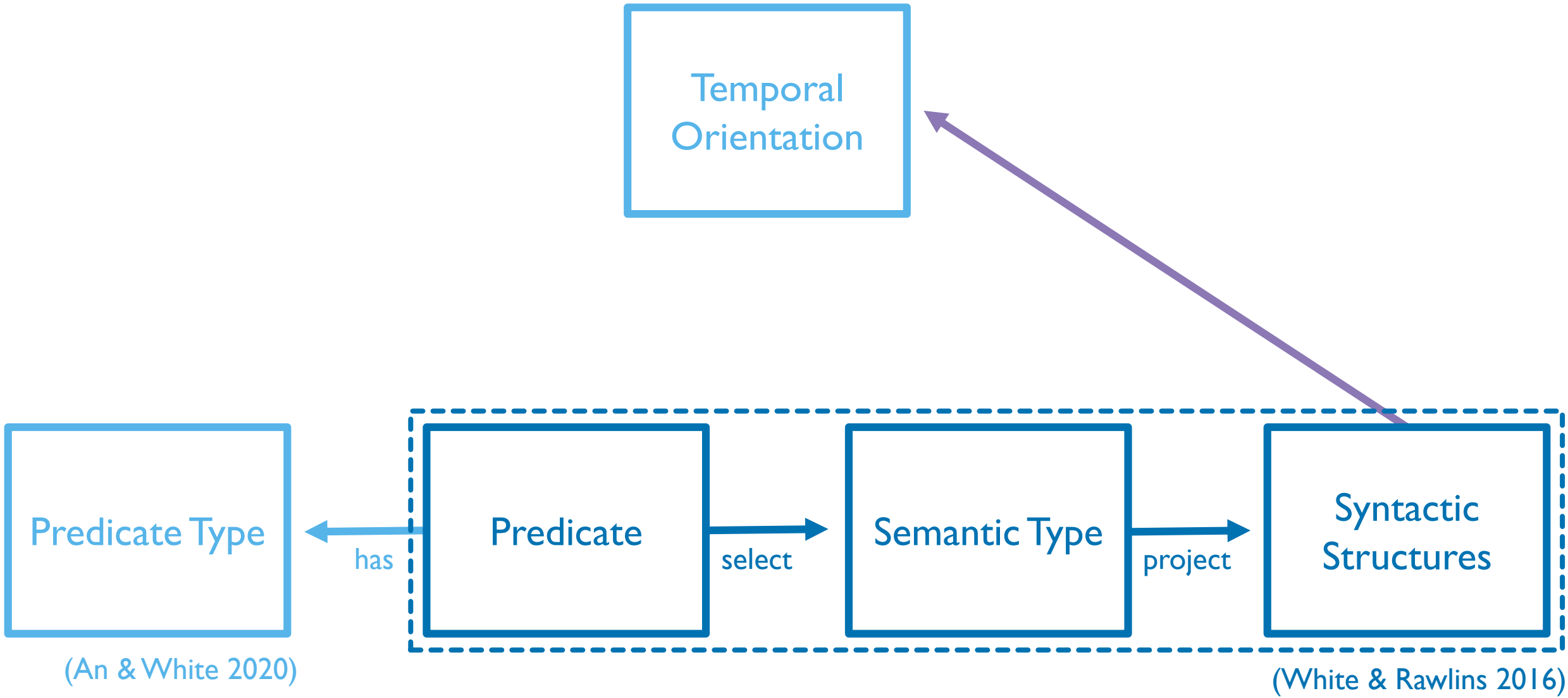
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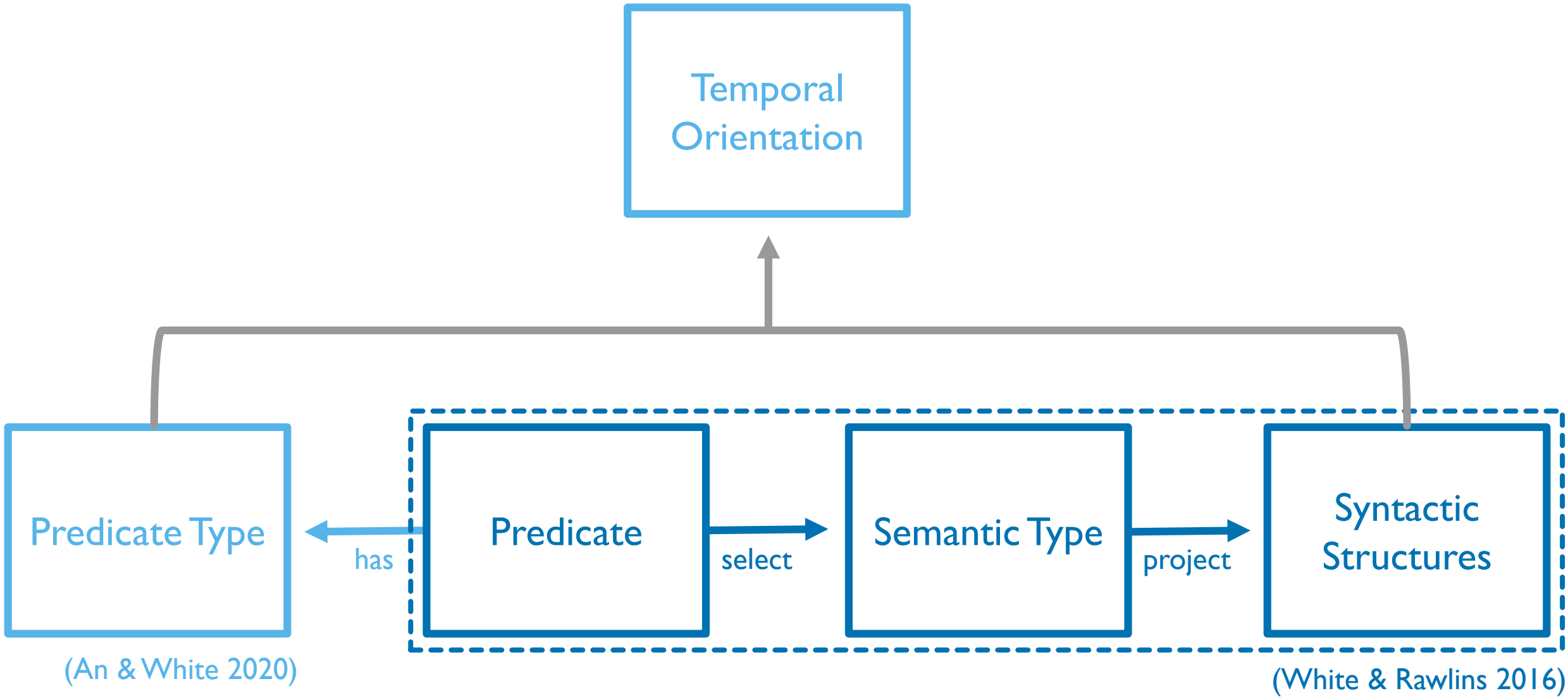
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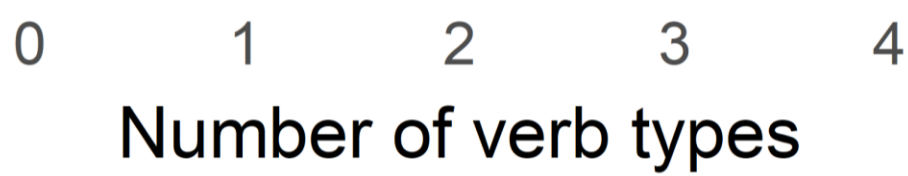
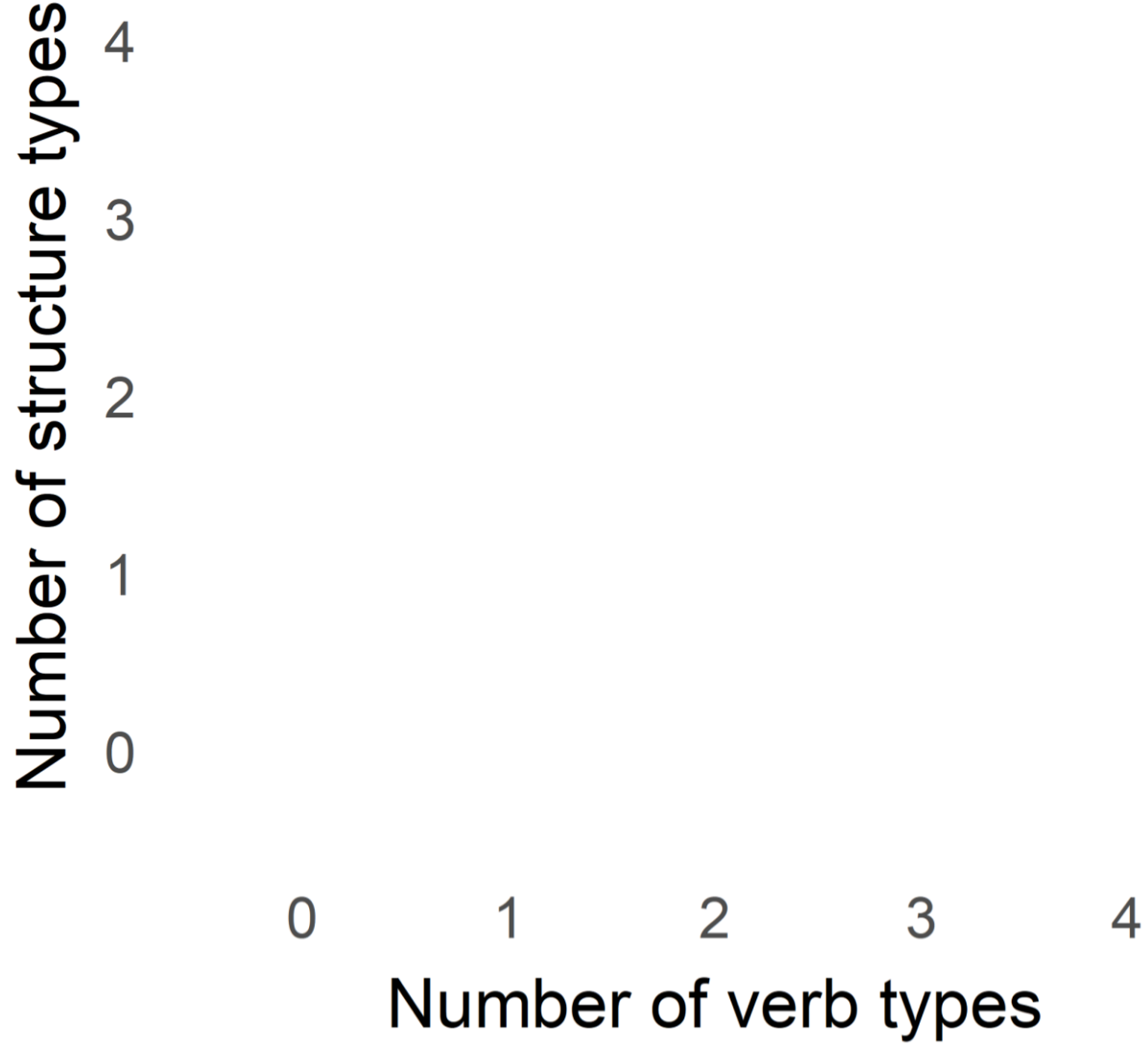
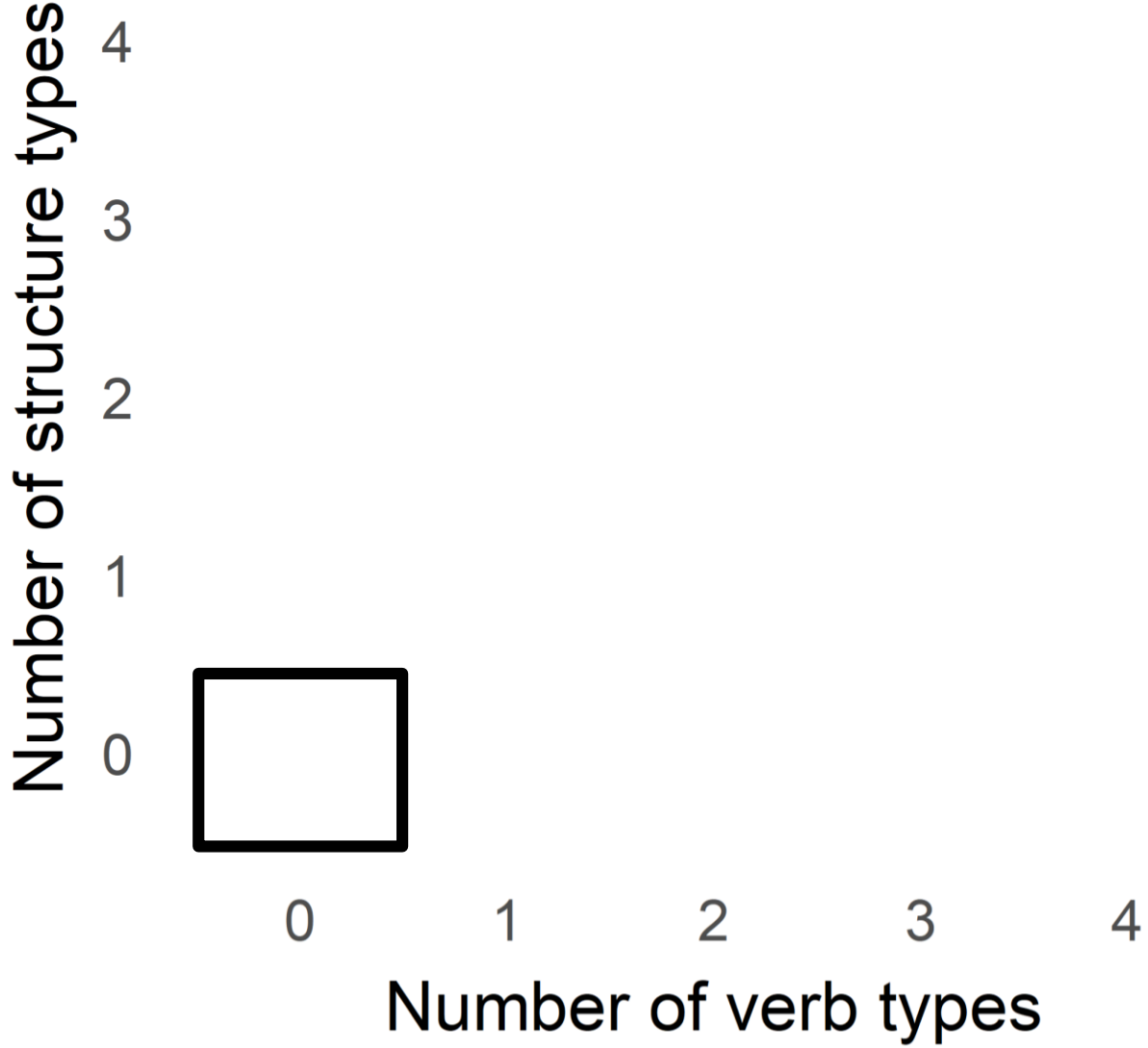
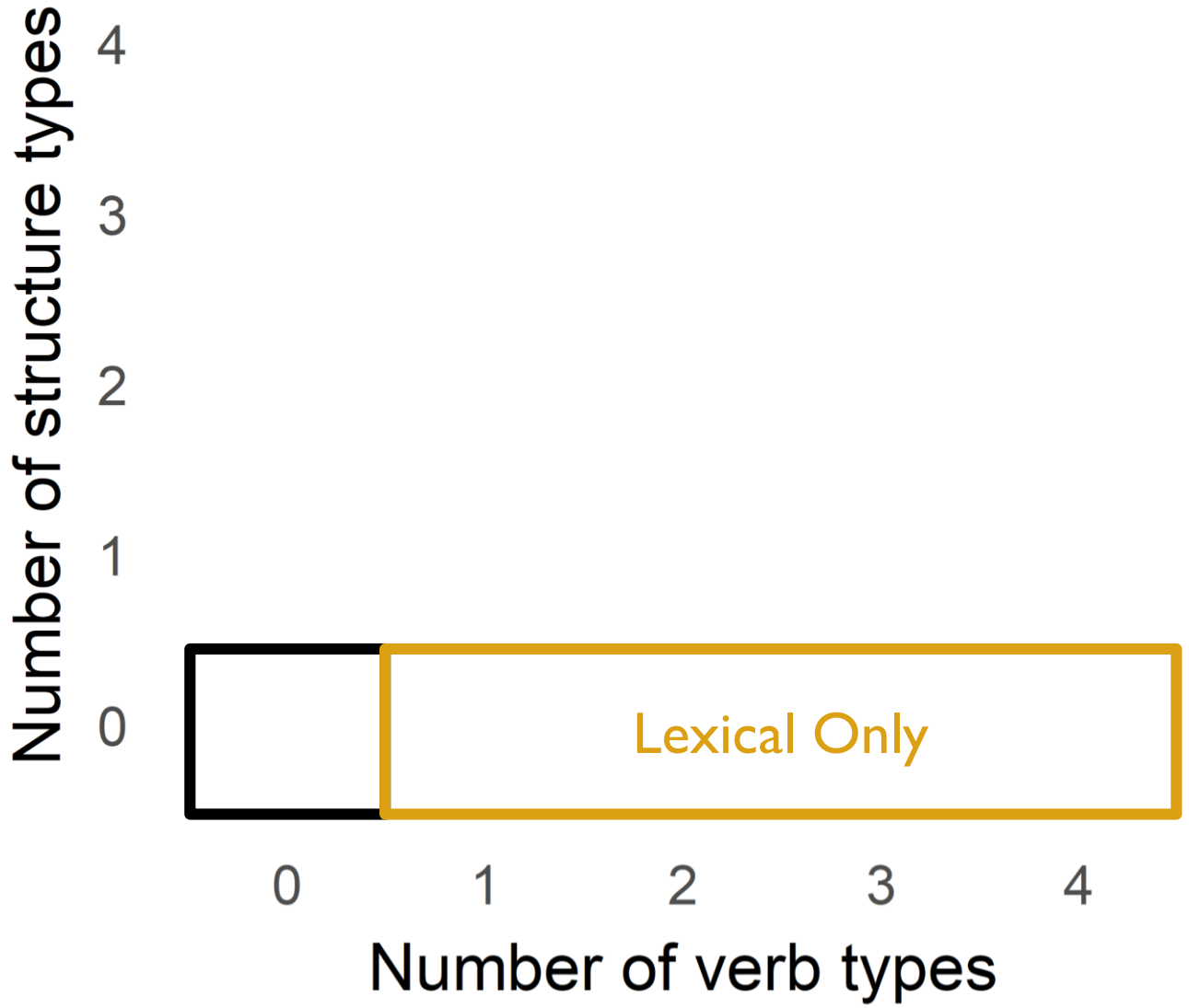
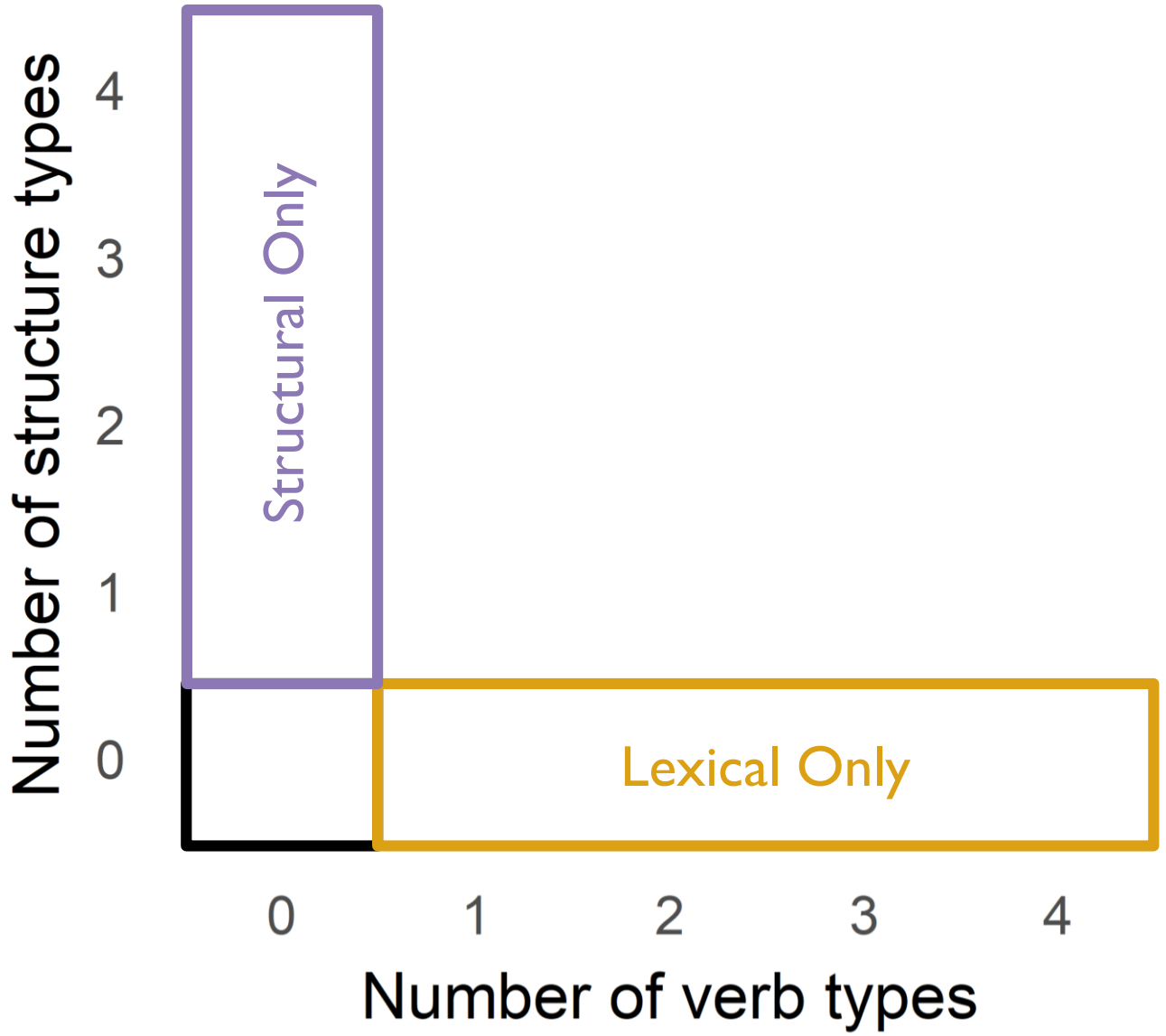
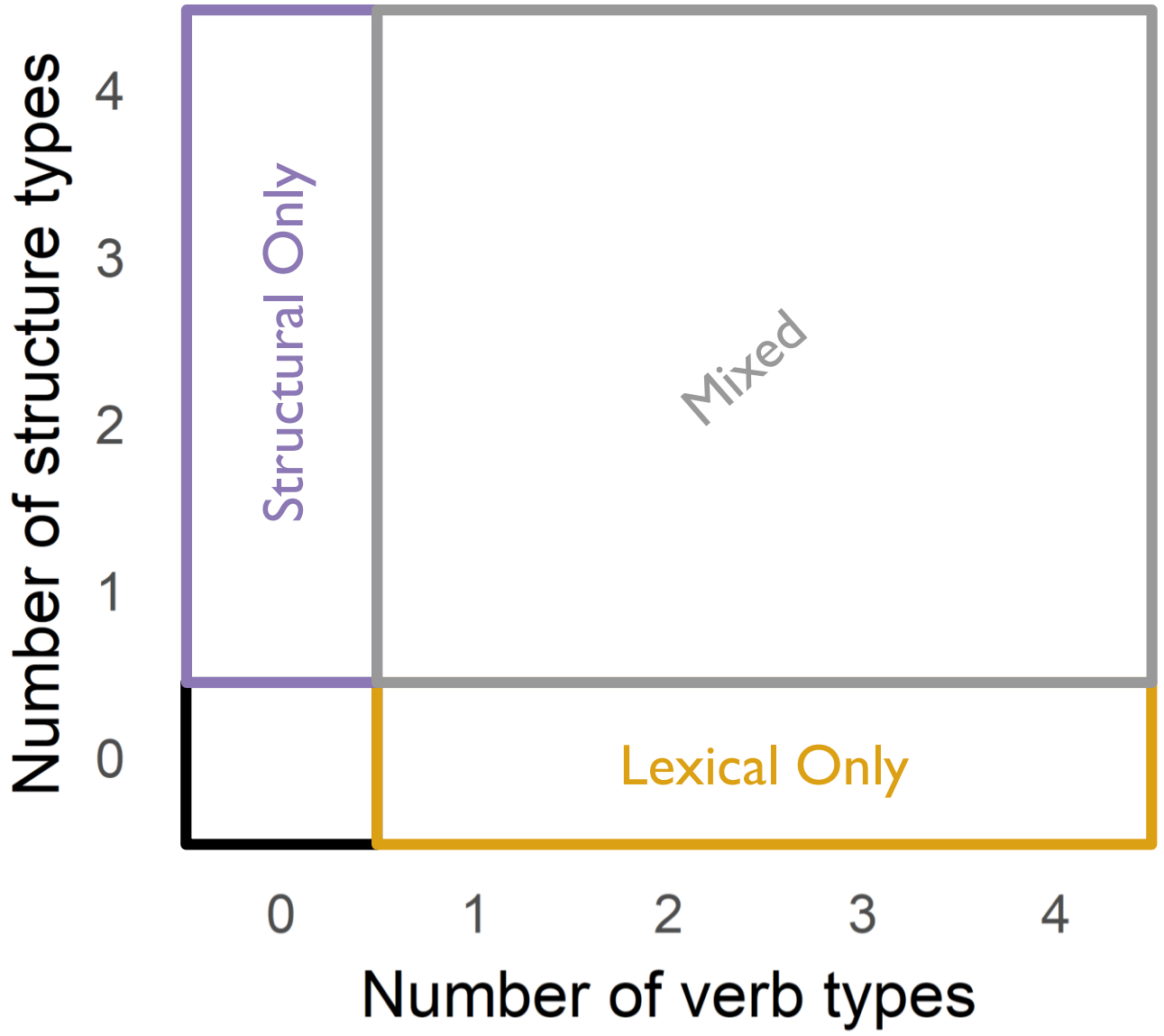

0
1
2
3
4
Number of verb types

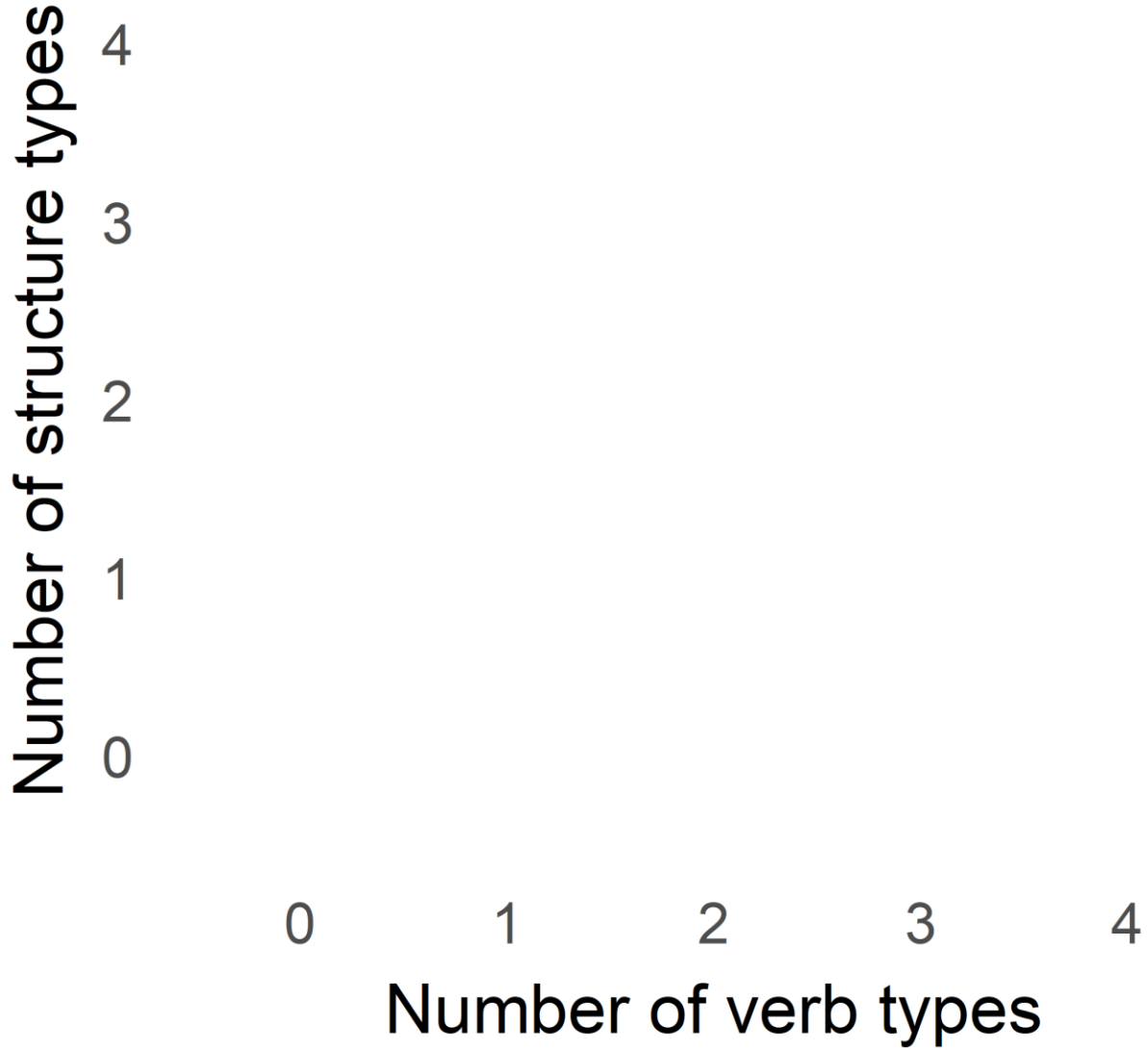

Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types

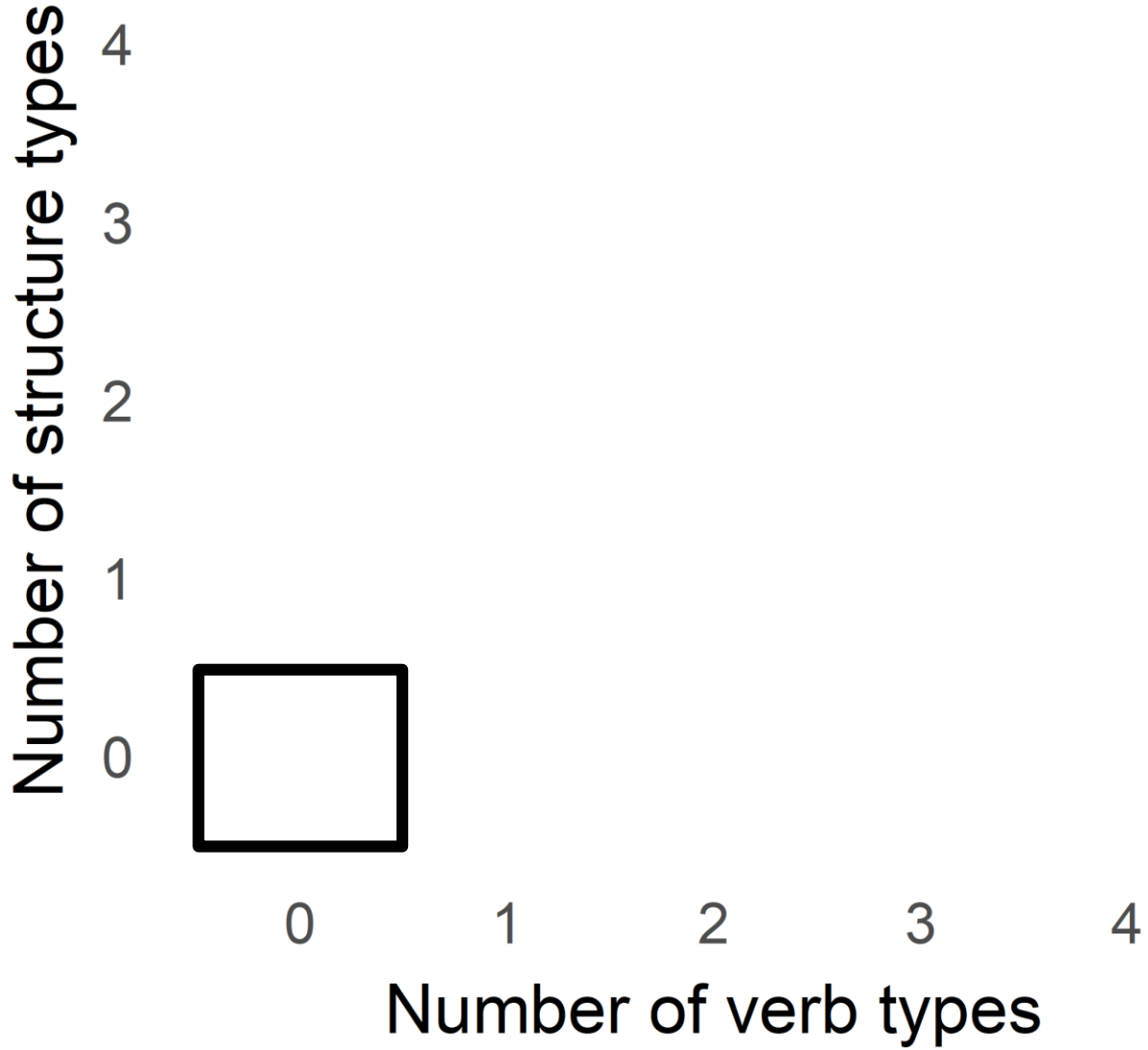

Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types

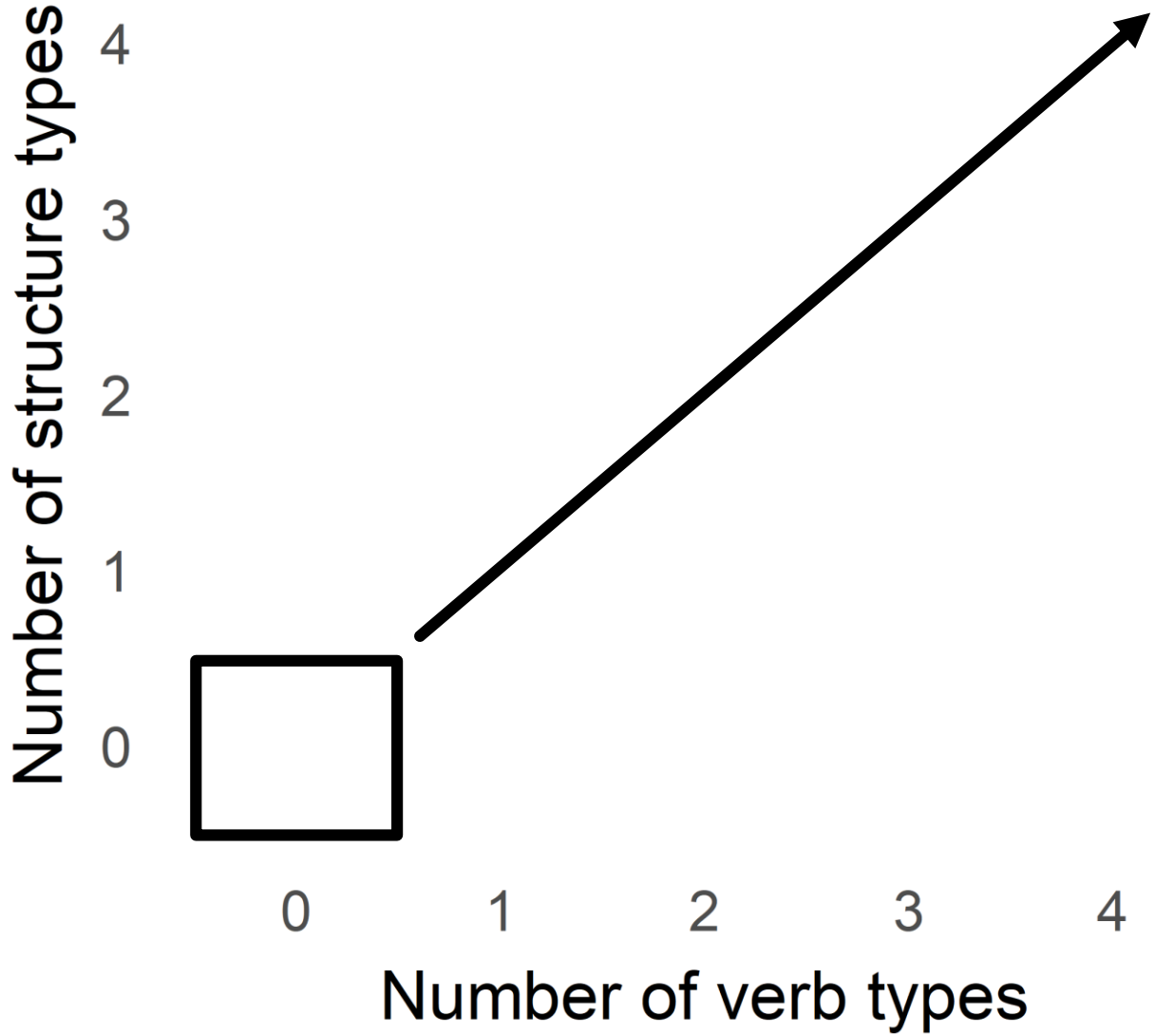

Number of structure types
4
3
2
1
0
Lexical Only
0
1
2
3
4
Number of verb types

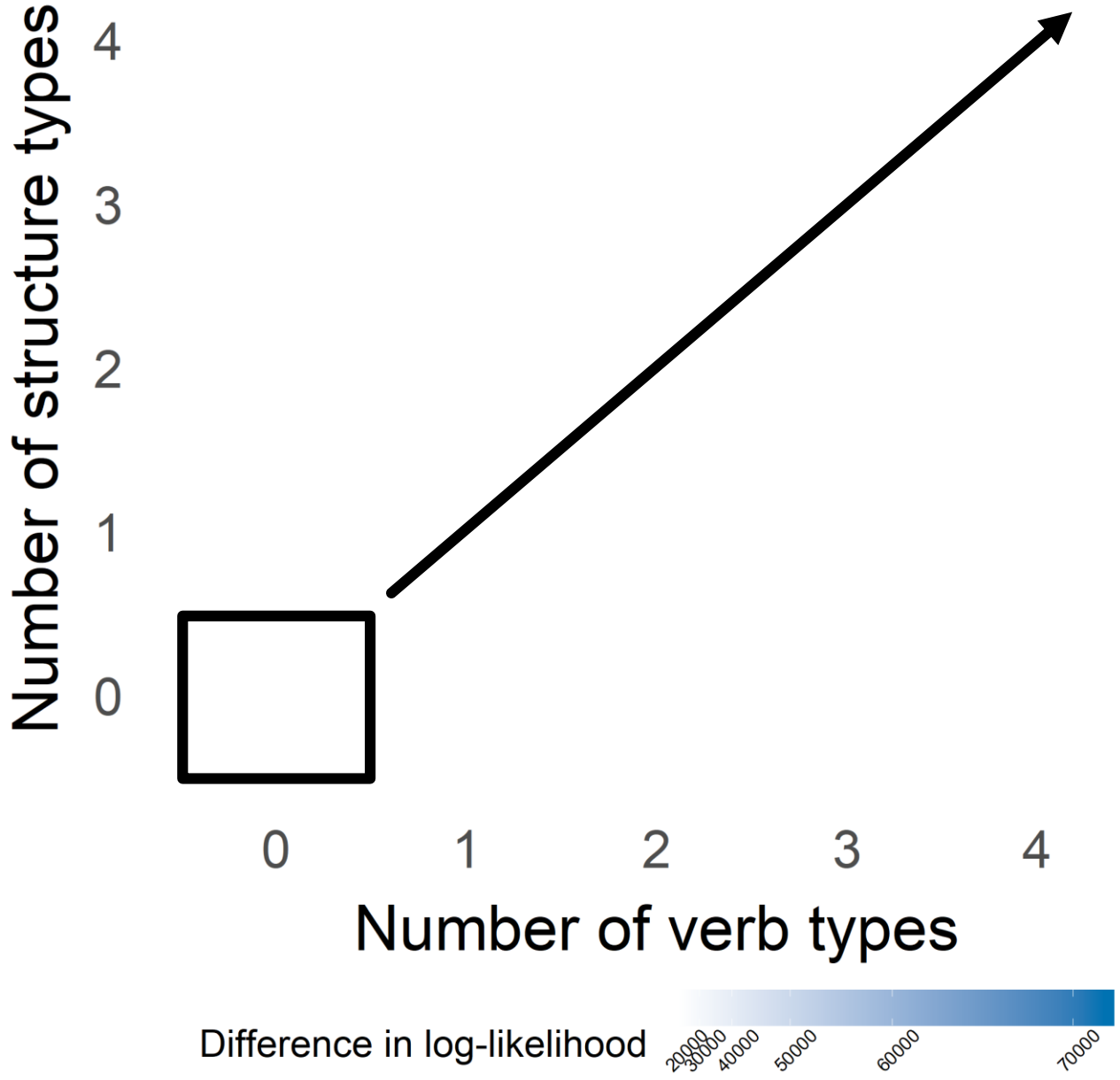

Number of structure types
4
3
2
1
0
Structural Only
Lexical Only
0
1
2
3
4
Number of verb types

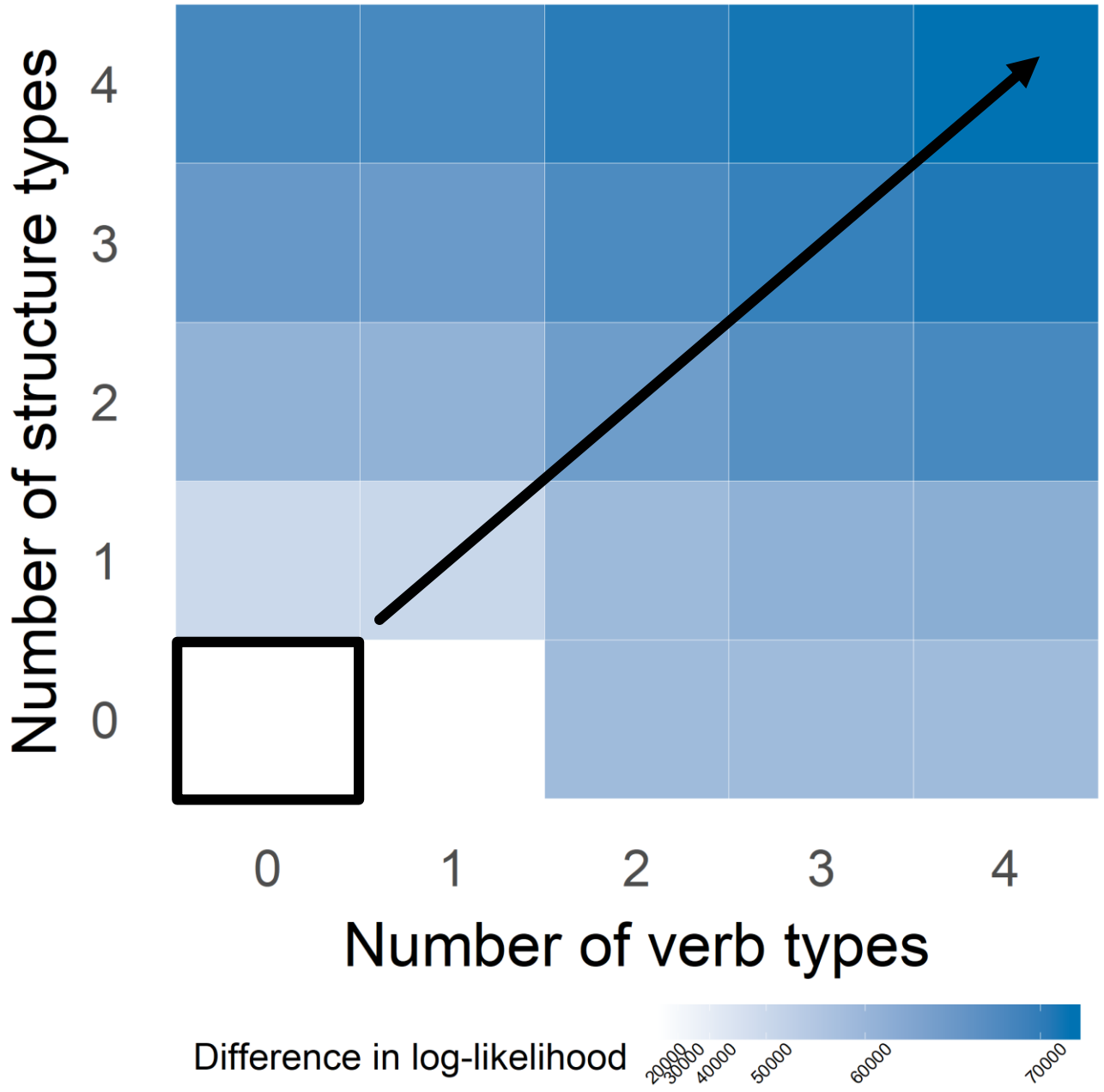

Number of structure types
4
3
2
1
0
Structural Only
Mixed
Lexical Only
0
1
2
3
4
Number of verb types


Number of structure types
0
1
2
3
4
0
1
2
3
4
Number of verb types


Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types

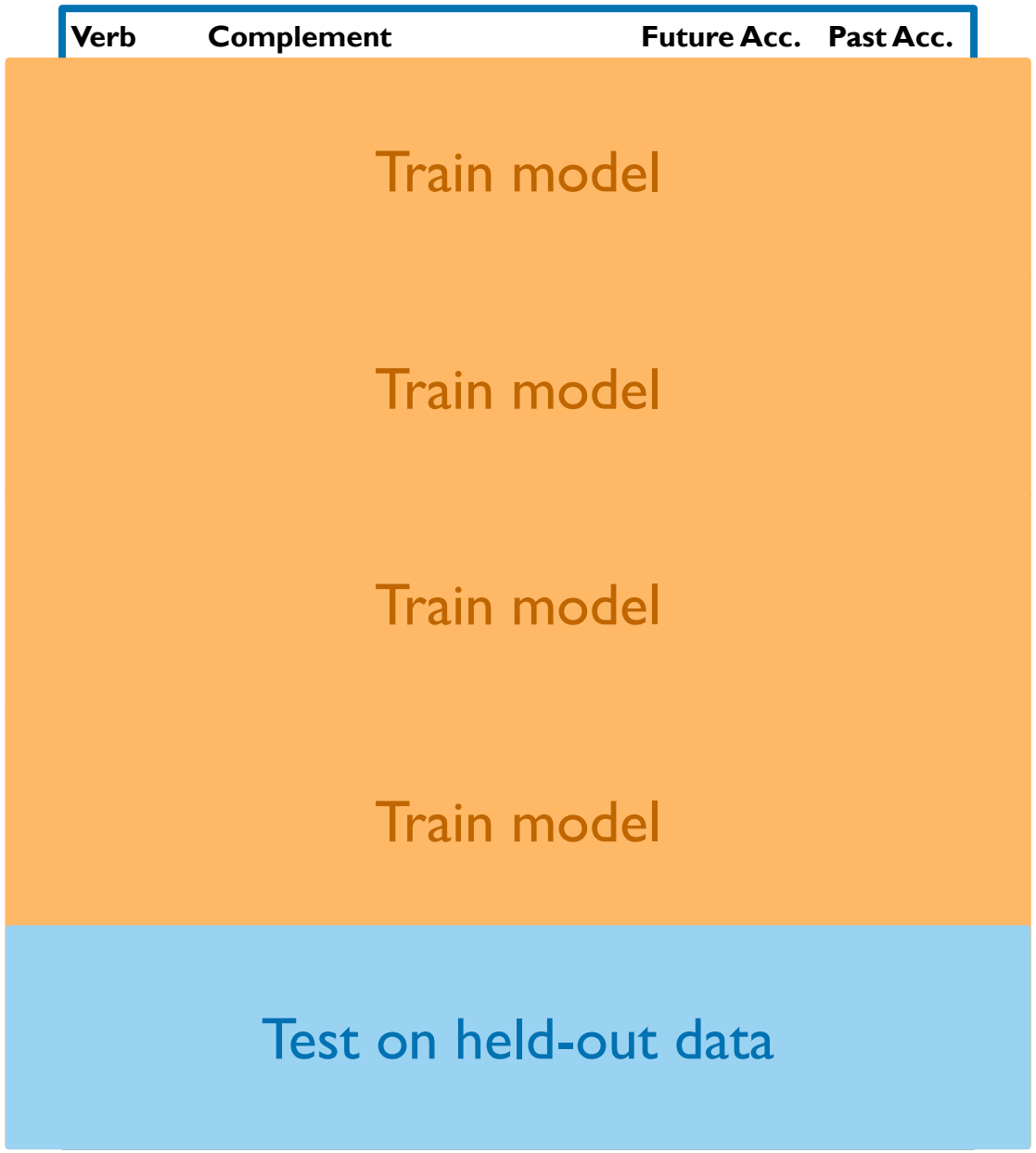

Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types

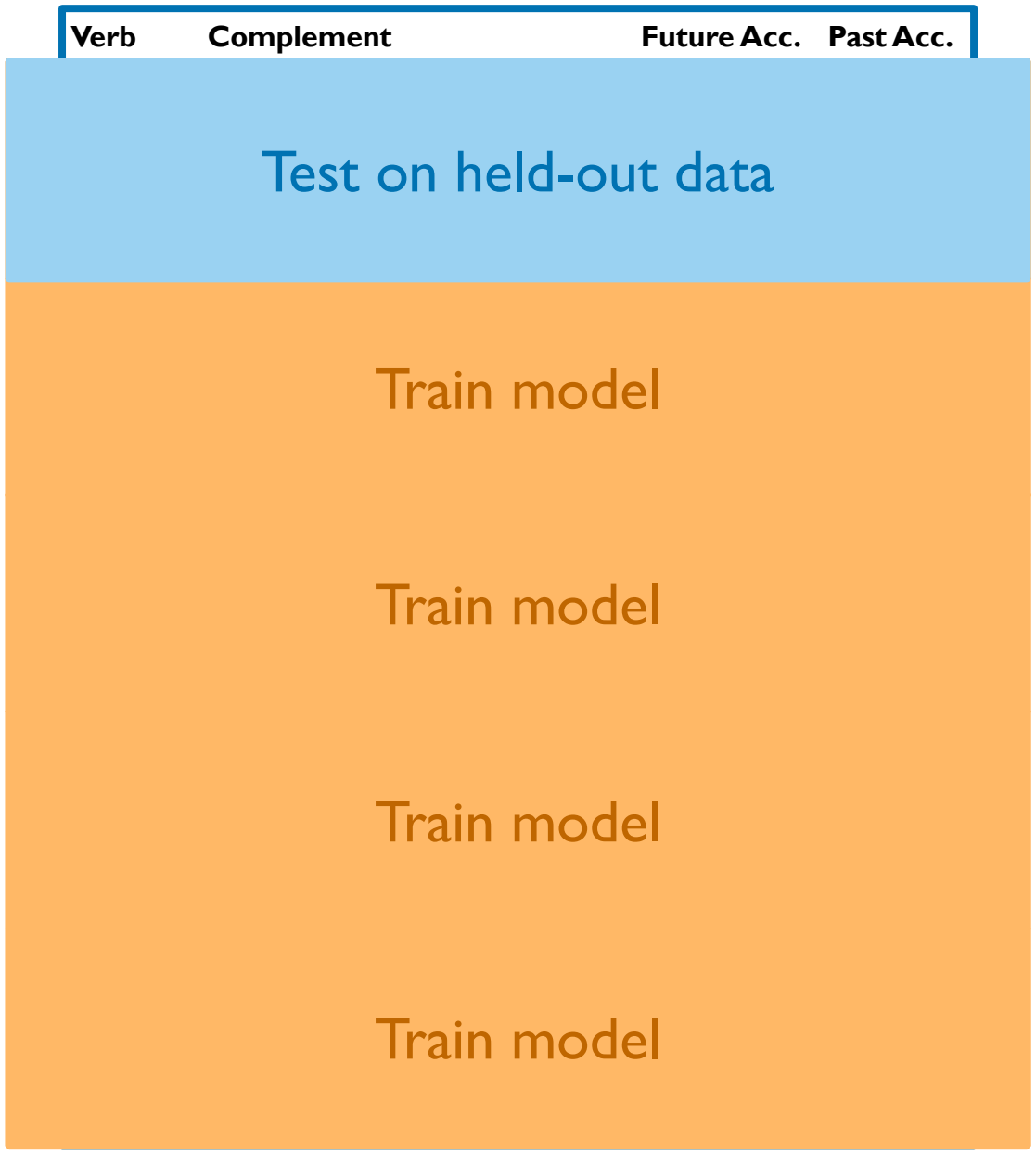

Number of structure types
0
1
2
3
4
0
1
2
3
4
Number of verb types
Difference in log-likelihood
20000
30000
40000
50000
60000
70000

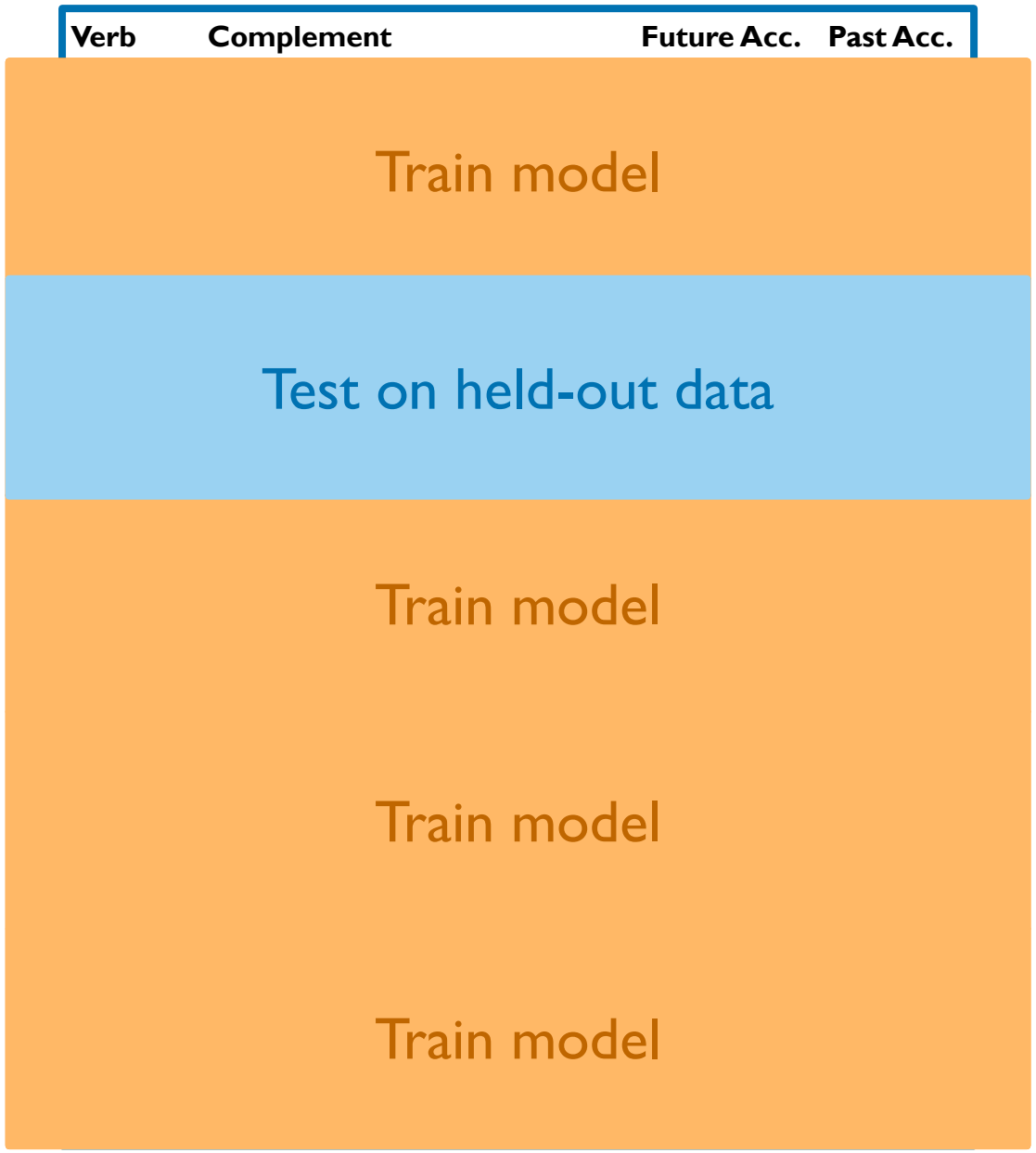

Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types
Difference in log-likelihood
20000
30000
40000
50000
60000
70000

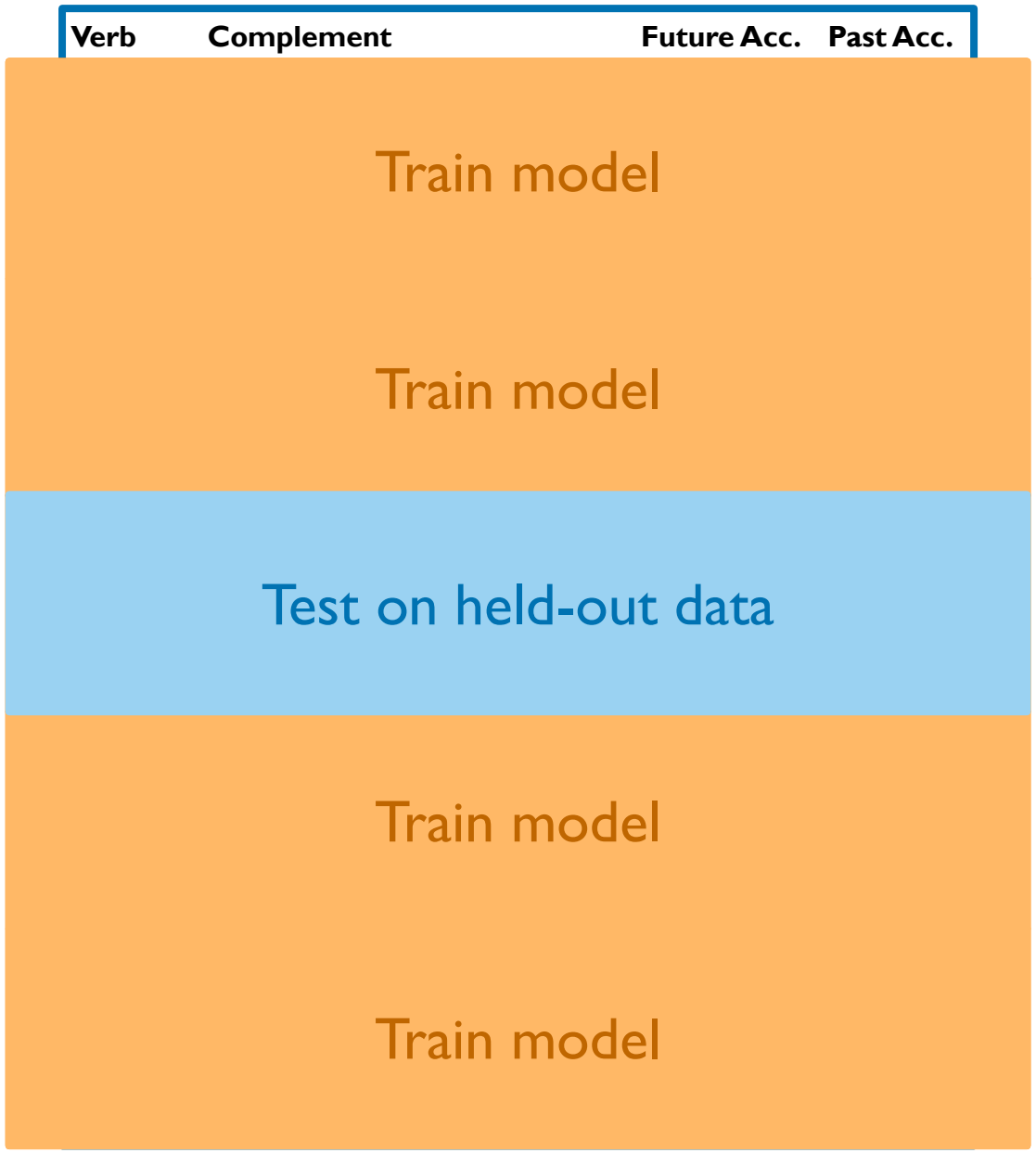
Verb	Complement	Future Acc.	Past Acc.
abhor	NP Ved VPing	-0.503955	0.413169
abhor	NP was Ved to VP[+eventive]	0.134924	-1.559801
absolve	NP Ved to VP[+eventive]	0.948428	-2.079783
accept	NP Ved VPing	4.774069	1.883071
accept	NP Ved to VP[-eventive]	2.434219	-1.854628
accept	NP was Ved to VP[+eventive]	2.946932	-2.002958
acclaim	NP Ved VPing	-2.137957	0.221483
acclaim	NP Ved to VP[+eventive]	-2.549958	-0.554269
acclaim	NP was Ved to VP[-eventive]	1.382240	-0.742686
add	NP Ved VPing	3.664288	-3.777042
add	NP Ved to VP[+eventive]	0.503324	-0.172519
add	NP was Ved to VP[+eventive]	1.878762	-2.685818
address	NP Ved VPing	1.876711	3.596447
address	NP was Ved to VP[+eventive]	0.928784	-1.928204
admire	NP Ved VPing	-0.070897	-0.475992
admit	NP Ved VPing	-0.690028	4.566390
admit	NP Ved to VP[+eventive]	-3.257618	0.955866
admit	NP Ved to VP[-eventive]	0.373650	-2.930481
admit	NP was Ved to VP[+eventive]	-1.103509	1.371476
admit	NP was Ved to VP[-eventive]	0.318550	1.463886

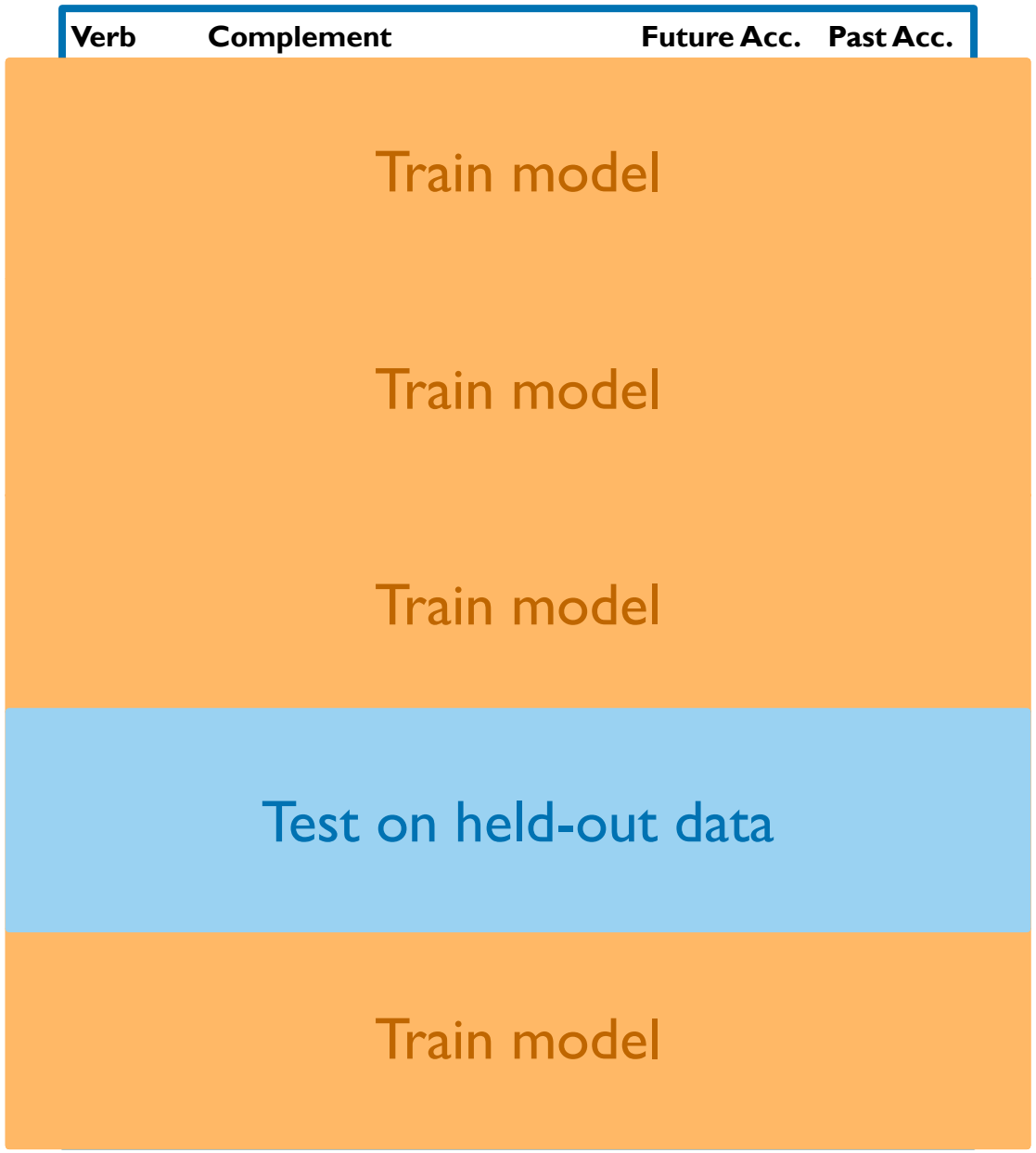
Verb	Complement	Future Acc.	Past Acc.
abhor	NP Ved VPing	-0.503955	0.413169
abhor	NP was Ved to VP[+eventive]	0.134924	-1.559801
absolve	NP Ved to VP[+eventive]	0.948428	-2.079783
accept	NP Ved VPing	4.774069	1.883071
accept	NP Ved to VP[-eventive]	2.434219	-1.854628
accept	NP was Ved to VP[+eventive]	2.946932	-2.002958
acclaim	NP Ved VPing	-2.137957	0.221483
acclaim	NP Ved to VP[+eventive]	-2.549958	-0.554269
acclaim	NP was Ved to VP[-eventive]	1.382240	-0.742686
add	NP Ved VPing	3.664288	-3.777042
add	NP Ved to VP[+eventive]	0.503324	-0.172519
add	NP was Ved to VP[+eventive]	1.878762	-2.685818
address	NP Ved VPing	1.876711	3.596447
address	NP was Ved to VP[+eventive]	0.928784	-1.928204
admire	NP Ved VPing	-0.070897	-0.475992
admit	NP Ved VPing	-0.690028	4.566390
admit	NP Ved to VP[+eventive]	-3.257618	0.955866
admit	NP Ved to VP[-eventive]	0.373650	-2.930481
admit	NP was Ved to VP[+eventive]	-1.103509	1.371476
admit	NP was Ved to VP[-eventive]	0.318550	1.463886


Verb
Complement
Future Acc.
Past Acc.
Train model
Train model
Train model
Train model
Test on held-out data


Verb
Complement
Future Acc.
Past Acc.
Test on held-out data
Train model
Train model
Train model
Train model


Verb
Complement
Future Acc.
Past Acc.
Train model
Test on held-out data
Train model
Train model
Train model


Verb
Complement
Future Acc.
Past Acc.
Train model
Train model
Test on held-out data
Train model
Train model


Verb
Complement
Future Acc.
Past Acc.
Train model
Train model
Train model
Test on held-out data
Train model

TALK OUTLINE

- Introduction
- Three Hypotheses
- Data Collection
- Model Design

TALK OUTLINE

- Introduction
- Three Hypotheses
- Data Collection
- Model Design
- **Analysis and Results**

Number of structure types

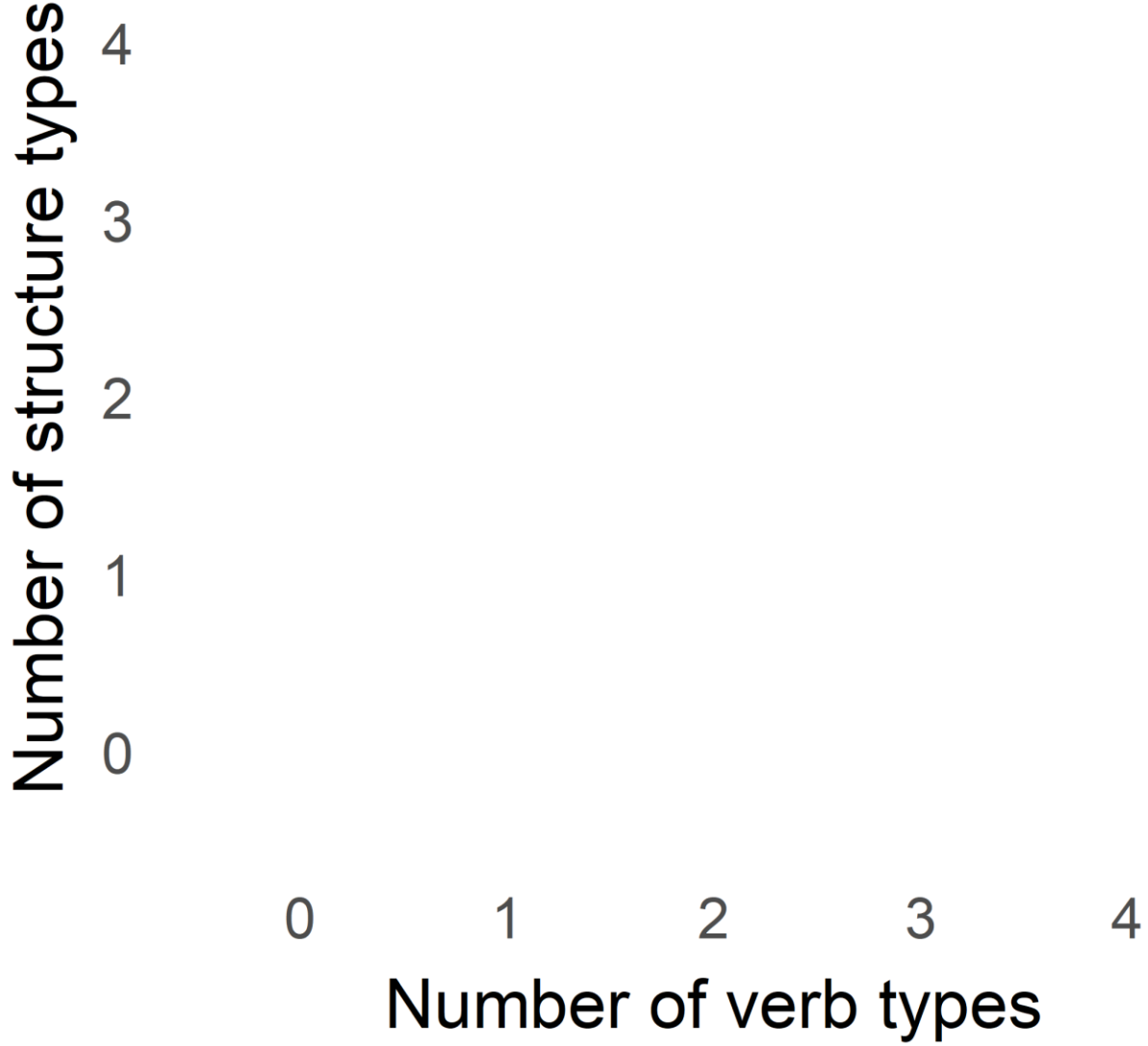
4

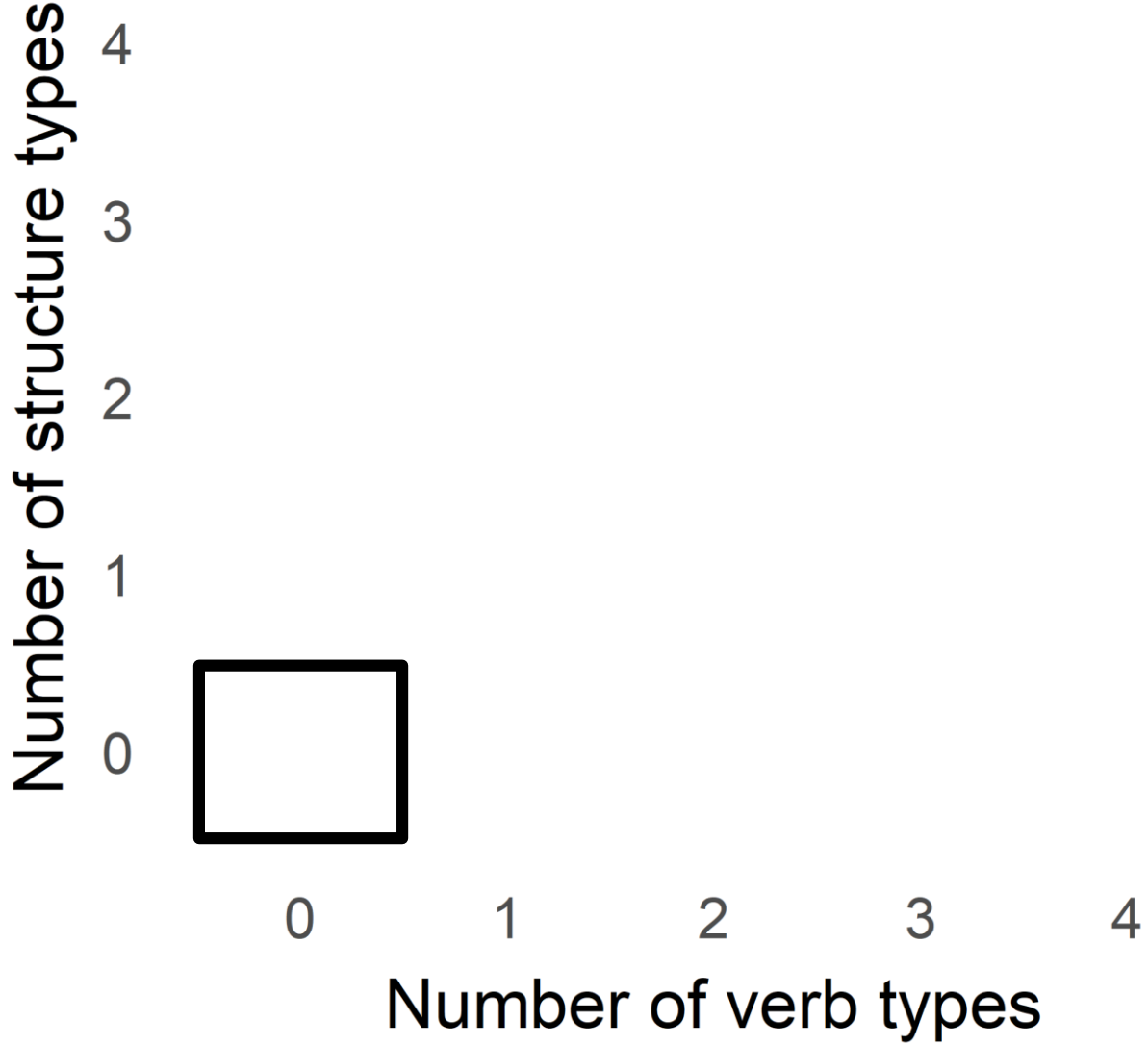
3

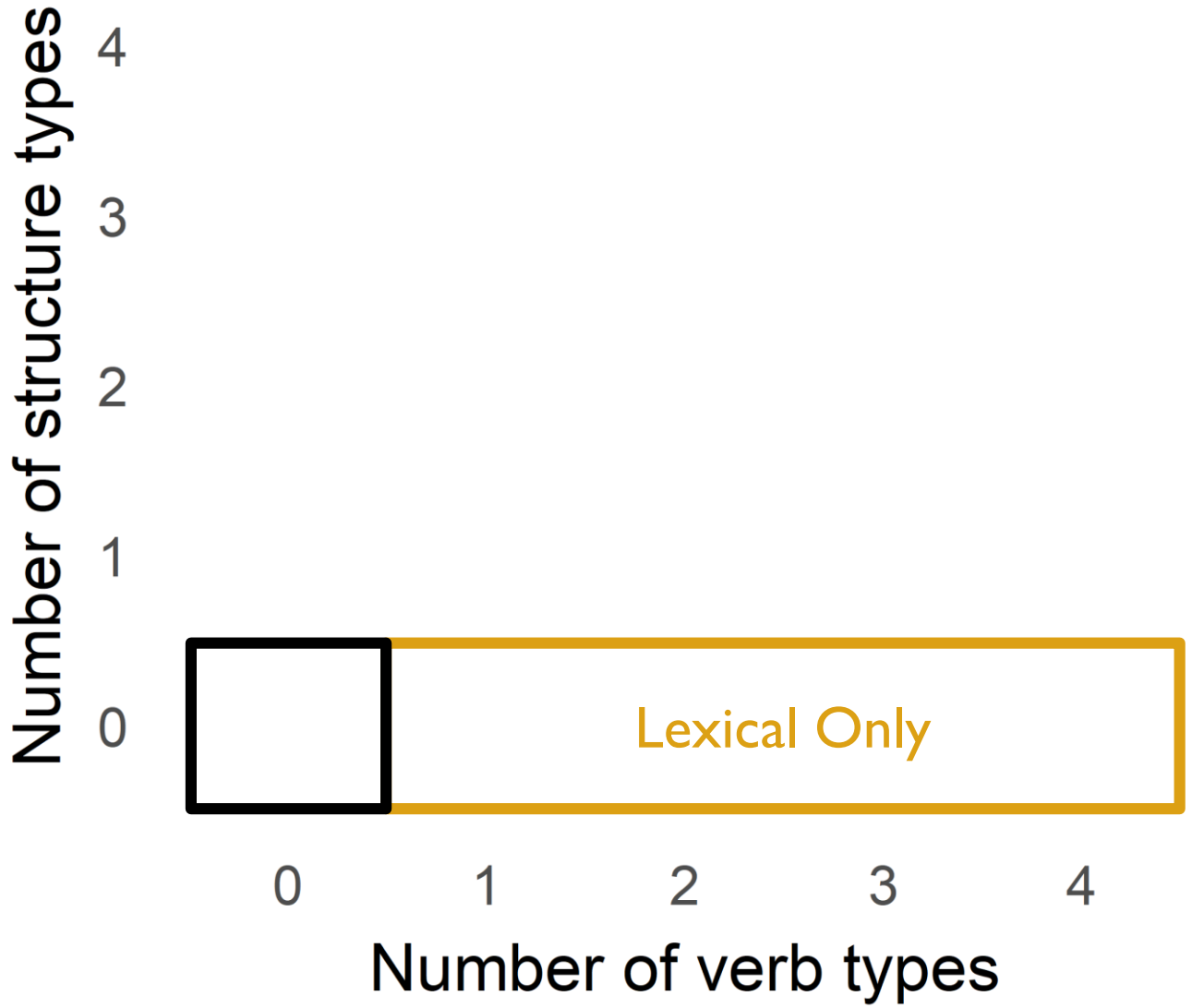
2

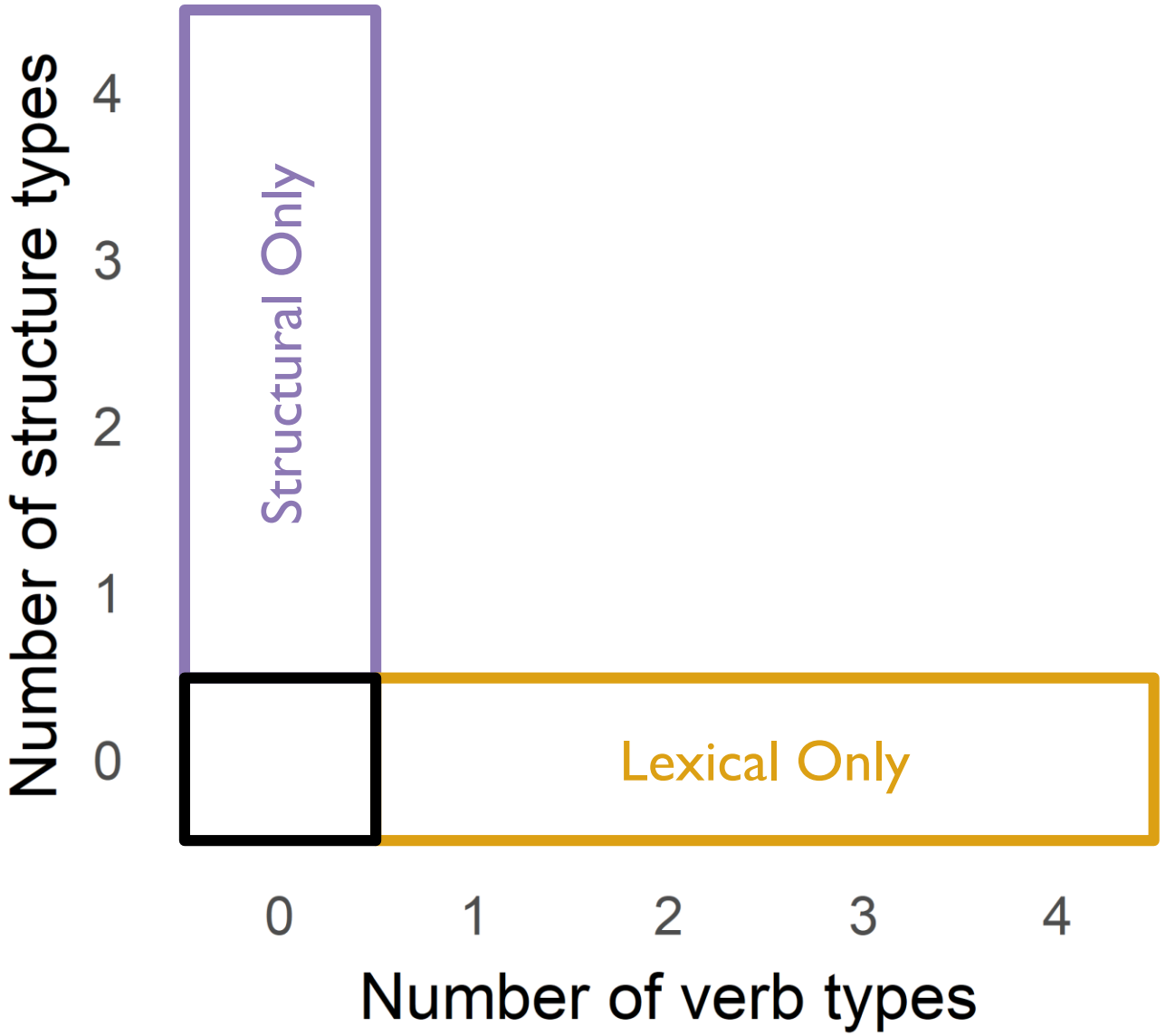
1

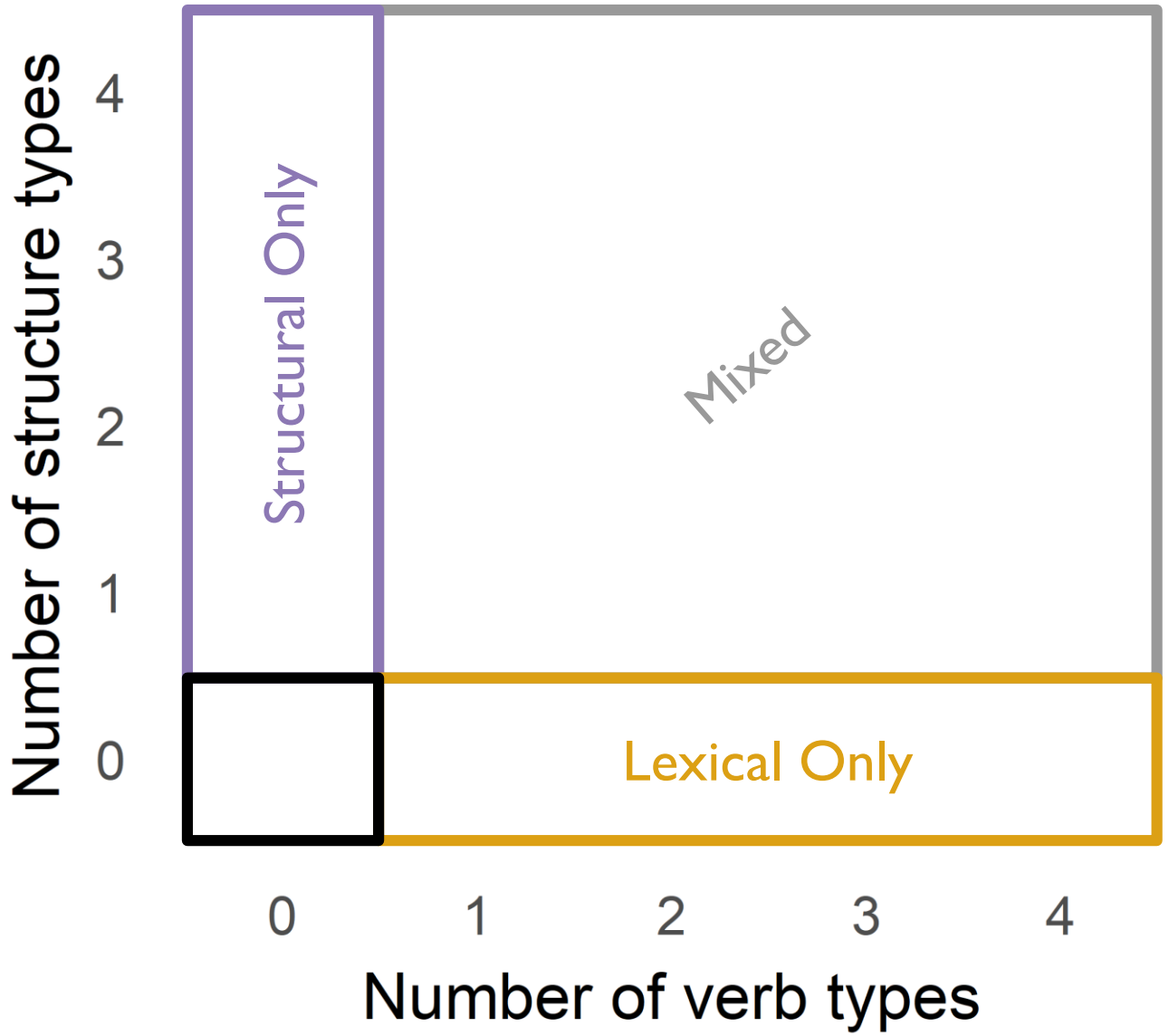
0

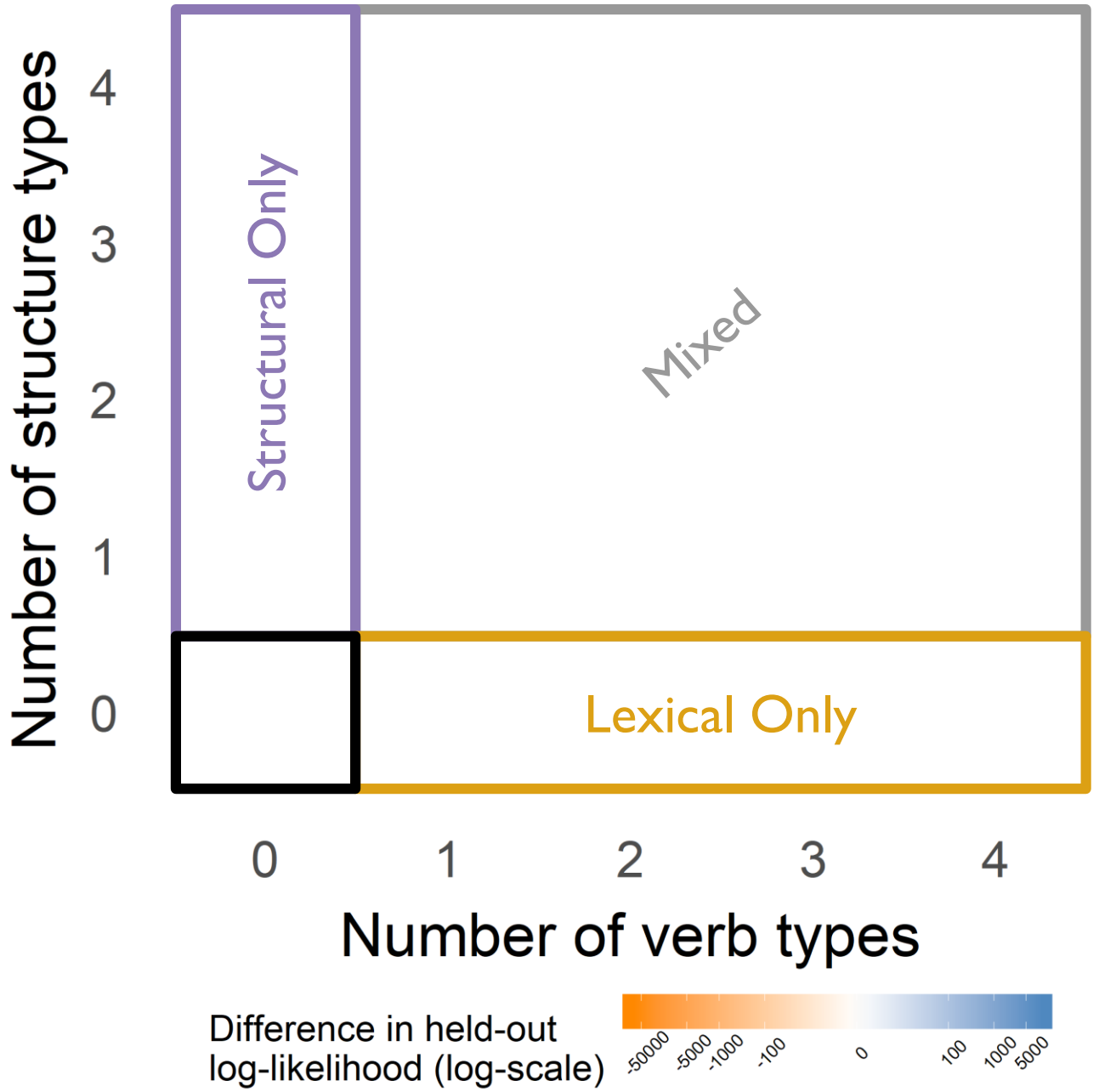

Number of structure types
0
1
2
3
4
0
1
2
3
4
Number of verb types

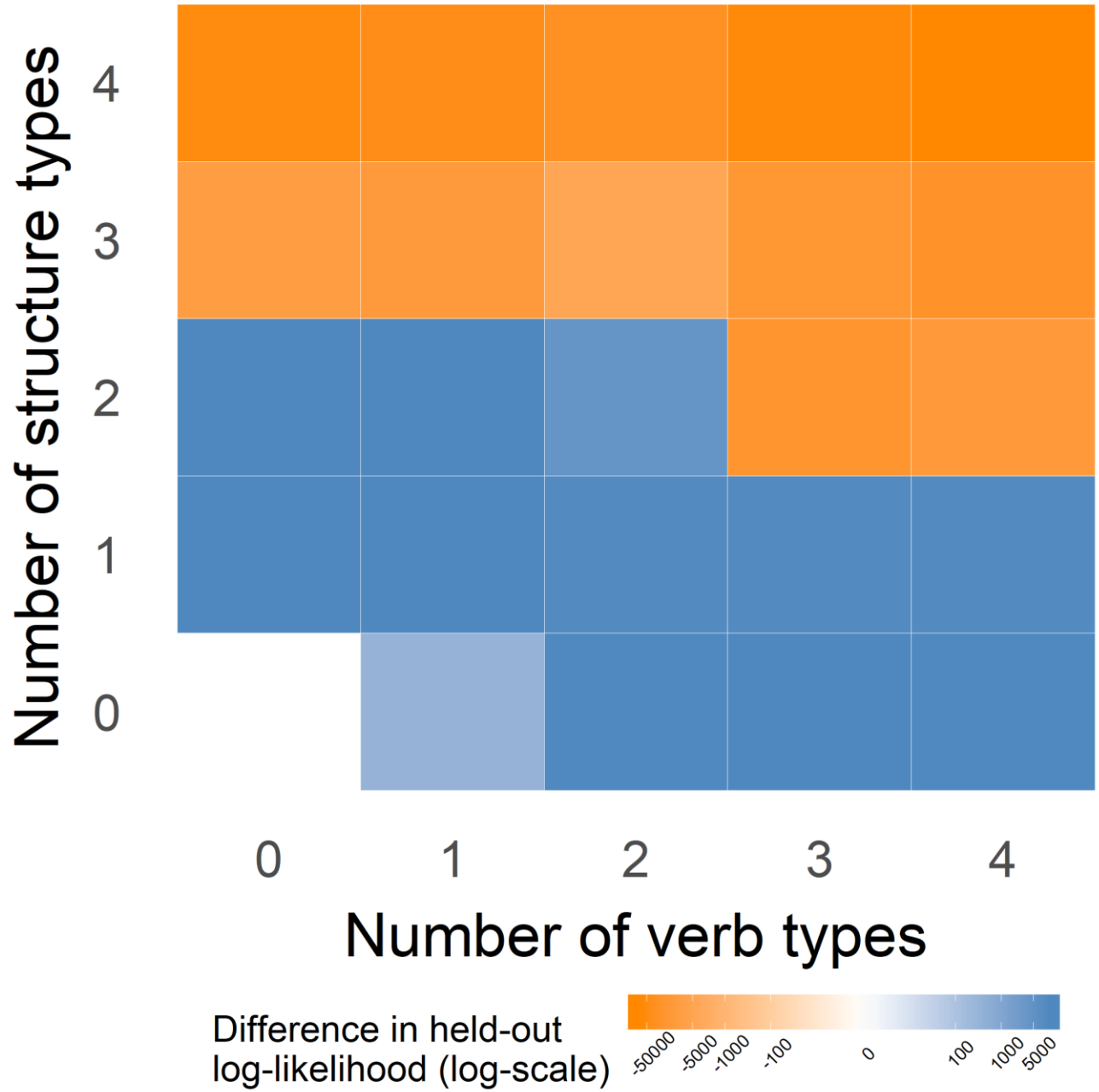

Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types

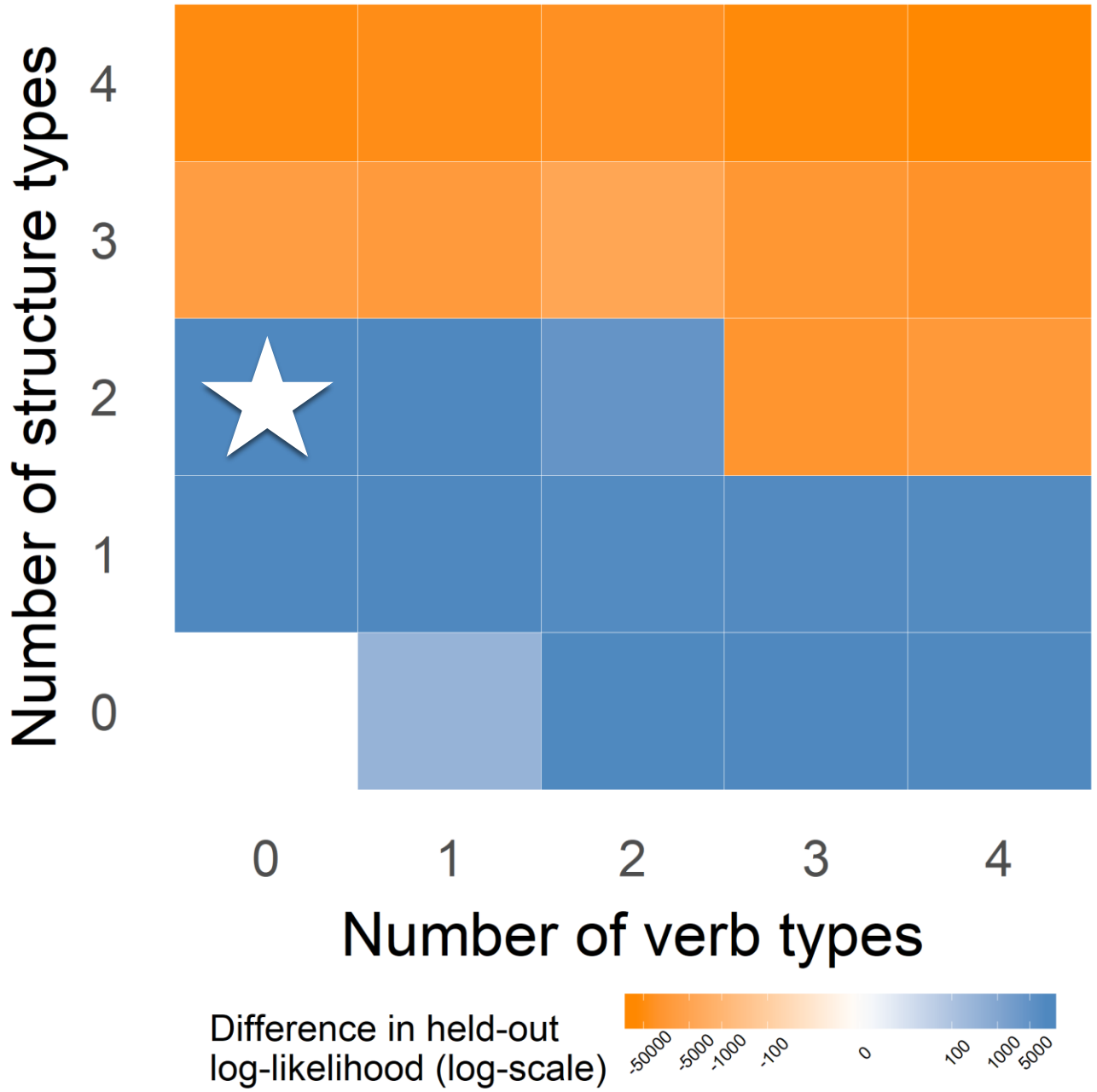

Number of structure types
4
3
2
1
0
Lexical Only
0
1
2
3
4
Number of verb types

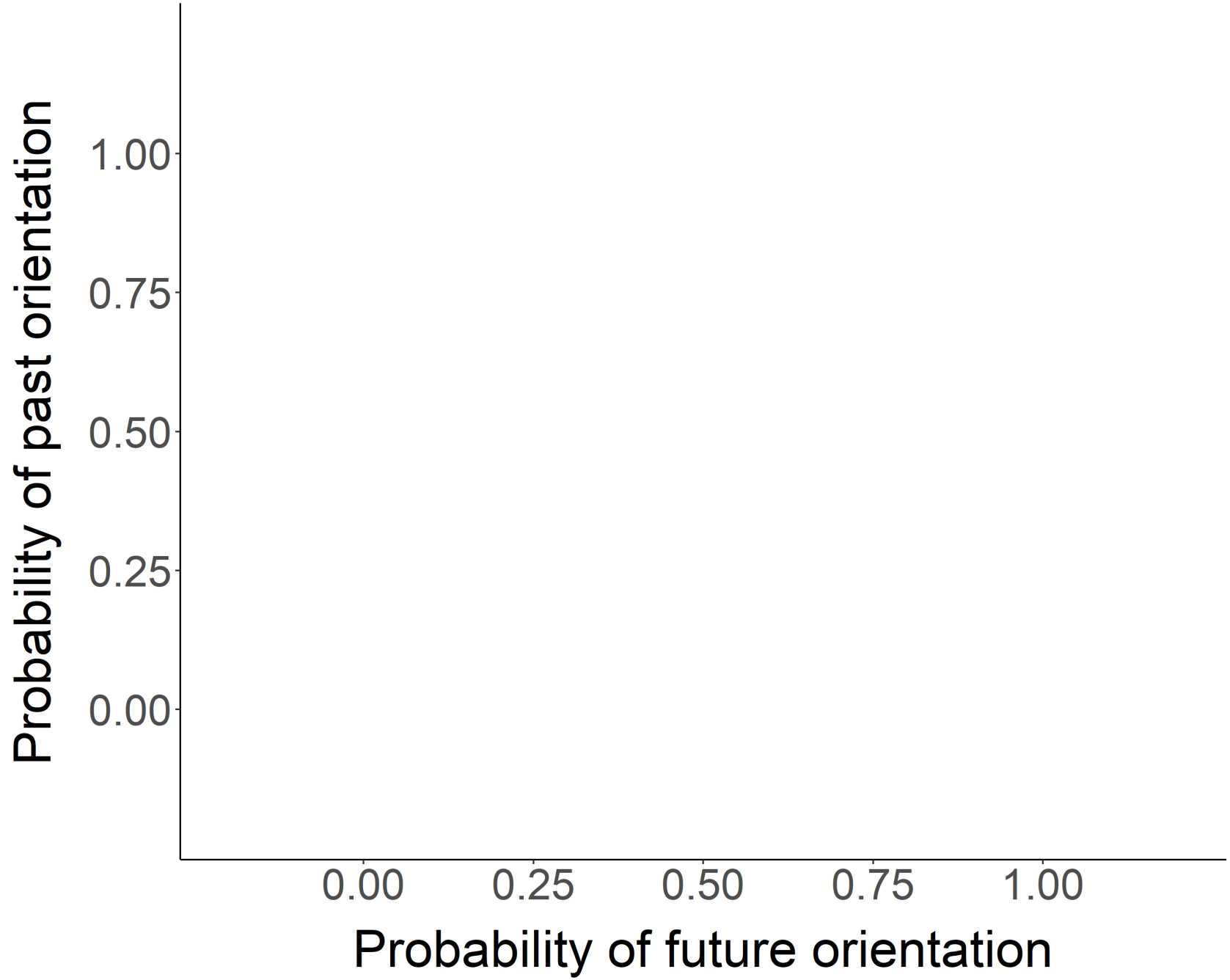

Number of structure types
4
3
2
1
0
Structural Only
Lexical Only
0
1
2
3
4
Number of verb types

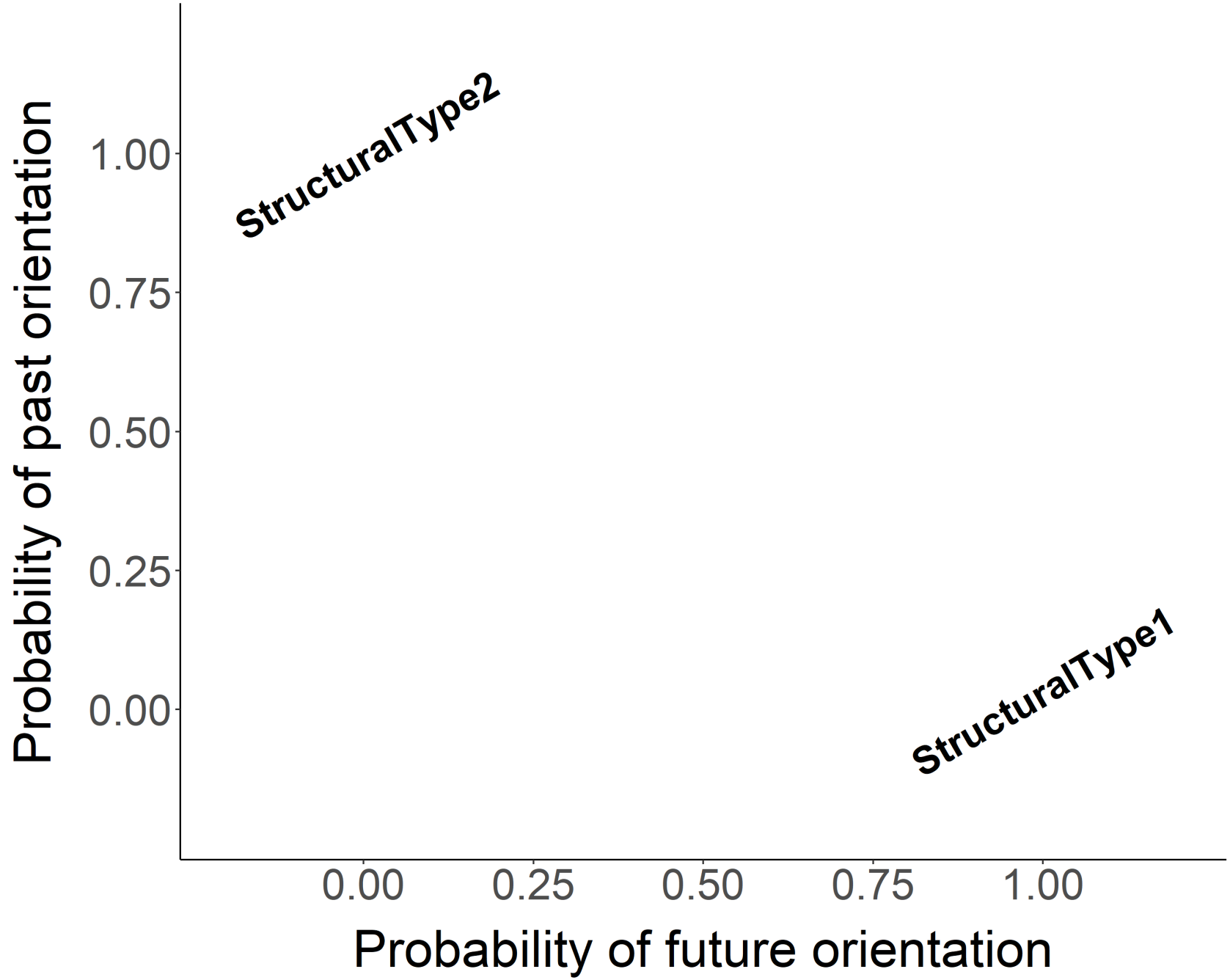

Number of structure types
4
3
2
1
0
Structural Only
Mixed
Lexical Only
0
1
2
3
4
Number of verb types

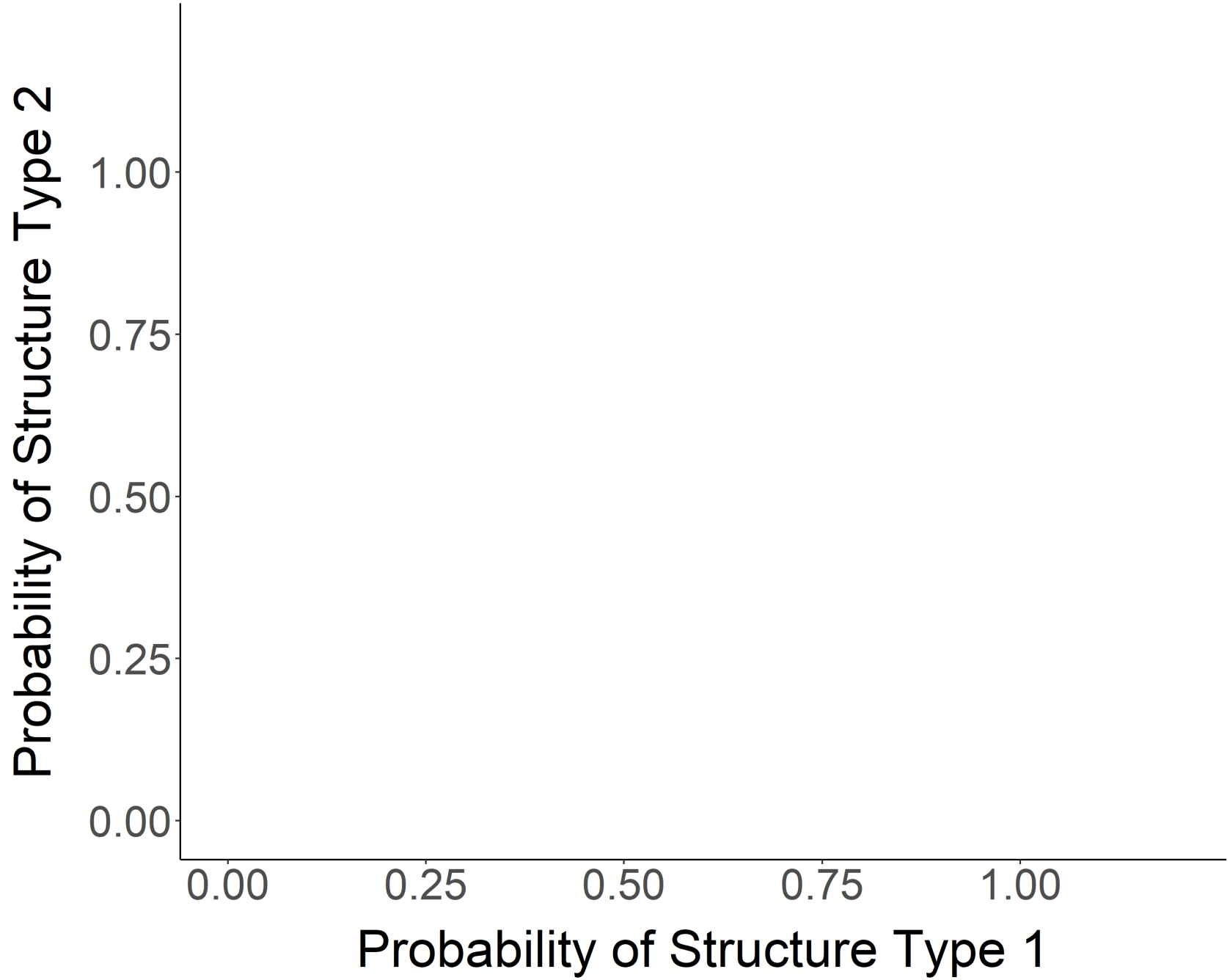

Number of structure types
4
3
2
1
0
Structural Only
Mixed
Lexical Only
0
1
2
3
4
Number of verb types
Difference in held-out
log-likelihood (log-scale)
-50000
-5000
-1000
-100
0
100
1000
5000


Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types
Difference in held-out
log-likelihood (log-scale)
-50000
-5000
-1000
-100
0
100
1000
5000


Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types
Difference in held-out
log-likelihood (log-scale)
-50000
-5000
-1000
-100
0
100
1000
5000


Probability of past orientation
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Probability of future orientation


StructuralType2
StructuralType1
Probability of past orientation
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Probability of future orientation


Probability of Structure Type 2
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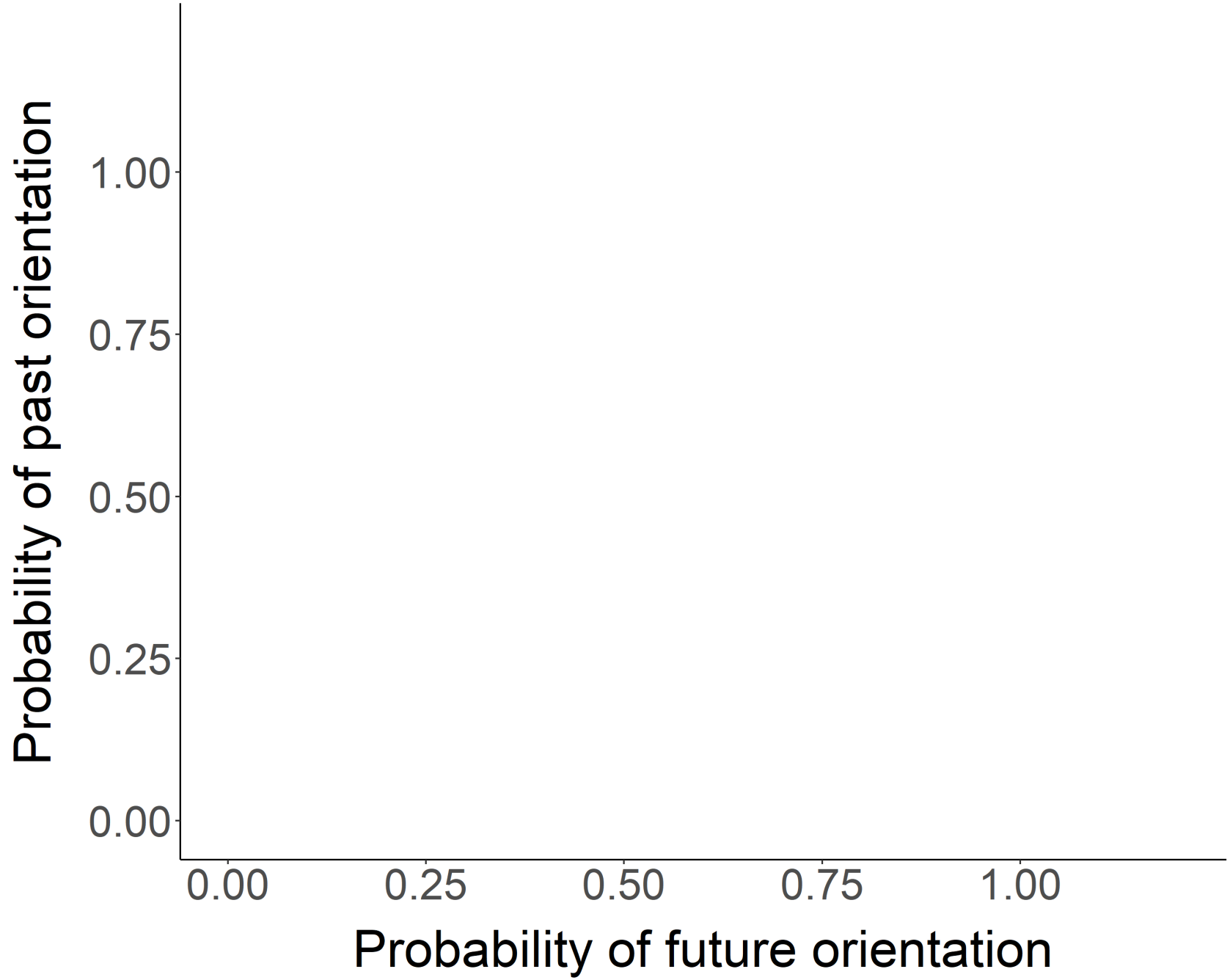
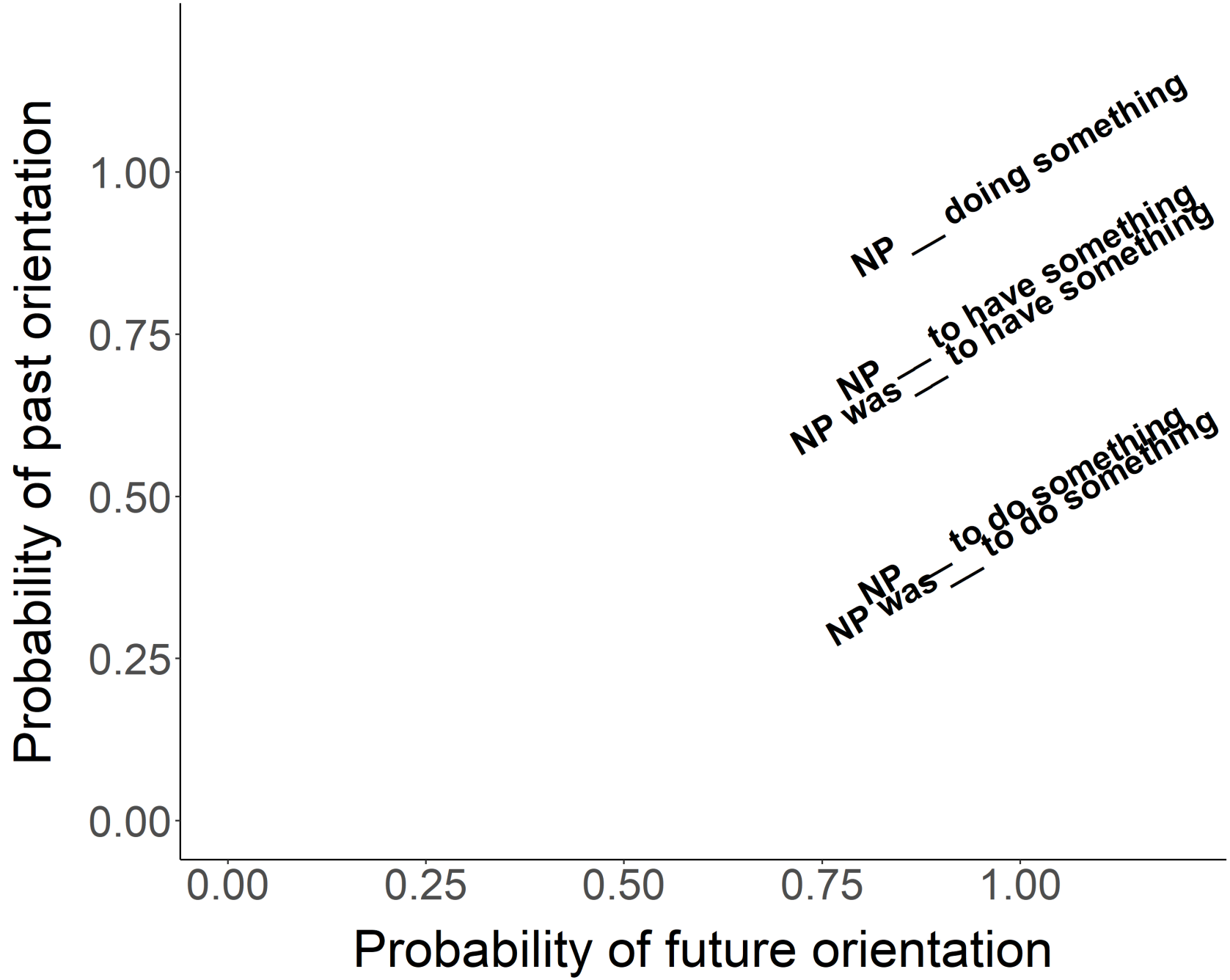
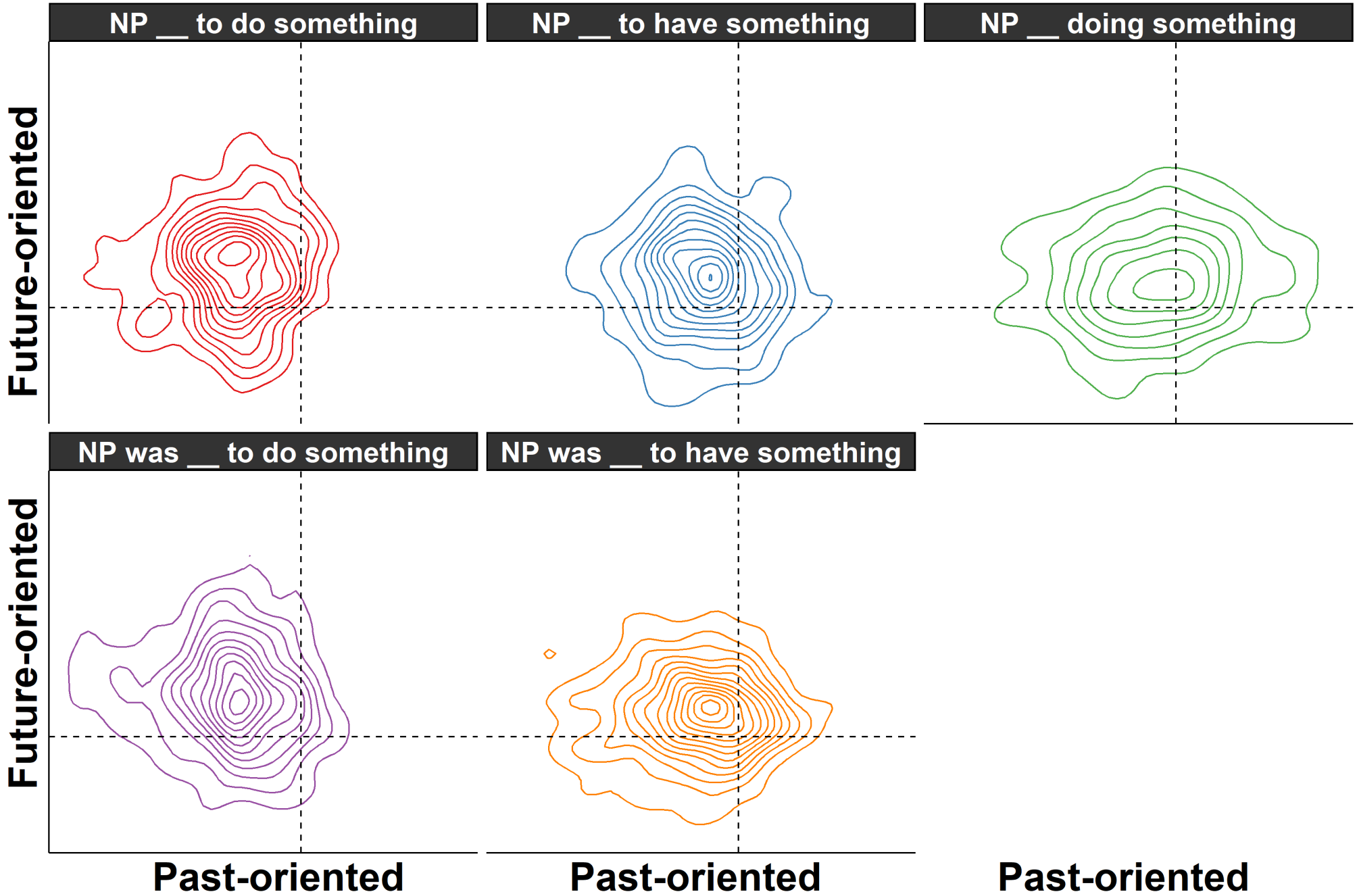
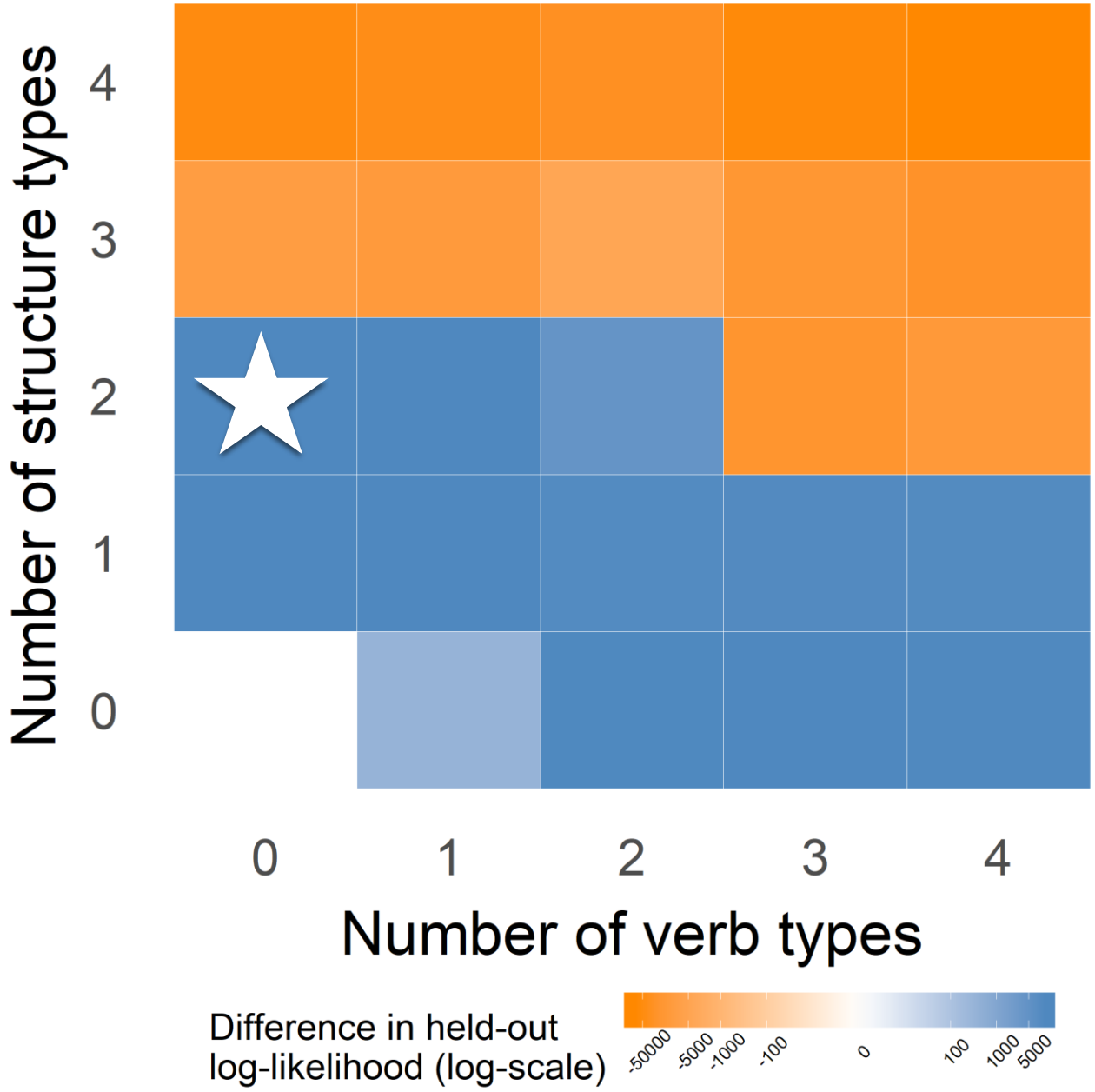
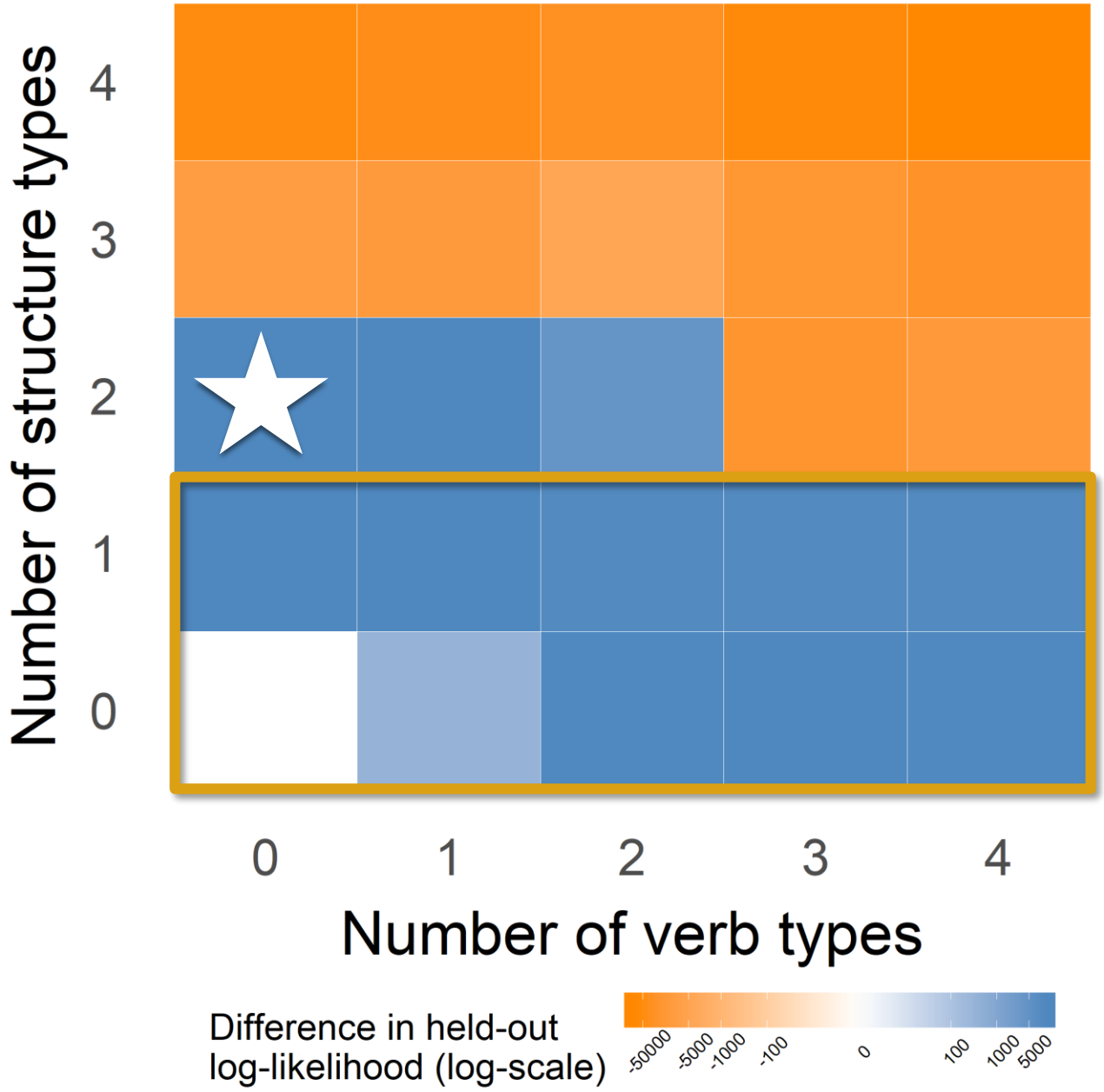
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Probability of Structure Type 1

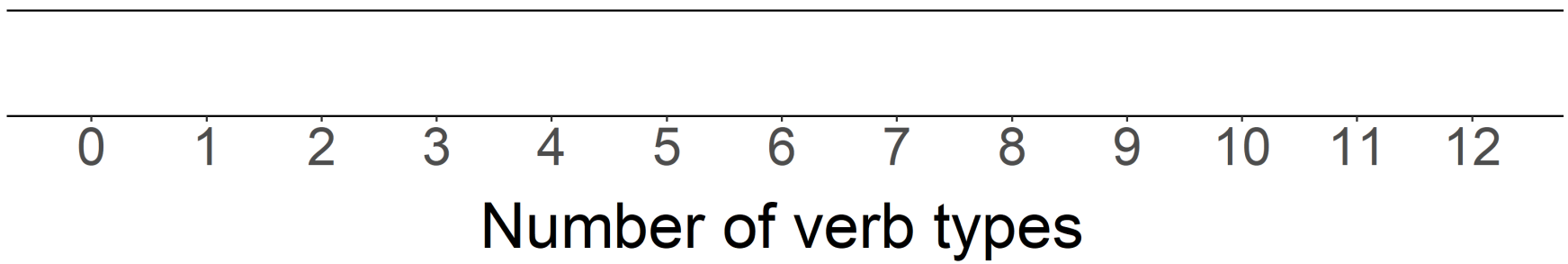

Probability of past orientation
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Probability of future orientation

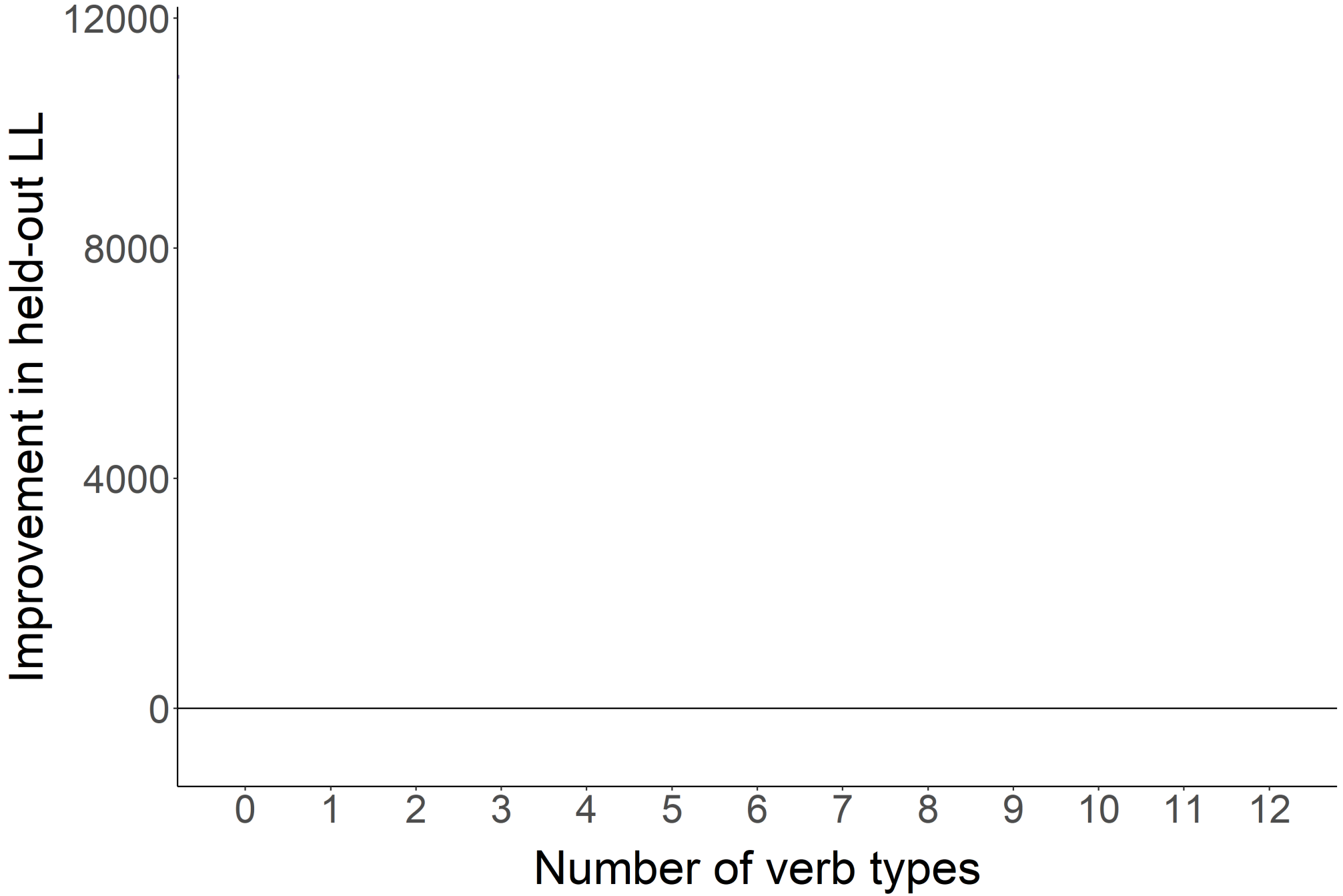

Probability of past orientation
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Probability of future orientation
NP __ doing something
NP was __ doing something
NP __ to have something
NP was __ to have something
NP __ to do something
NP was __ to do something

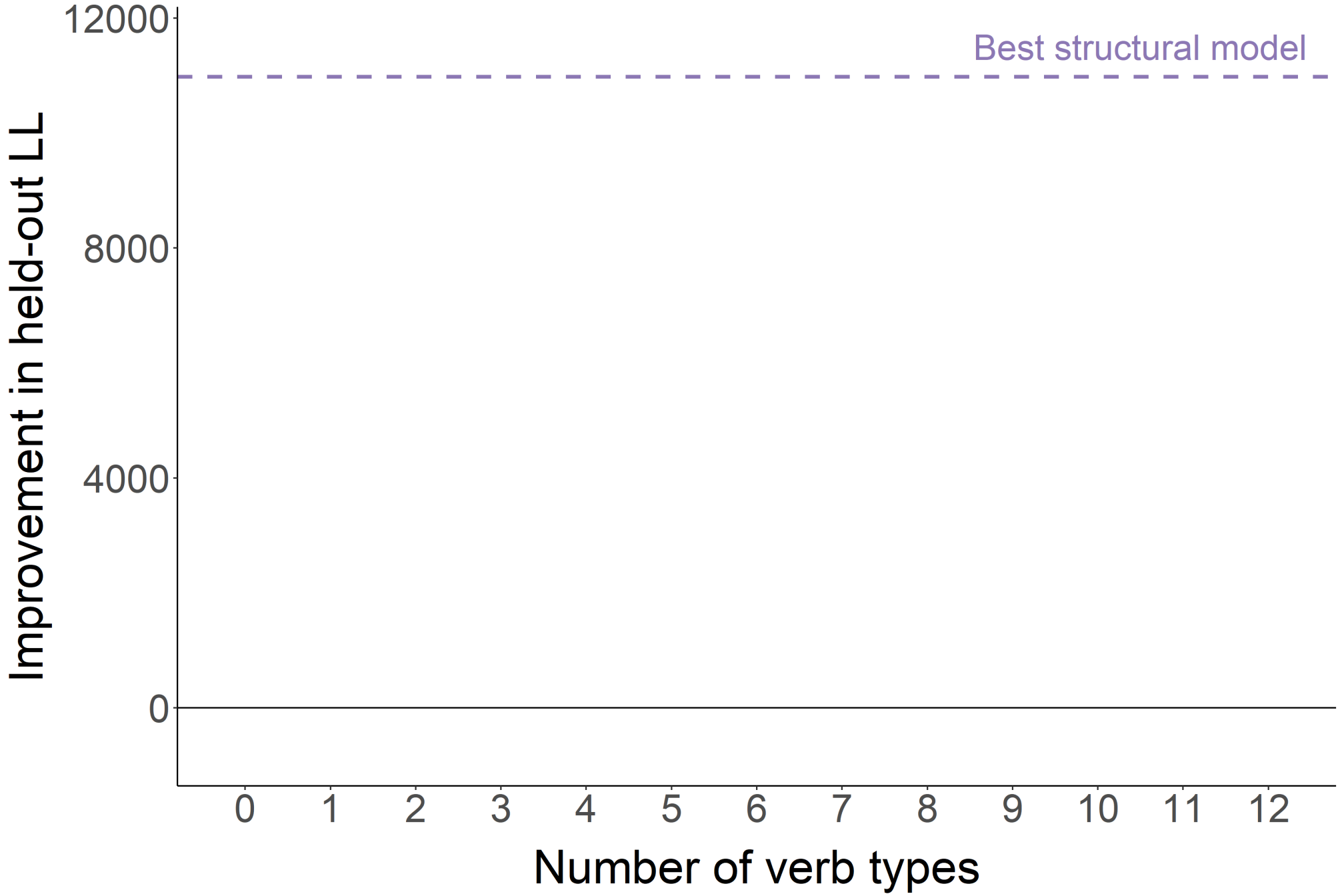

NP __ to do something
NP __ to have something
NP __ doing something
NP was __ to do something
NP was __ to have something
Future-oriented
Future-oriented
Past-oriented
Past-oriented
Past-oriented

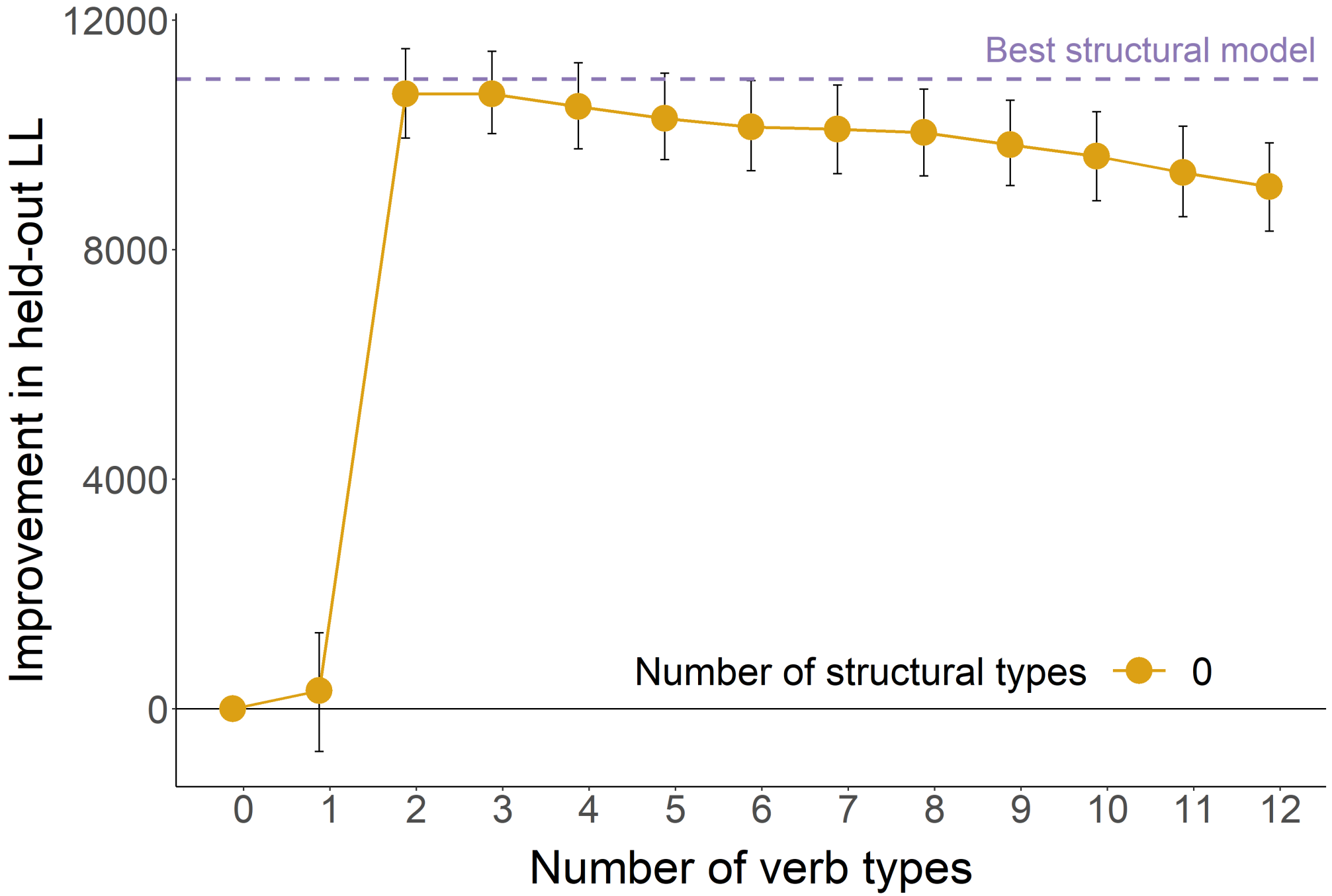

Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types
Difference in held-out
log-likelihood (log-scale)
-50000
-5000
-1000
-100
0
100
1000
5000

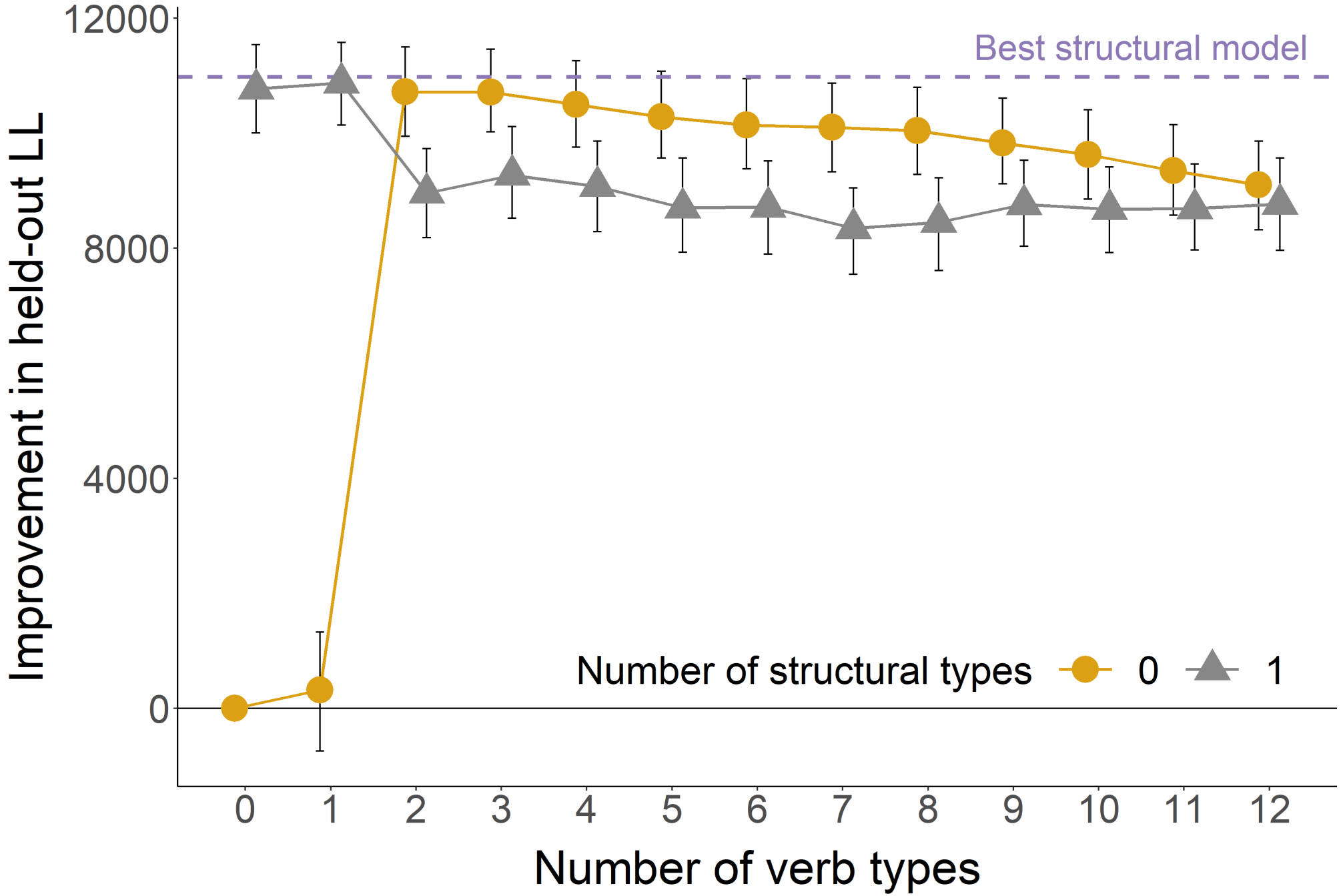

Number of structure types
4
3
2
1
0
0
1
2
3
4
Number of verb types
Difference in held-out
log-likelihood (log-scale)
-50000
-5000
-1000
-100
0
100
1000
5000


0 1 2 3 4 5 6 7 8 9 10 11 12
Number of verb types


12000
8000
4000
0
Improvement in held-out LL
0
1
2
3
4
5
6
7
8
9
10
11
12
Number of verb types


12000
8000
4000
0
Improvement in held-out LL
Best structural model
0
1
2
3
4
5
6
7
8
9
10
11
12
Number of verb types


12000
8000
4000
0
Improvement in held-out LL
Best structural model
Number of structural types
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Number of verb types


12000
8000
4000
0
Improvement in held-out LL
Best structural model
Number of structural types
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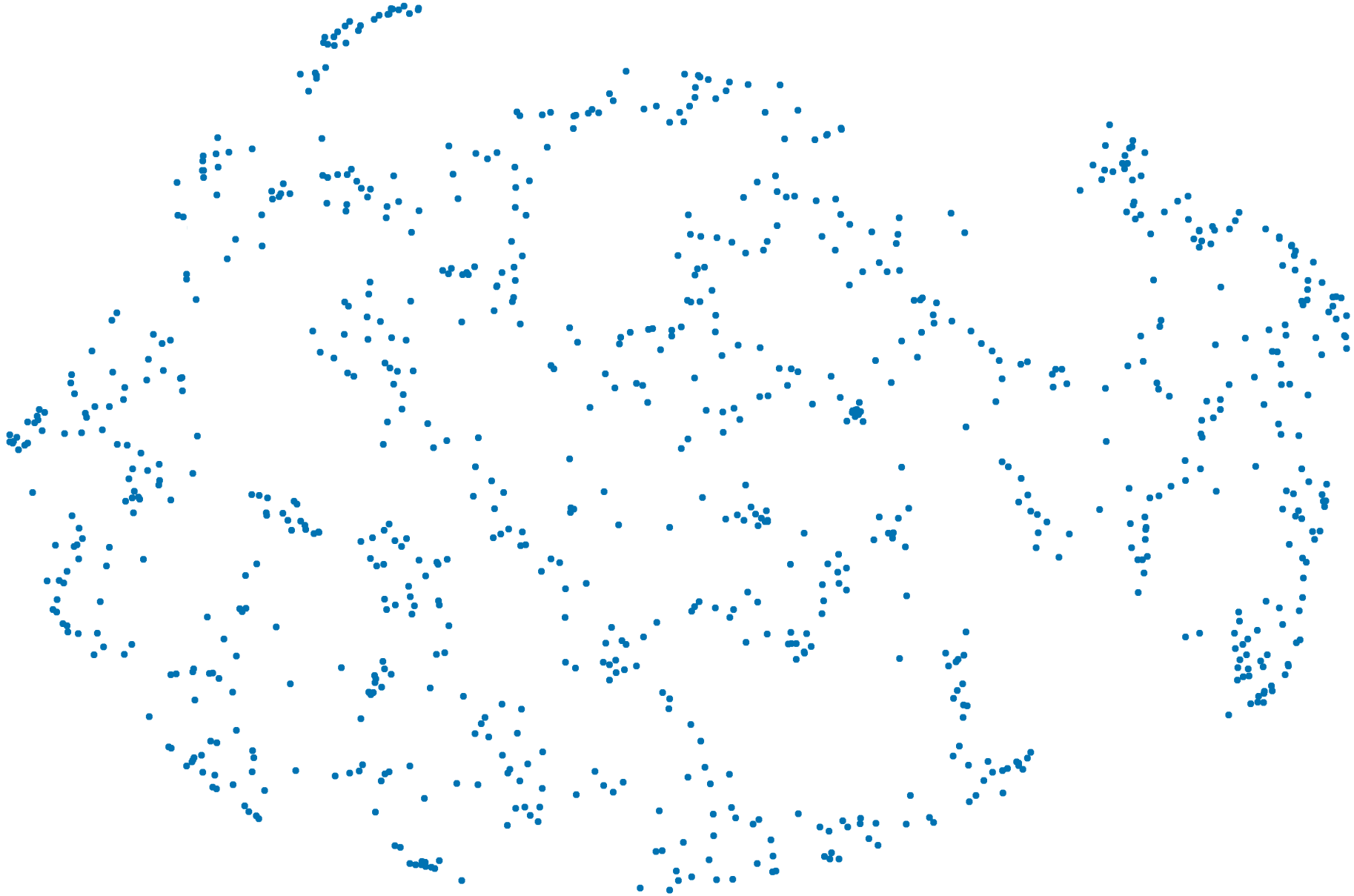
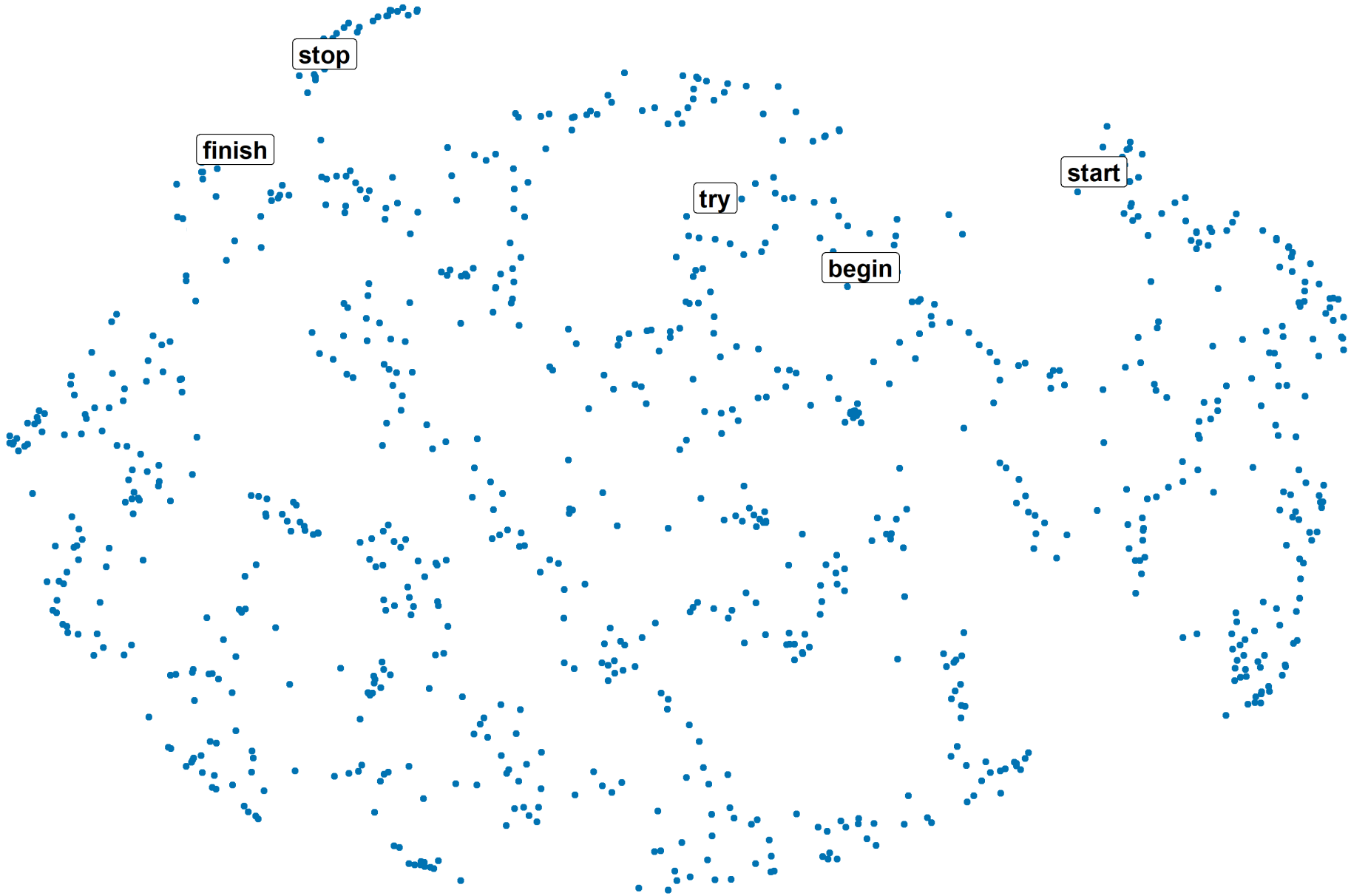
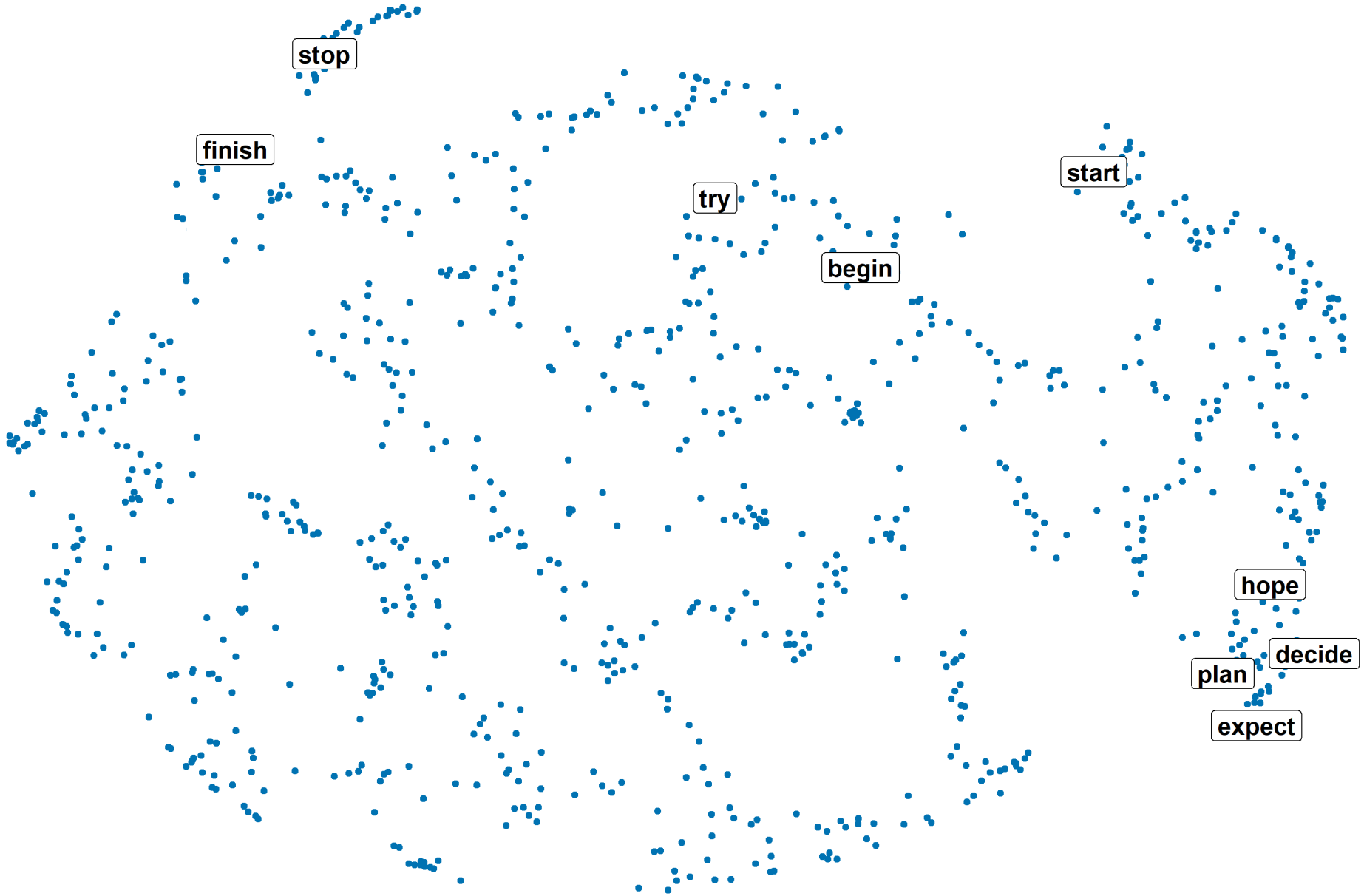
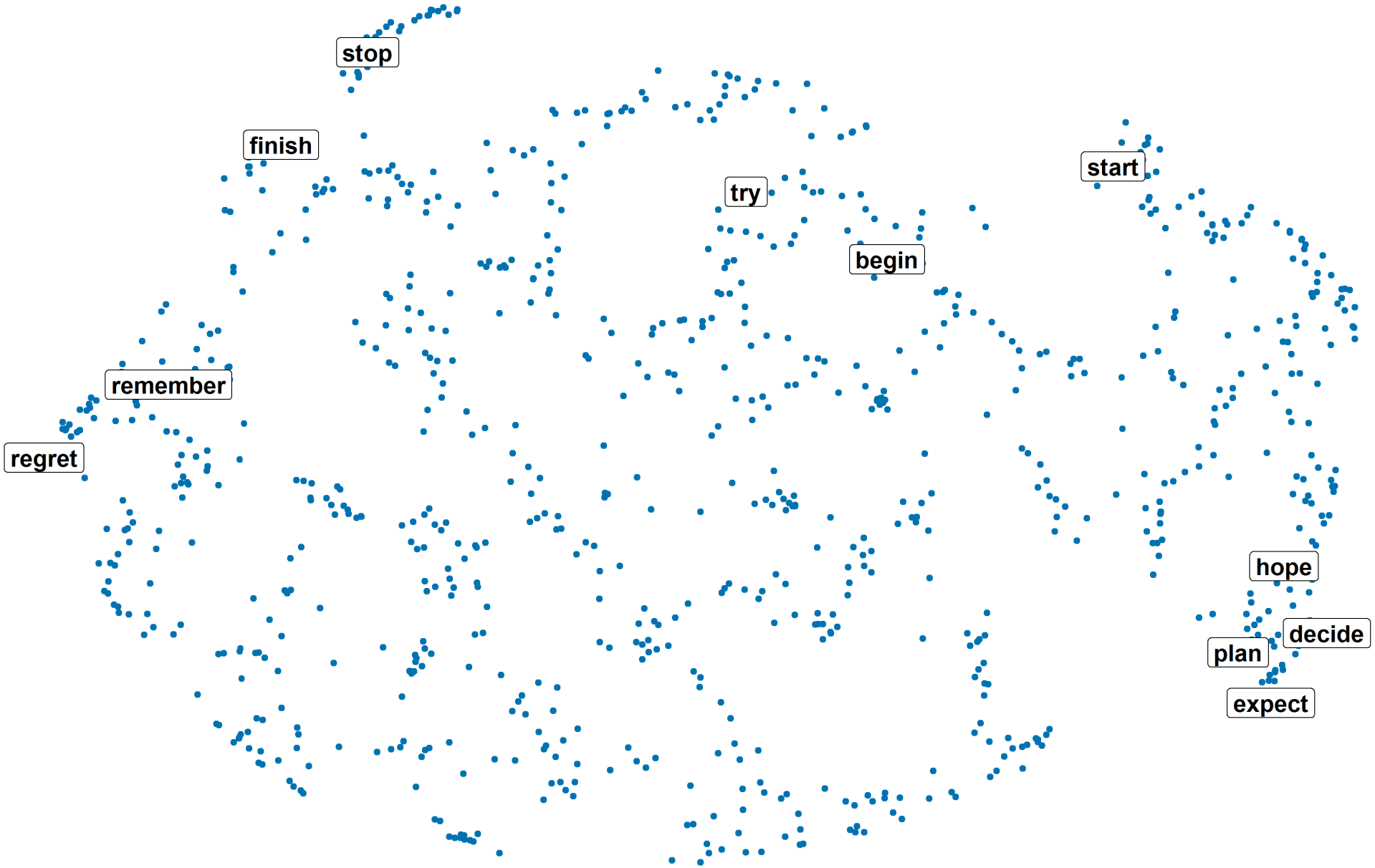
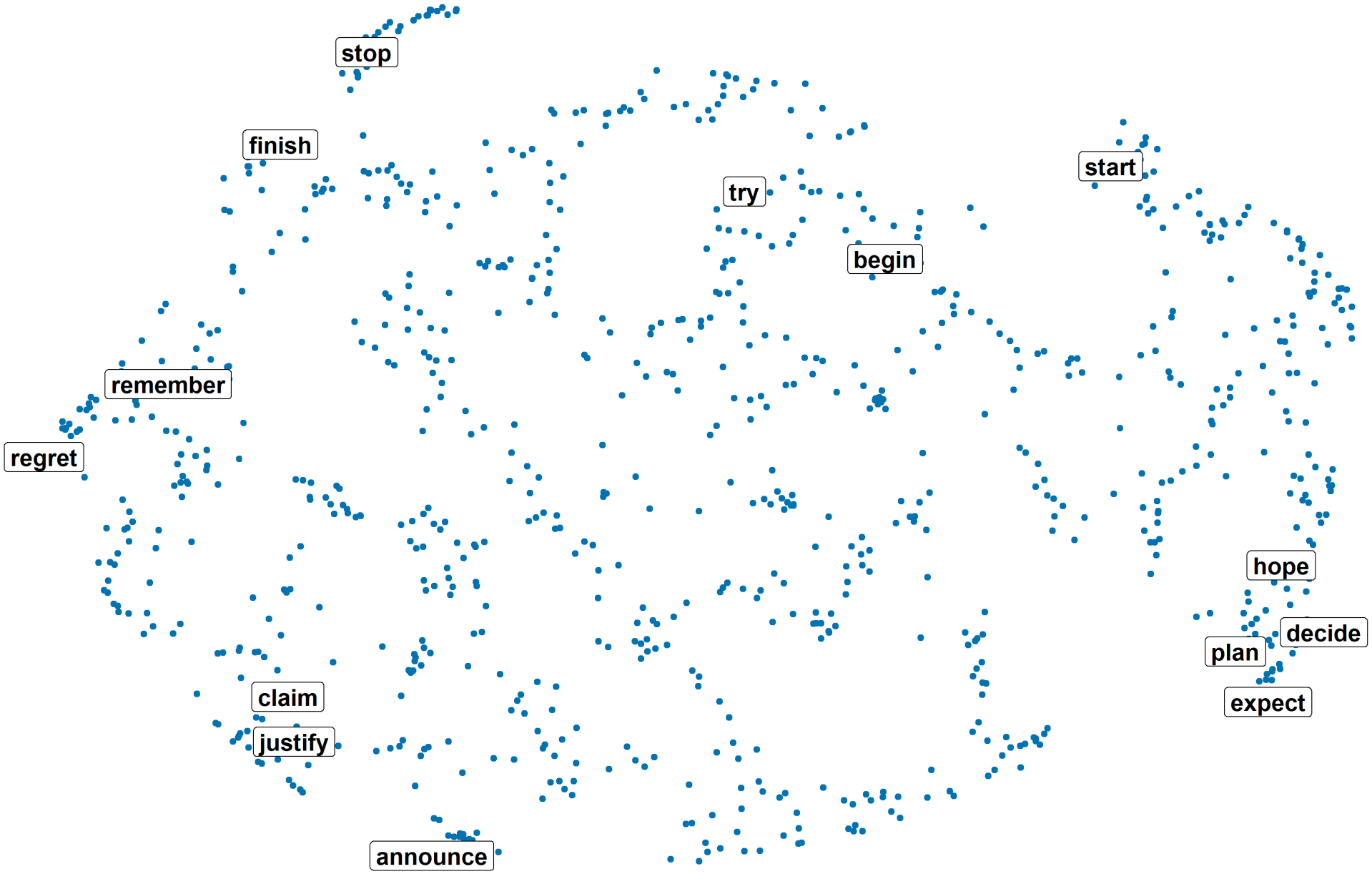
1
0
1
2
3
4
5
6
7
8
9
10
11
12
Number of verb types

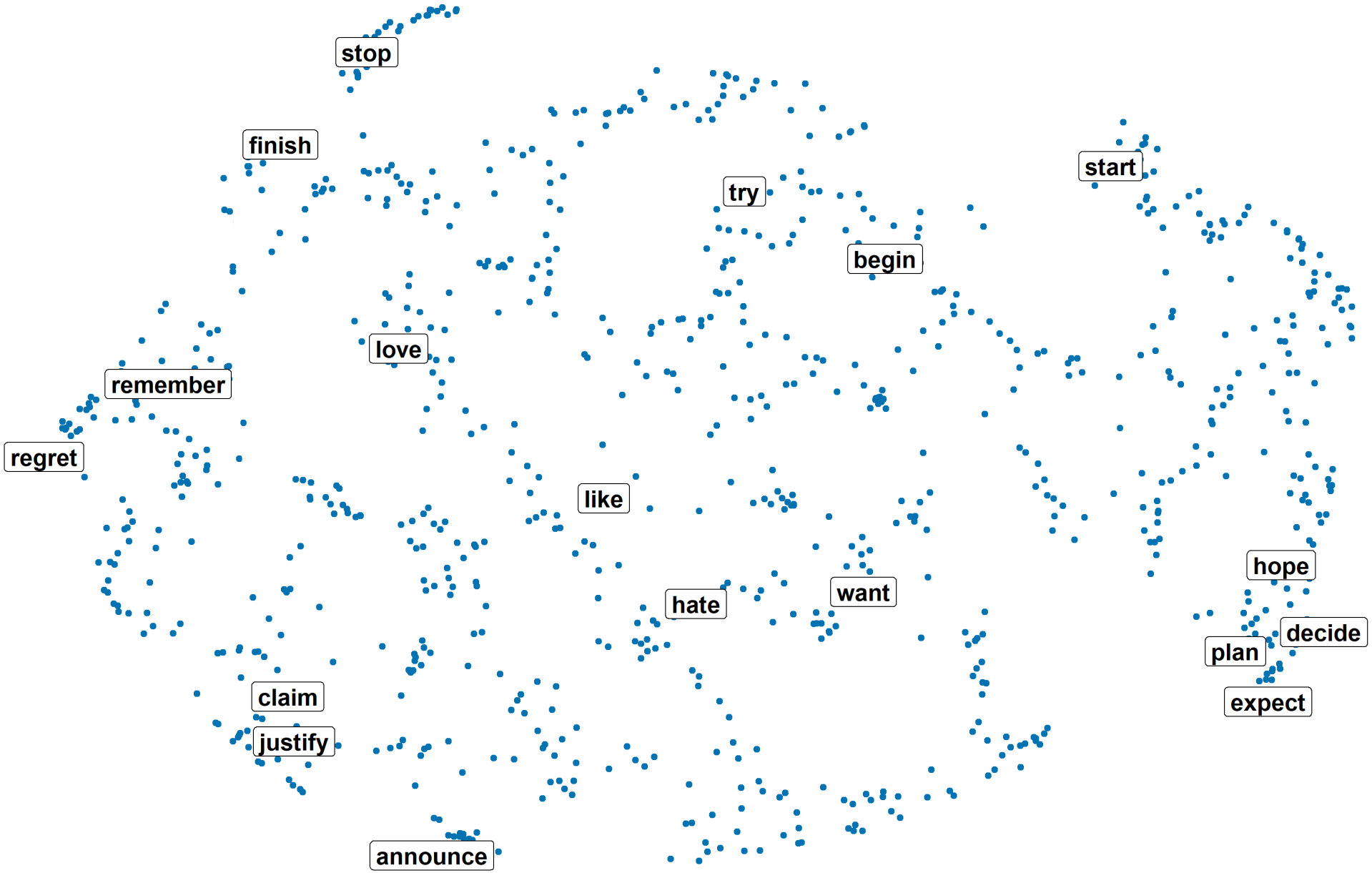



stop
finish
try
start
begin


stop
finish
try
start
begin
hope
decide
plan
expect


stop
finish
try
start
begin
remember
regret
hope
decide
plan
expect


stop
finish
try
start
begin
remember
regret
hope
decide
plan
claim
expect
justify
announce


stop
finish
try
start
begin
love
remember
regret
like
hope
want
hate
decide
plan
claim
expect
justify
announce

CONCLUSION

Both **constructional** and **lexical** models do fit the data, but in different ways, **mixed** models less so.

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Both **constructional** and **lexical** models do fit the data, but in different ways, **mixed** models less so.

These models capture fine-grained information about verbal semantics in areas related to temporality.

Lexicon-scale datasets of verb features like this can enable us to empirically test theoretical possibilities.

Thank you!

Data is available at **megaattitude.io**

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APPENDICES

ANNOTATOR INSTRUCTIONS

In this experiment, we are interested in words that talk about things like memories, desires, and other mental states, such as *remember* or *hope*. Specifically, we're interested in what these words tell us about the time the memory or desire is about.

The way we are investigating this is by looking at the "acceptability" of sentences that are made up of words about memories, desires, etc. and times, such as *the future* or *the past*. **An "acceptable" sentence is something a native speaker of English would say, even if the situation the sentence describes sounds vague or implausible**.

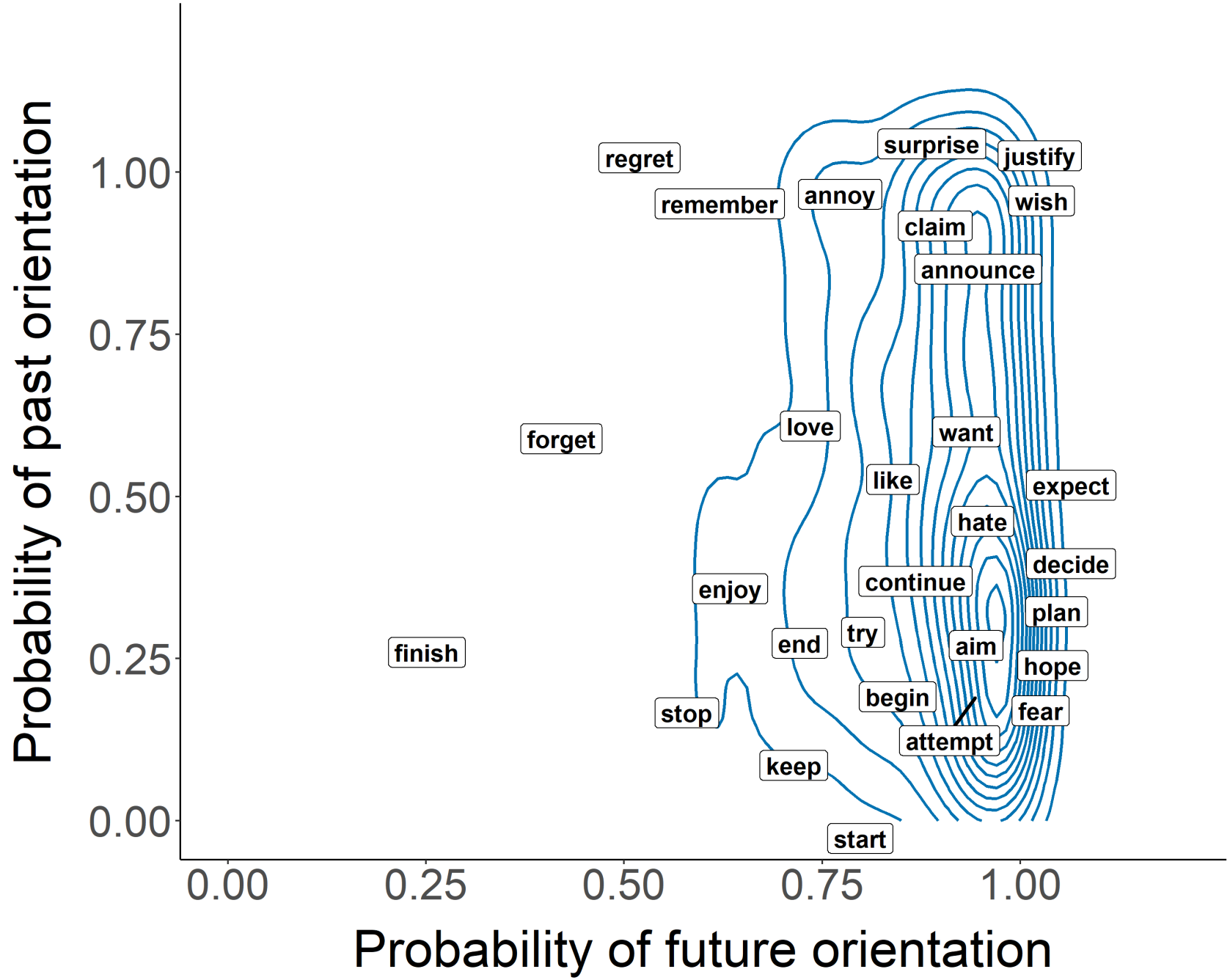
Your task will be to respond about the acceptability of each sentence on a scale from 1 to 7 that will appear under each question, where 1 corresponds to *terrible* and 7 corresponds to *perfect*.

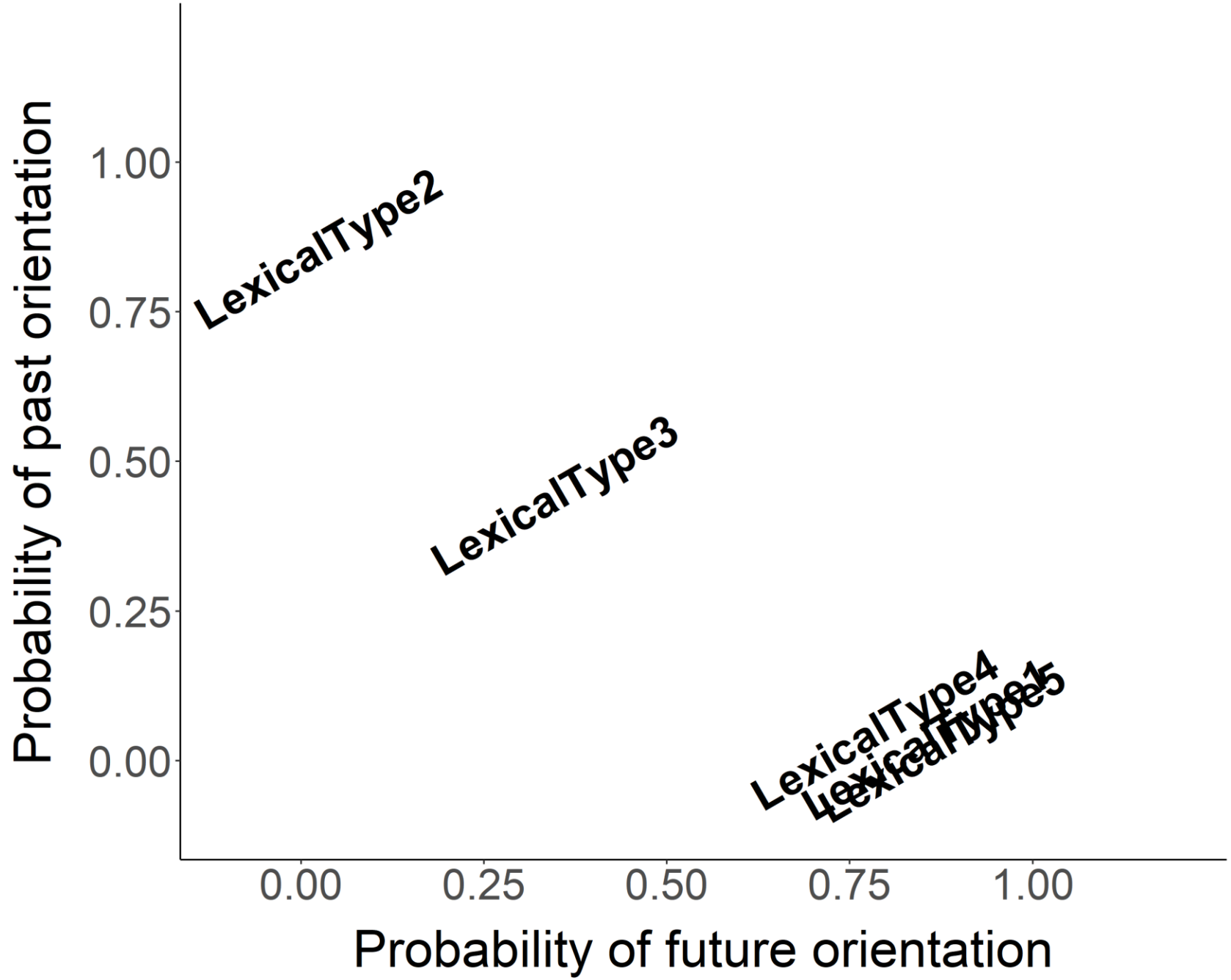
For instance, you might be presented with the sentence *Someone wanted to do something in the future*. In this case you would select a 6 or a 7, since desires are usually about the future.

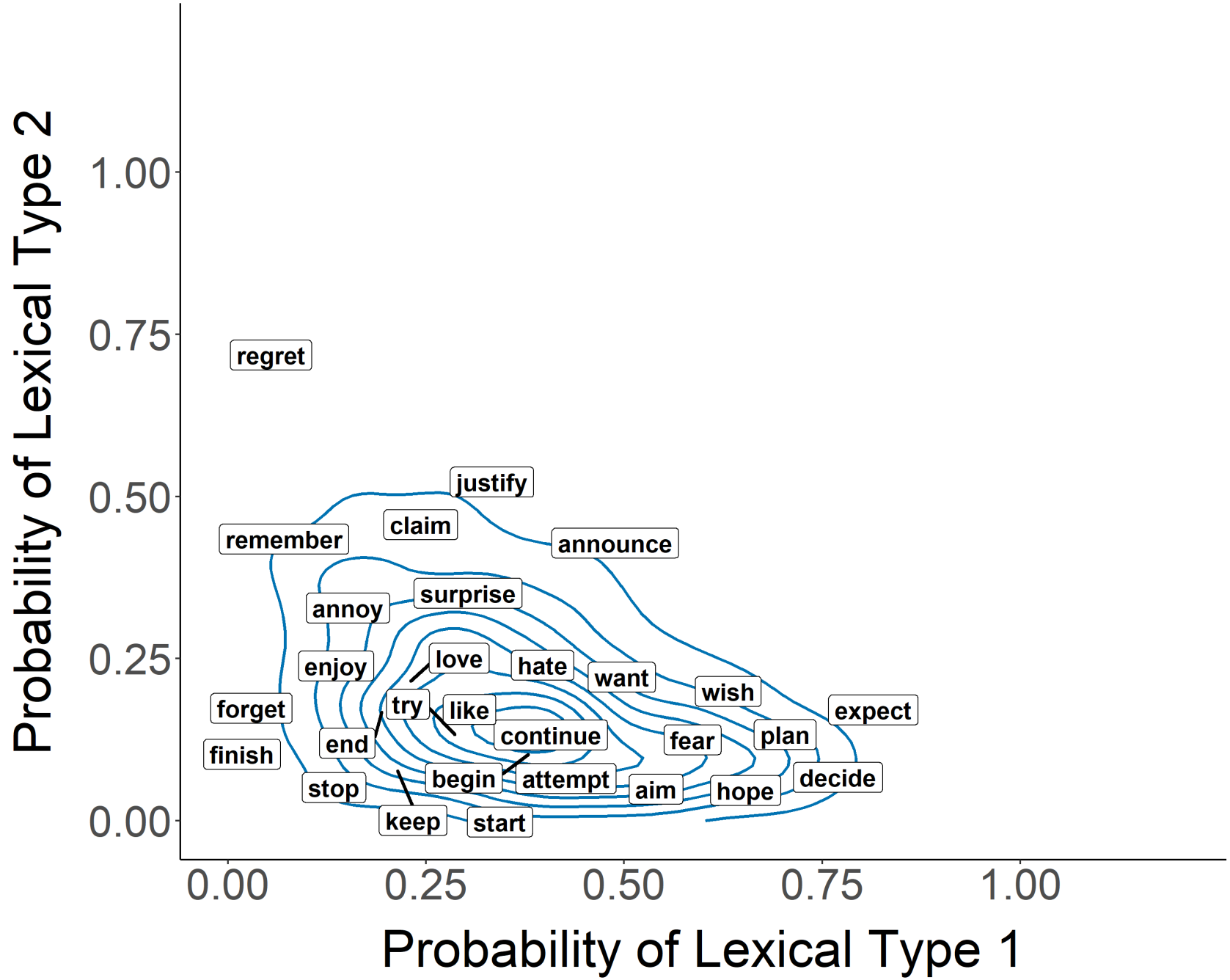
If the sentence were *Someone will regret doing something in the past*, then you might select 1 or 2, since regrets are also about the future.

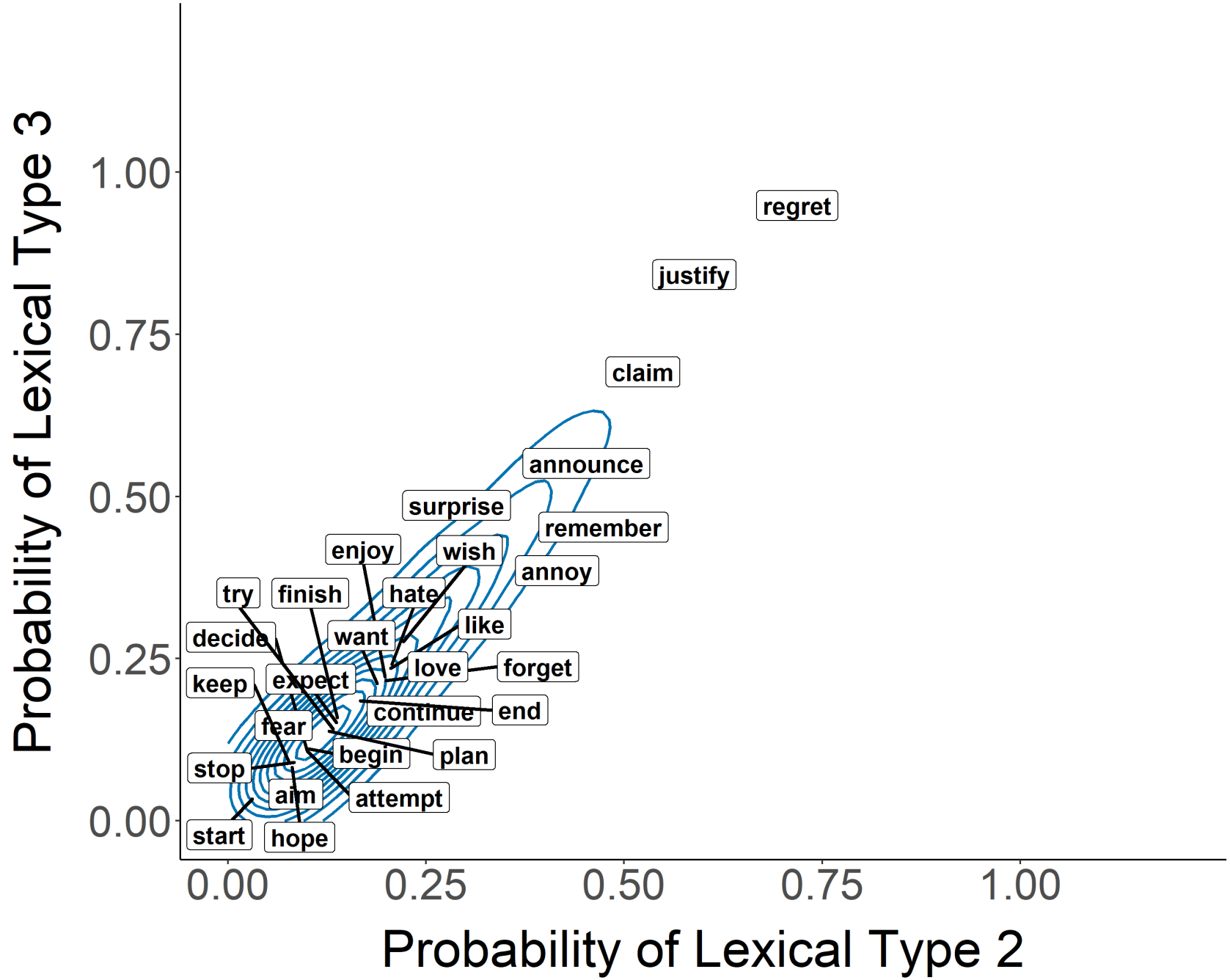
And if the sentence were *Someone will imagine doing something in the past*, you might select a number near the middle, since imagining is often about the future, but it's not impossible for it to be about the past.

Try to answer the questions as quickly and accurately as possible, considering whether they present an order of events that makes sense.


Probability of past orientation
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Probability of future orientation
regret
remember
surprise
justify
annoy
wish
claim
announce
forget
love
want
like
expect
hate
decide
enjoy
continue
plan
try
end
aim
hope
finish
begin
fear
stop
attempt
keep
start


Probability of past orientation
1.00
0.75
0.50
0.25
0.00
LexicalType2
LexicalType3
LexicalType4
LexicalType1
LexicalType5
0.00
0.25
0.50
0.75
1.00
Probability of future orientation


Probability of Lexical Type 2
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Probability of Lexical Type 1
regret
justify
claim
remember
announce
surprise
annoy
enjoy
love
hate
want
wish
expect
forget
try
like
continue
fear
plan
finish
end
begin
attempt
aim
hope
decide
stop
keep
start


Probability of Lexical Type 3
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0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Probability of Lexical Type 2
regret
justify
claim
announce
surprise
remember
enjoy
wish
annoy
try
finish
hate
like
decide
want
love
forget
keep
expect
continue
end
fear
begin
plan
stop
aim
attempt
start
hope