

Morpho-phonetic detail influences listeners' comprehension

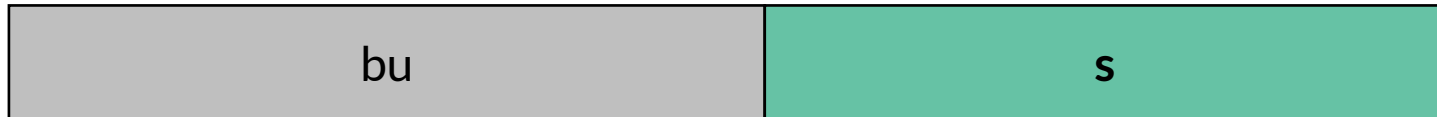
Dominic Schmitz, Dinah Baer-Henney, and Ingo Plag

13th Mediterranean Morphology Meeting

Background: Durational Differences in /s/

Background: Durational Differences in /s/

non-morphemic /s/



plural /s/



is- and *has-*clitic /s/



Background: Durational Differences in /s/

non-morphemic /s/



plural /s/



is- and *has-*clitic /s/



Research Question

Research Question

Can listeners make use of these differences in comprehension?

Research Question

Can listeners make use of these differences in comprehension?

→ How can we test this?

Research Question

Can listeners make use of these differences in comprehension?

→ How can we test this?

- if durational information is used in comprehension,
a mismatch of durations should show an effect on comprehension

Research Question

Can listeners make use of these differences in comprehension?

→ How can we test this?

- if durational information is used in comprehension, a mismatch of durations should show an effect on comprehension
- we investigated this in a number-decision task mouse-tracking experiment

Method: Number-Decision with Mouse-Tracking

one

two or more



Method: Stimuli

- pseudowords adopted from a previous production study (Schmitz et al., 2021) were used to rule out potentially confounding lexical (Caselli et al., 2016; Gahl, 2008) and contextual effects (Klatt, 1976; Wightman et al., 1992)

Method: Stimuli

- pseudowords adopted from a previous production study (Schmitz et al., 2021) were used to rule out potentially confounding lexical (Caselli et al., 2016; Gahl, 2008) and contextual effects (Klatt, 1976; Wightman et al., 1992)

ɪ	i:	u:	ʌ	aʊ	eɪ
<i>glip</i>	<i>pleep</i>	<i>cloop</i>	<i>prup</i>	<i>bloup</i>	<i>glaip</i>
<i>glit</i>	<i>pleet</i>	<i>cloot</i>	<i>prut</i>	<i>blout</i>	<i>glait</i>
<i>glik</i>	<i>pleek</i>	<i>clook</i>	<i>pruk</i>	<i>blouk</i>	<i>glaik</i>
<i>glif</i>	<i>pleef</i>	<i>cloof</i>	<i>pruf</i>	<i>blouf</i>	<i>glaiif</i>
<i>glips</i>	<i>pleeps</i>	<i>cloops</i>	<i>prups</i>	<i>bloups</i>	<i>glaiips</i>
<i>glits</i>	<i>pleets</i>	<i>cloots</i>	<i>pruts</i>	<i>blouts</i>	<i>glaits</i>
<i>gliks</i>	<i>pleeks</i>	<i>clooks</i>	<i>pruks</i>	<i>blouks</i>	<i>glaiks</i>
<i>glifs</i>	<i>pleefs</i>	<i>cloofs</i>	<i>prufs</i>	<i>bloufs</i>	<i>glaiifs</i>

Method: Stimuli

- pseudowords adopted from a previous production study (Schmitz et al., 2021) were used to rule out potentially confounding lexical (Caselli et al., 2016; Gahl, 2008) and contextual effects (Klatt, 1976; Wightman et al., 1992)

ɪ	i:	u:	ʌ	aʊ	eɪ	
<i>glip</i>	<i>pleep</i>	<i>cloop</i>	<i>prup</i>	<i>bloup</i>	<i>glaip</i>	} singulars
<i>glit</i>	<i>pleet</i>	<i>cloot</i>	<i>prut</i>	<i>blout</i>	<i>glait</i>	
<i>glik</i>	<i>pleek</i>	<i>clook</i>	<i>pruk</i>	<i>blouk</i>	<i>glaik</i>	
<i>glif</i>	<i>pleef</i>	<i>cloof</i>	<i>pruf</i>	<i>blouf</i>	<i>glaiif</i>	
<i>glips</i>	<i>pleeps</i>	<i>cloops</i>	<i>prups</i>	<i>bloups</i>	<i>glaiips</i>	} plurals / clitic forms
<i>glits</i>	<i>pleets</i>	<i>cloots</i>	<i>pruts</i>	<i>blouts</i>	<i>glaits</i>	
<i>gliks</i>	<i>pleeks</i>	<i>clooks</i>	<i>pruks</i>	<i>blouks</i>	<i>glaiiks</i>	
<i>glifs</i>	<i>pleefs</i>	<i>cloofs</i>	<i>prufs</i>	<i>bloufs</i>	<i>glaiifs</i>	

Method: Stimuli

Method: Stimuli

- to allow for a disambiguation of plural and clitic /s/ items were embedded into real word **contexts**, for example:

Method: Stimuli

- to allow for a disambiguation of plural and clitic /s/ items were embedded into real word **contexts**, for example:

Plural: *The [gɪps] ate their lunch together.*

Method: Stimuli

- to allow for a disambiguation of plural and clitic /s/ items were embedded into real word **contexts**, for example:

Plural: *The [gɪps] ate their lunch together.*

is-clitic: *The [gɪps] eating cake with the bloup.*

Method: Stimuli

- to allow for a disambiguation of plural and clitic /s/ items were embedded into real word **contexts**, for example:

Plural: *The [gɪps] ate their lunch together.*

is-clitic: *The [gɪps] eating cake with the bloup.*

has-clitic: *The [gɪps] eaten the bloup's lunch.*

Method: Stimuli

Method: Stimuli

- for each pseudoword, three audio stimuli were created by manipulating the /s/ duration accordingly (Plag et al., 2017)

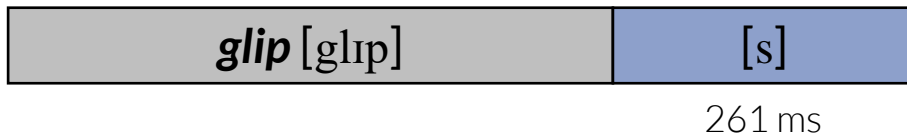
Method: Stimuli

- for each pseudoword, three audio stimuli were created by manipulating the /s/ duration accordingly (Plag et al., 2017)

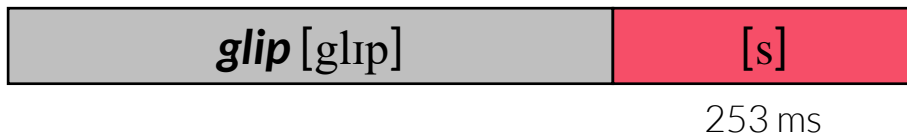
plural



is-clitic



has-clitic



Method: Stimuli

Method: Stimuli

- the durationally manipulated items were then embedded into the pertinent contexts:

Method: Stimuli

- the durationally manipulated items were then embedded into the pertinent contexts:

Plural: *The [glɪps]/[glɪps]/[glɪps] ate their lunch together.*


Method: Stimuli

- the durationally manipulated items were then embedded into the pertinent contexts:

match
mismatch
↓
↙ ↘
Plural: *The [glɪps]/[glɪps]/[glɪps] ate their lunch together.*

Method: Stimuli

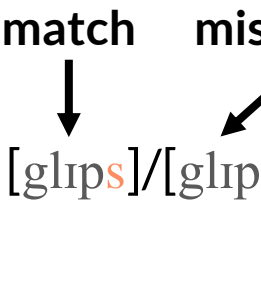
- the durationally manipulated items were then embedded into the pertinent contexts:

match
mismatch

Plural: *The [glɪps]/[glɪps]/[glɪps] ate their lunch together.*

is-clitic: *The [glɪps]/[glɪps] eating cake with the bloup.*

Method: Stimuli

- the durationally manipulated items were then embedded into the pertinent contexts:

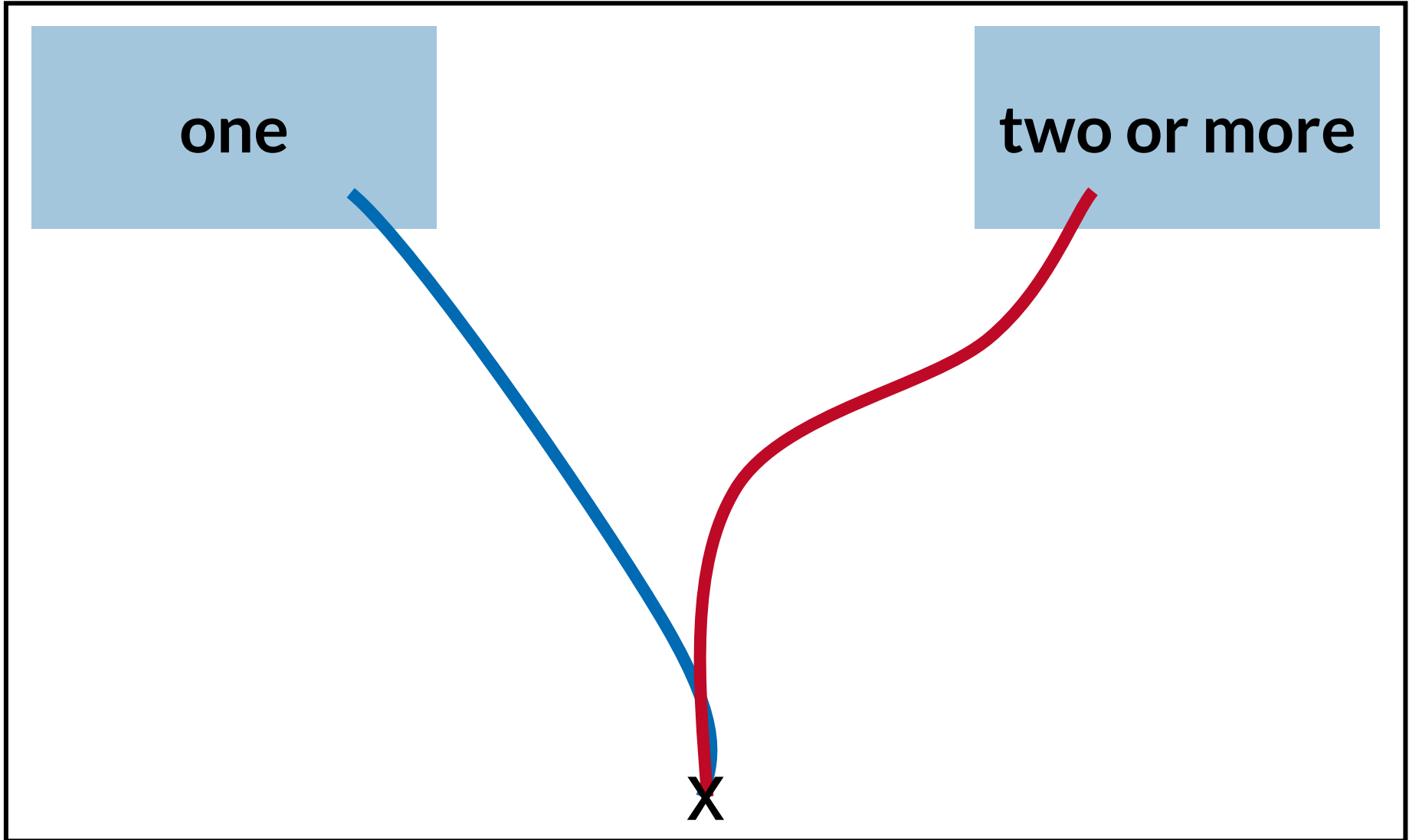


Plural: The [glɪps]/[glɪps]/[glɪps] ate their lunch together.

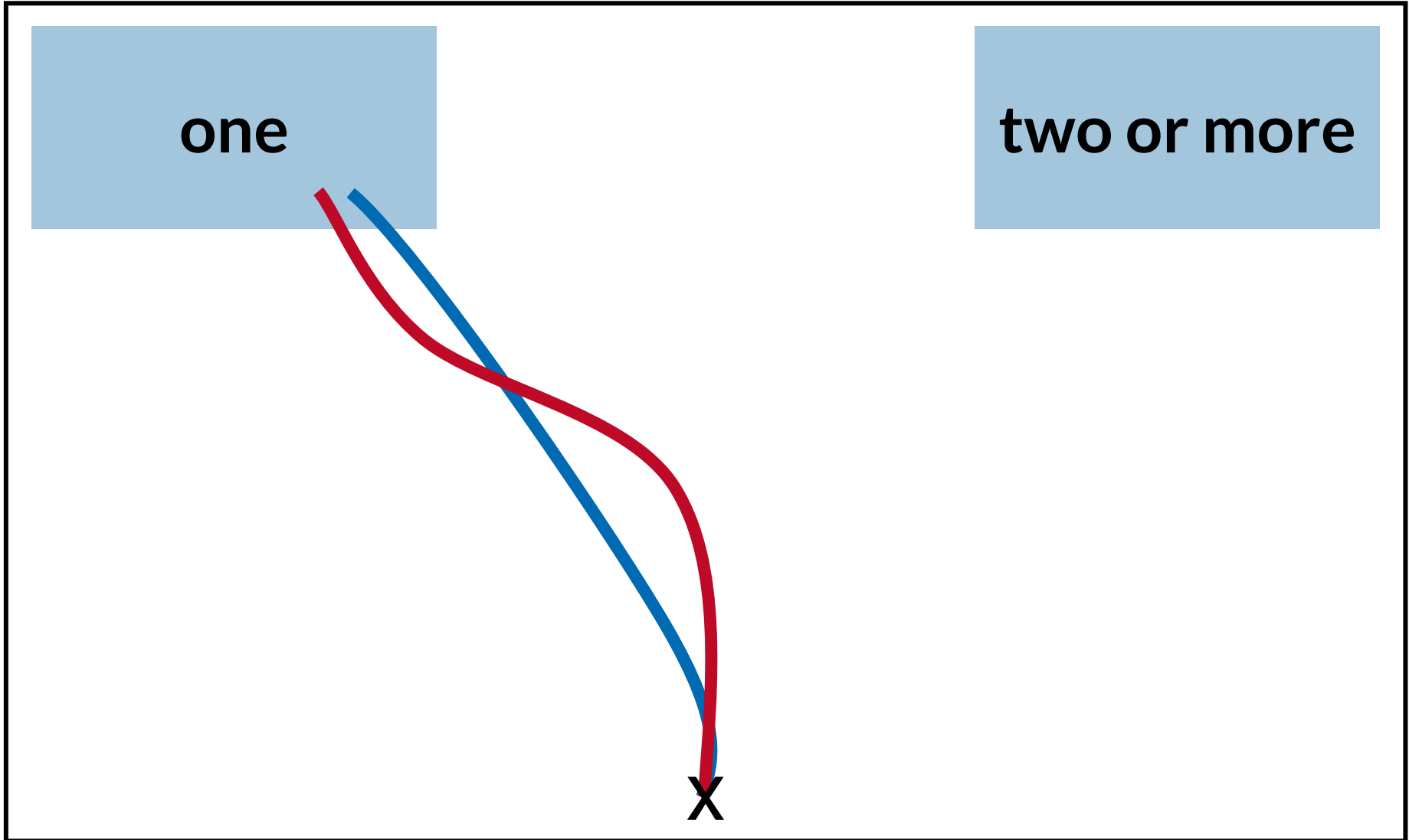
is-clitic: The [glɪps]/[glɪps] eating cake with the bloup.

has-clitic: The [glɪps]/[glɪps] eaten the bloup's lunch.

Mouse-Tracks

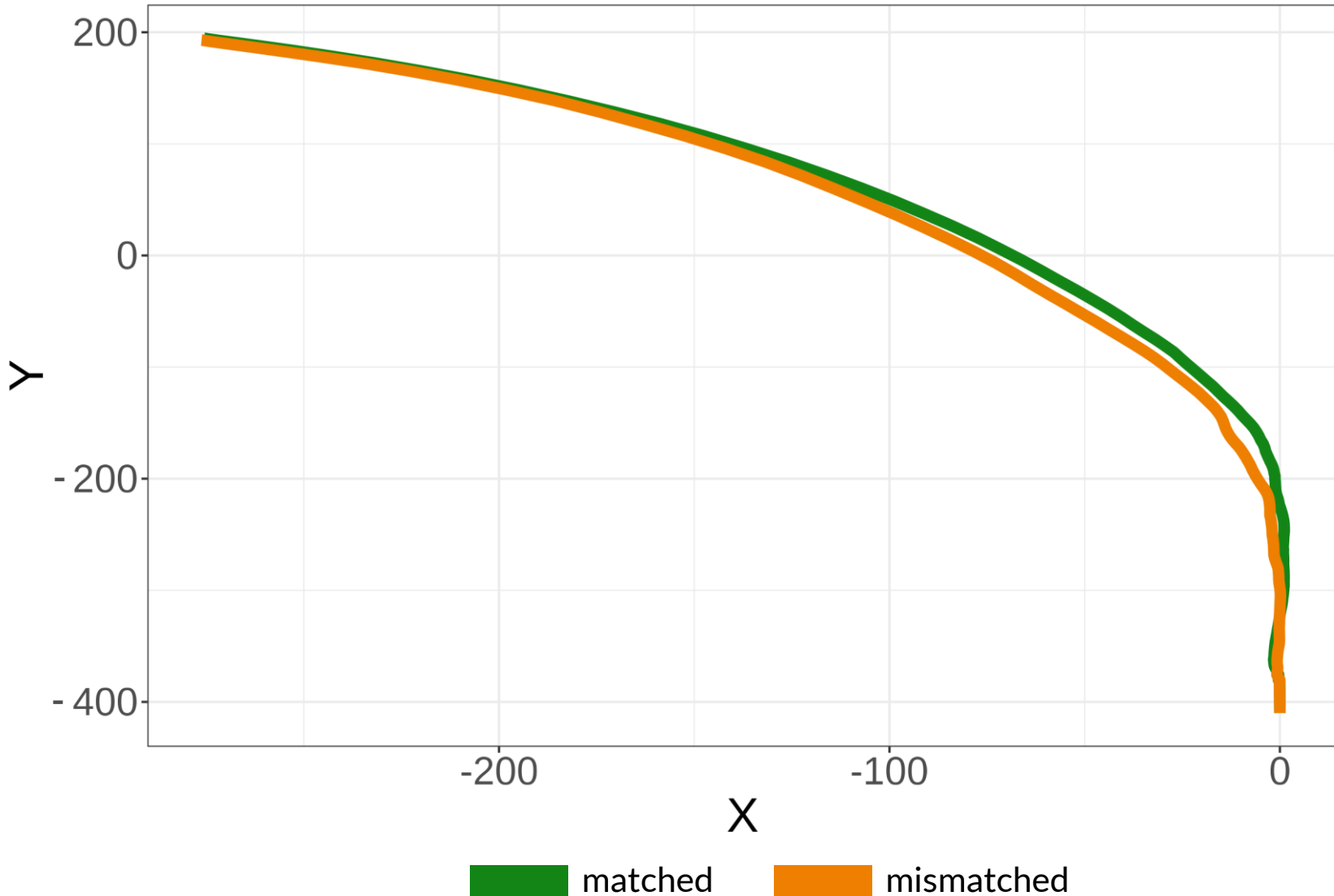


Mouse-Tracks



Mouse-Tracks: Raw Data

Mouse-Tracks: Raw Data



Analysis

Analysis

- there are many ways to analyse mouse-track data

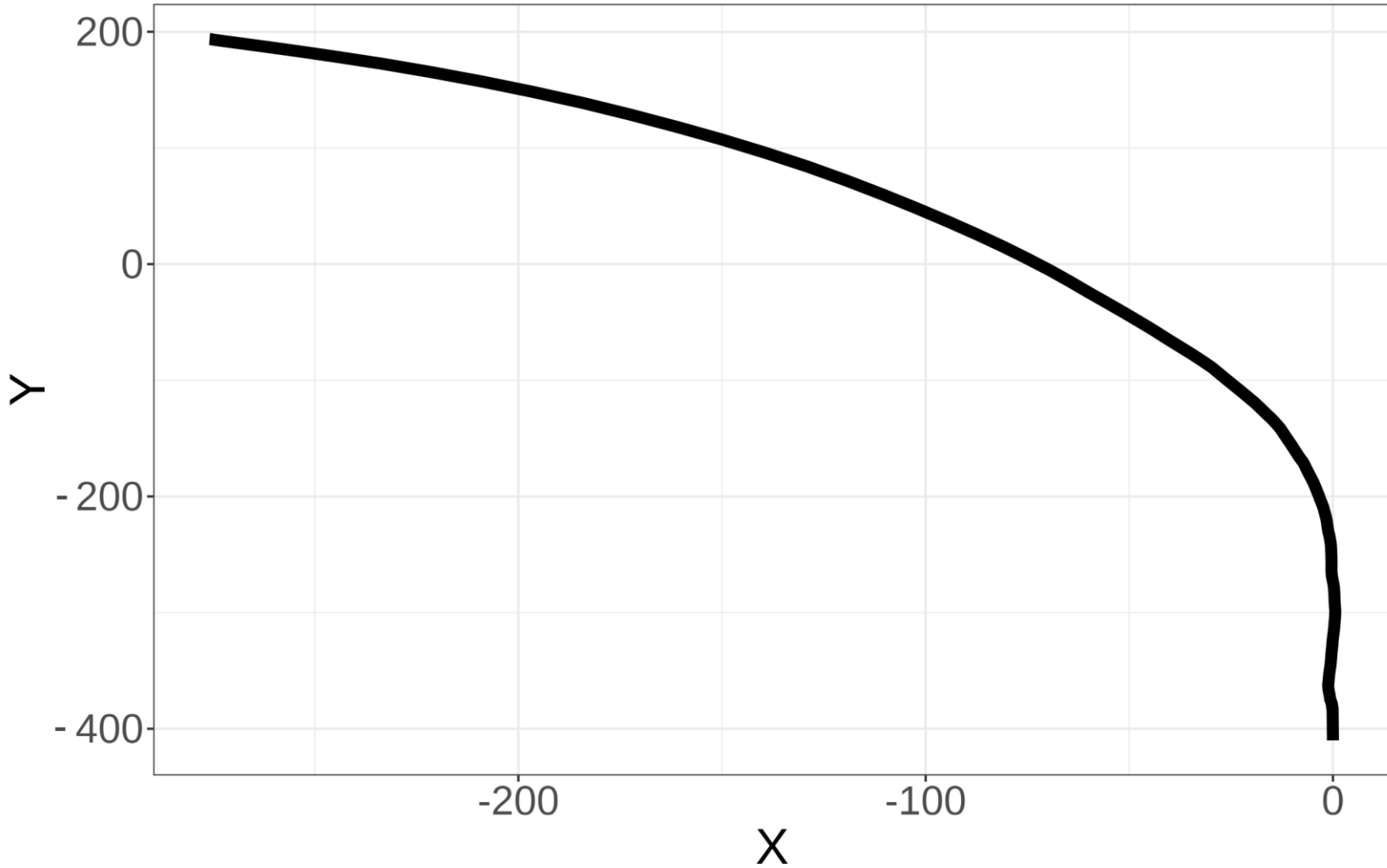
Analysis

- there are many ways to analyse mouse-track data
- we decided to use QGAMs – Quantile Generalized Additive Mixed models (Fasiolo et al., 2021)

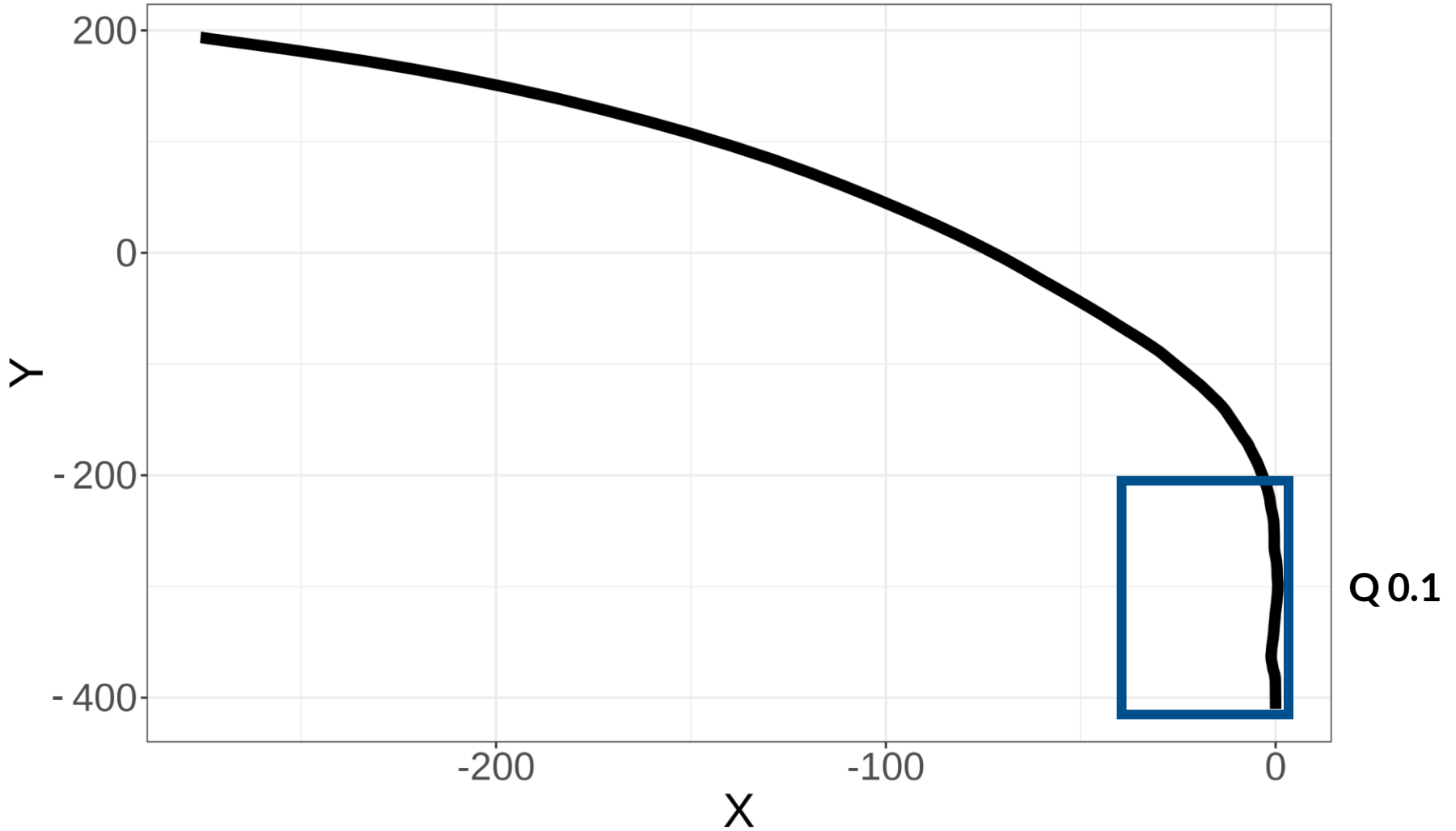
Analysis

- there are many ways to analyse mouse-track data
- we decided to use QGAMs – Quantile Generalized Additive Mixed models (Fasiolo et al., 2021)
- QGAMs are fitted to conditional quantiles of the dependent variable

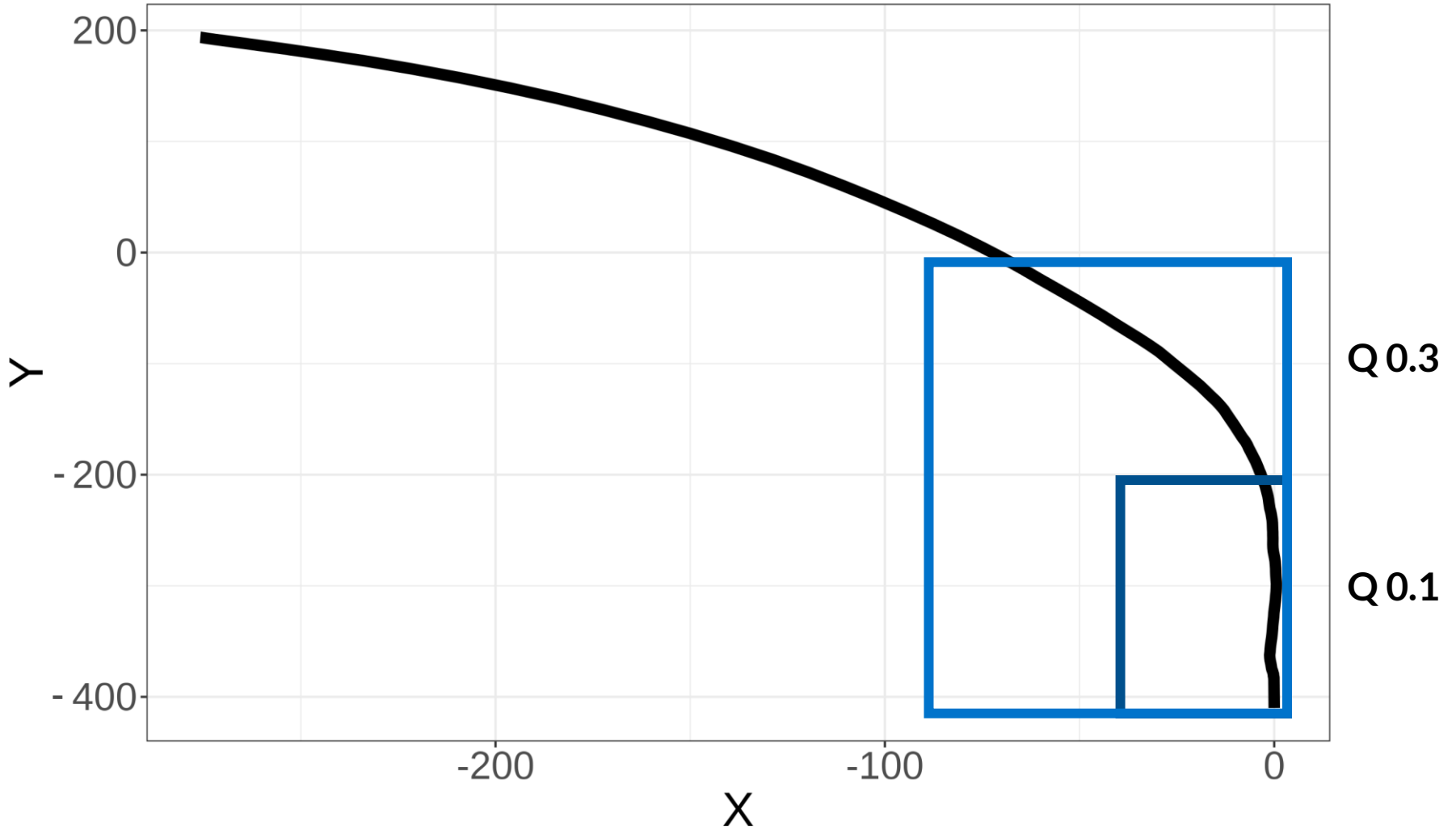
Analysis: Conditional Quantiles



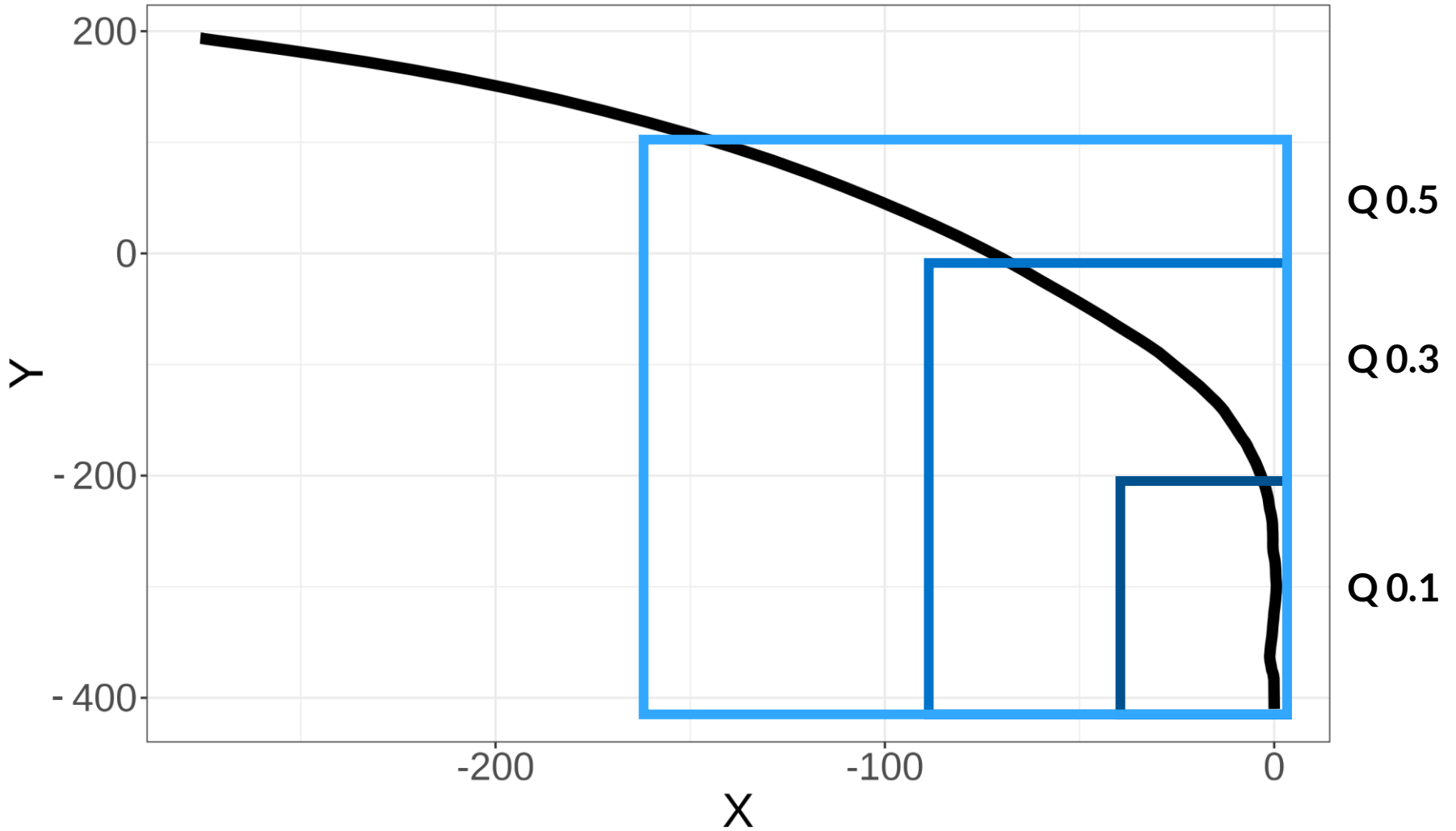
Analysis: Conditional Quantiles



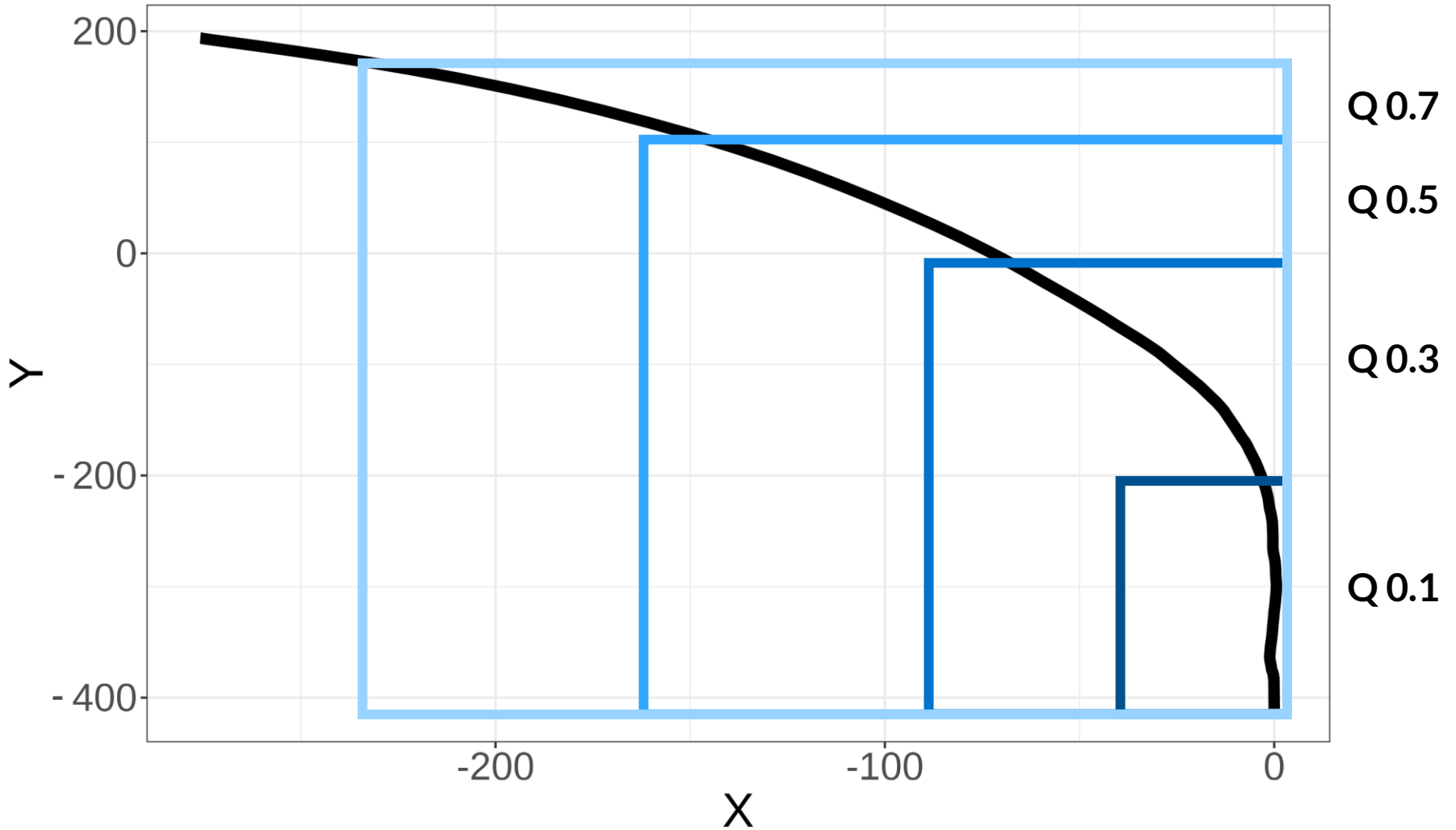
Analysis: Conditional Quantiles



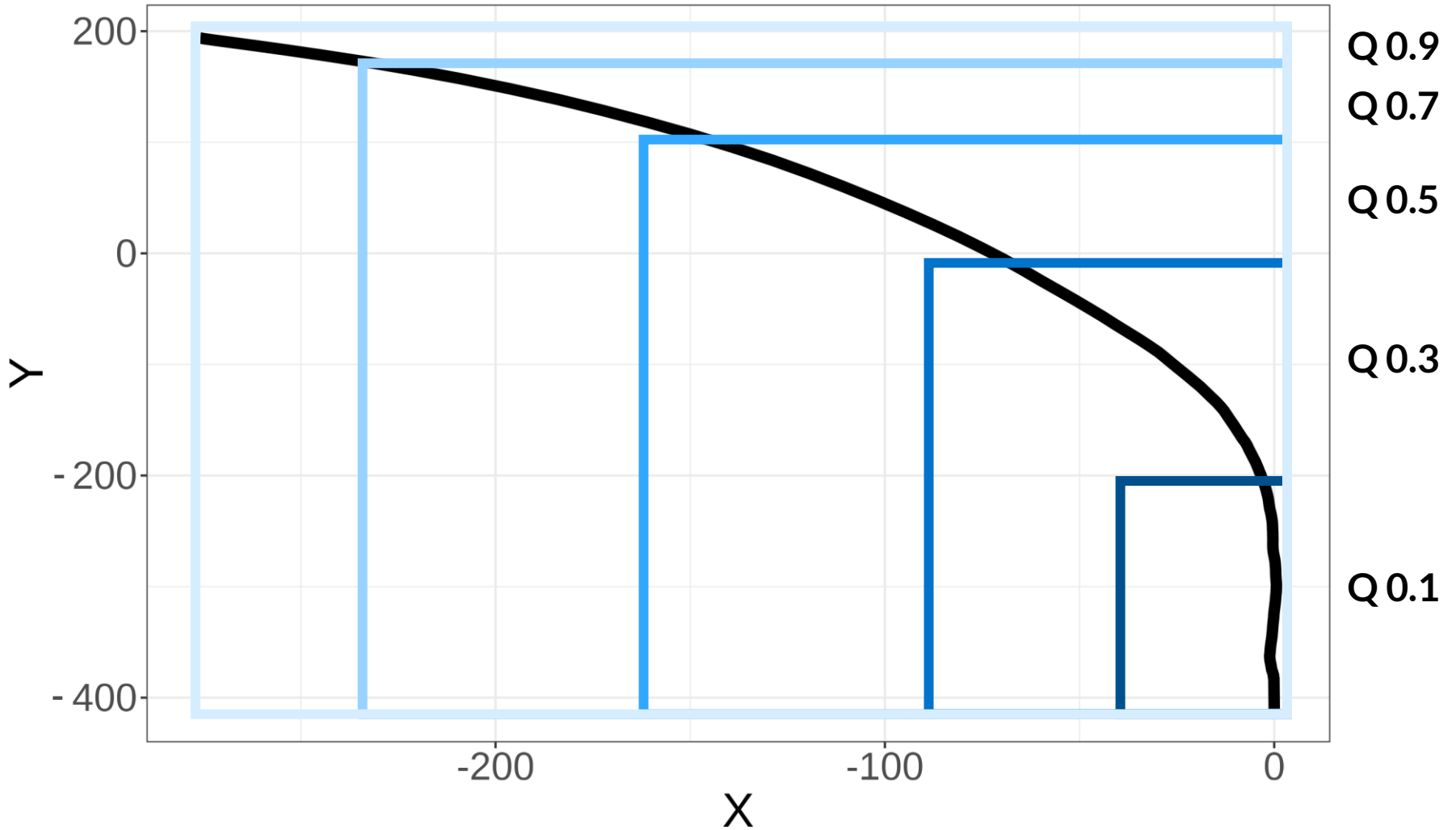
Analysis: Conditional Quantiles



Analysis: Conditional Quantiles



Analysis: Conditional Quantiles



Analysis: Modelling

Analysis: Modelling

- QGAMs were fitted for quantiles 0.1, 0.3, 0.5, 0.7, 0.9 with

Analysis: Modelling

- QGAMs were fitted for quantiles 0.1, 0.3, 0.5, 0.7, 0.9 with
 - response variables

X COORDINATES & Y COORDINATES

Analysis: Modelling

- QGAMs were fitted for quantiles 0.1, 0.3, 0.5, 0.7, 0.9 with

- response variables

X COORDINATES & Y COORDINATES

- smooth terms

ORDER

Analysis: Modelling

- QGAMs were fitted for quantiles 0.1, 0.3, 0.5, 0.7, 0.9 with

- response variables

X COORDINATES & Y COORDINATES

- smooth terms

ORDER

- parametric terms

CONDITION

Analysis: Modelling

- QGAMs were fitted for quantiles 0.1, 0.3, 0.5, 0.7, 0.9 with
 - response variables
X COORDINATES & Y COORDINATES
 - smooth terms
ORDER
 - parametric terms
CONDITION
 - random smooth terms
ITEM, PARTICIPANT

Analysis: Modelling

- QGAMs were fitted for quantiles 0.1, 0.3, 0.5, 0.7, 0.9 with

- response variables

X COORDINATES & Y COORDINATES

- smooth terms

ORDER

- parametric terms

CONDITION



matched vs. mismatched
do we find significantly
different mouse-tracks?

- random smooth terms

ITEM, PARTICIPANT

Analysis: Modelling

Analysis: Modelling

- QGAMs for four subsets were fitted

Analysis: Modelling

- QGAMs for four subsets were fitted

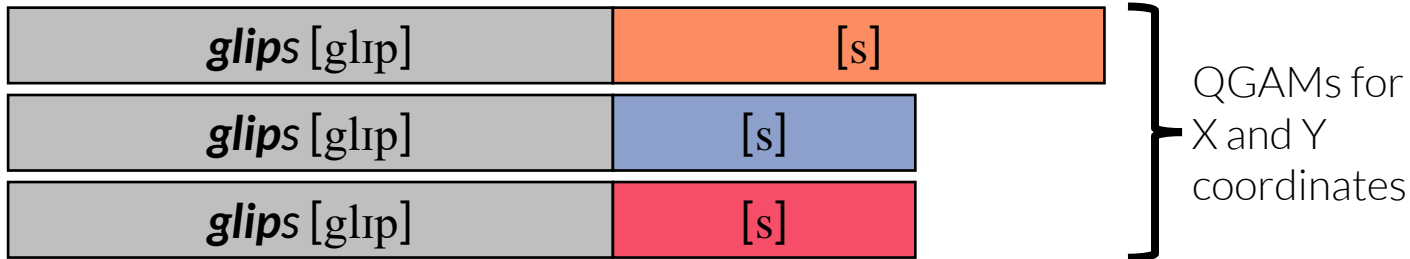
plural contexts

<i>glips</i> [glɪp]	[s]
<i>glips</i> [glɪp]	[s]
<i>glips</i> [glɪp]	[s]

Analysis: Modelling

- QGAMs for four subsets were fitted

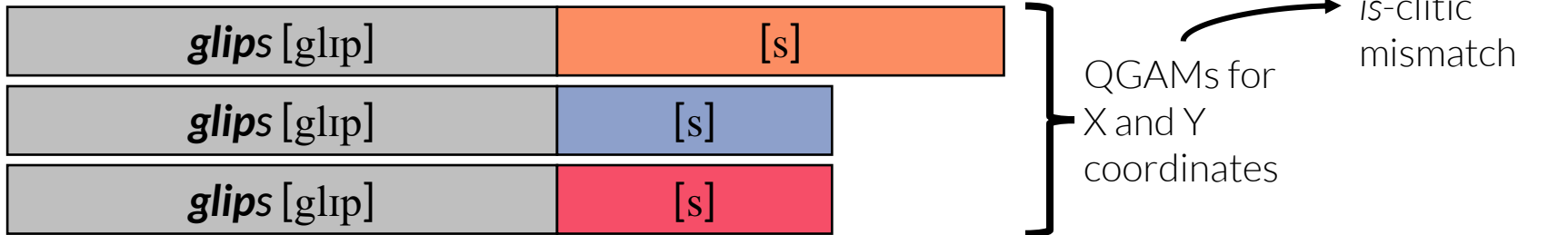
plural contexts



Analysis: Modelling

- QGAMs for four subsets were fitted

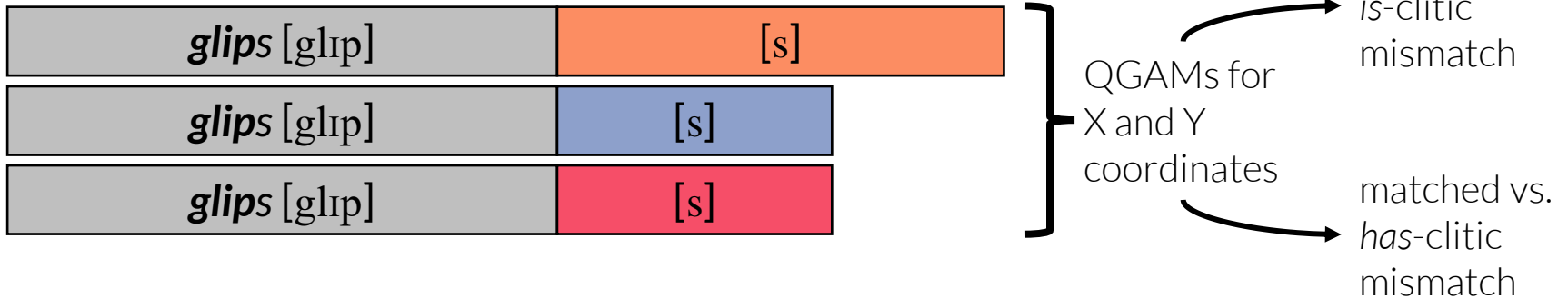
plural contexts



Analysis: Modelling

- QGAMs for four subsets were fitted

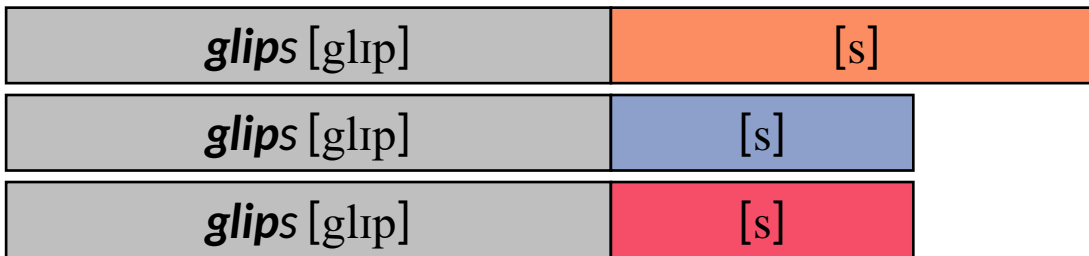
plural contexts



Analysis: Modelling

- QGAMs for four subsets were fitted

plural contexts

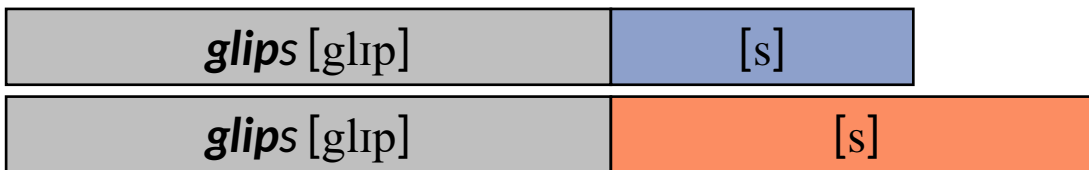


matched vs. *is*-clitic mismatch

QGAMs for X and Y coordinates

matched vs. *has*-clitic mismatch

is-clitic contexts

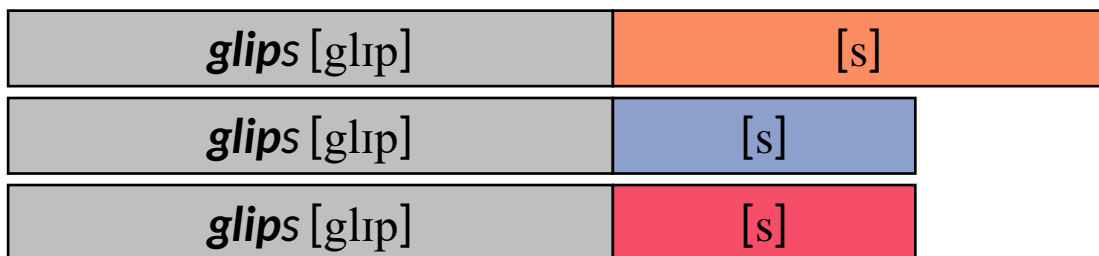


QGAMs for X and Y coordinates

Analysis: Modelling

- QGAMs for four subsets were fitted

plural contexts

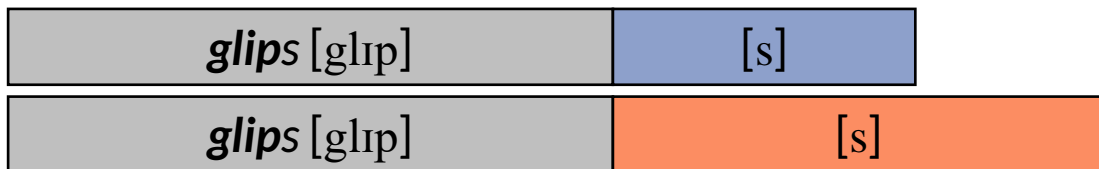


QGAMs for X and Y coordinates

matched vs. *is*-clitic mismatch

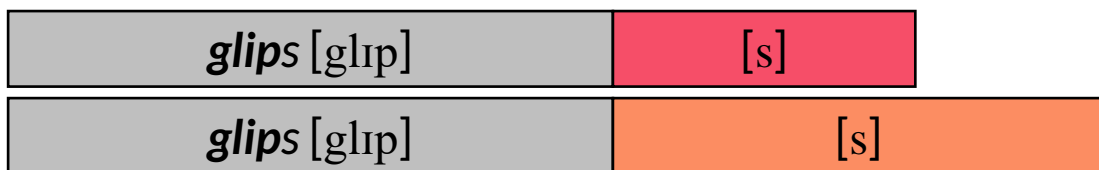
matched vs. *has*-clitic mismatch

is-clitic contexts



QGAMs for X and Y coordinates

has-clitic contexts



QGAMs for X and Y coordinates

Results: All Models

Results: All Models

- CONDITION shows significant effects across most QGAMs

plural context: plural match vs. is-clitic mismatch

X 0.1	X 0.3	X 0.5	X 0.7	X 0.9	Y 0.1	Y 0.3	Y 0.5	Y 0.7	Y 0.9
n.s.	n.s.	n.s.	***	***	***	***	***	***	n.s.

plural context: plural match vs. has-clitic mismatch

X 0.1	X 0.3	X 0.5	X 0.7	X 0.9	Y 0.1	Y 0.3	Y 0.5	Y 0.7	Y 0.9
**	***	***	n.s.	n.s.	n.s.	*	***	***	***

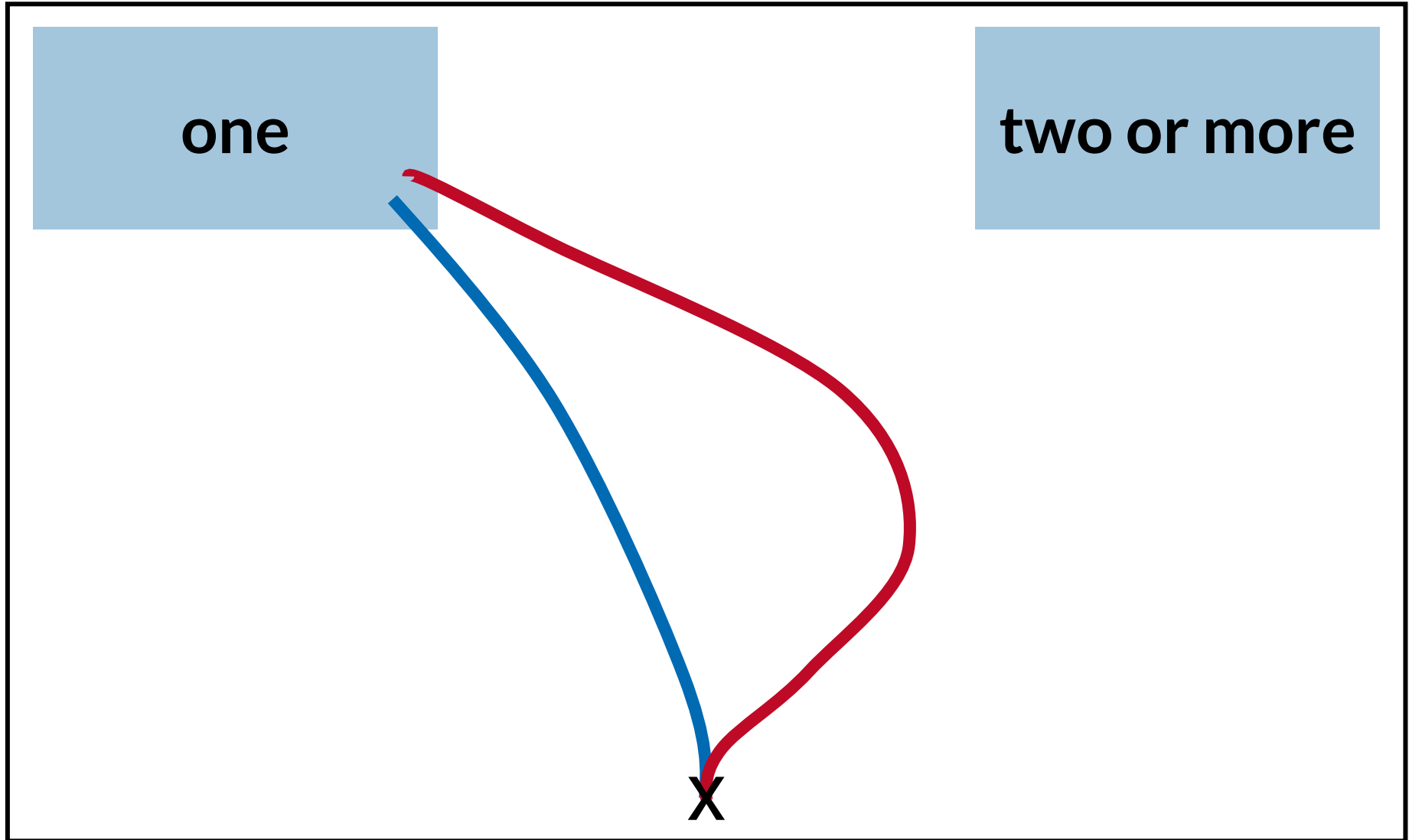
is-clitic context: is-clitic match vs. plural mismatch

X 0.1	X 0.3	X 0.5	X 0.7	X 0.9	Y 0.1	Y 0.3	Y 0.5	Y 0.7	Y 0.9
n.s.	n.s.	n.s.	***	***	n.s.	n.s.	n.s.	**	***

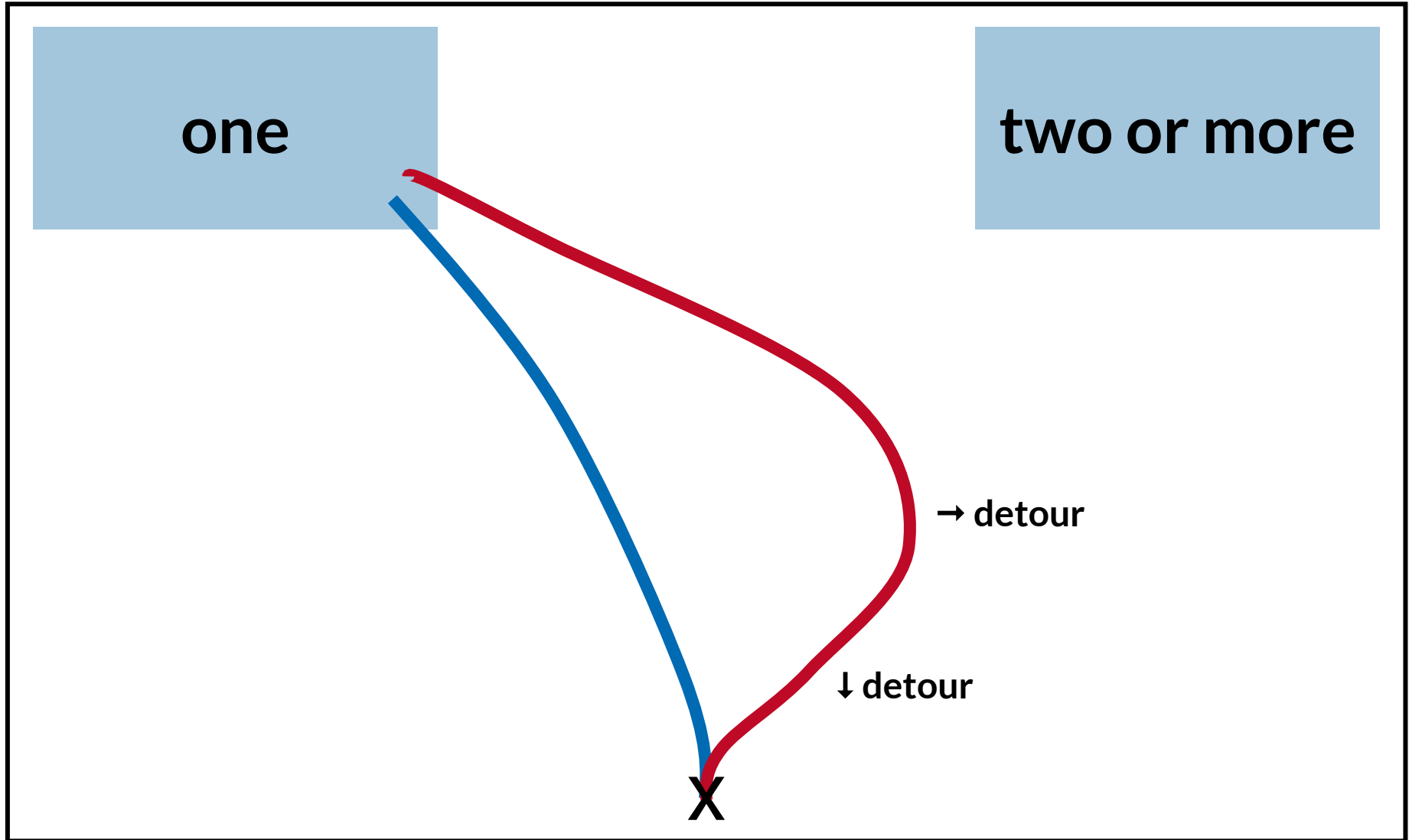
has-clitic context: has-clitic match vs. plural mismatch

X 0.1	X 0.3	X 0.5	X 0.7	X 0.9	Y 0.1	Y 0.3	Y 0.5	Y 0.7	Y 0.9
***	n.s.	n.s.	**	***	*	***	***	***	n.s.

What left/right & higher/lower mean



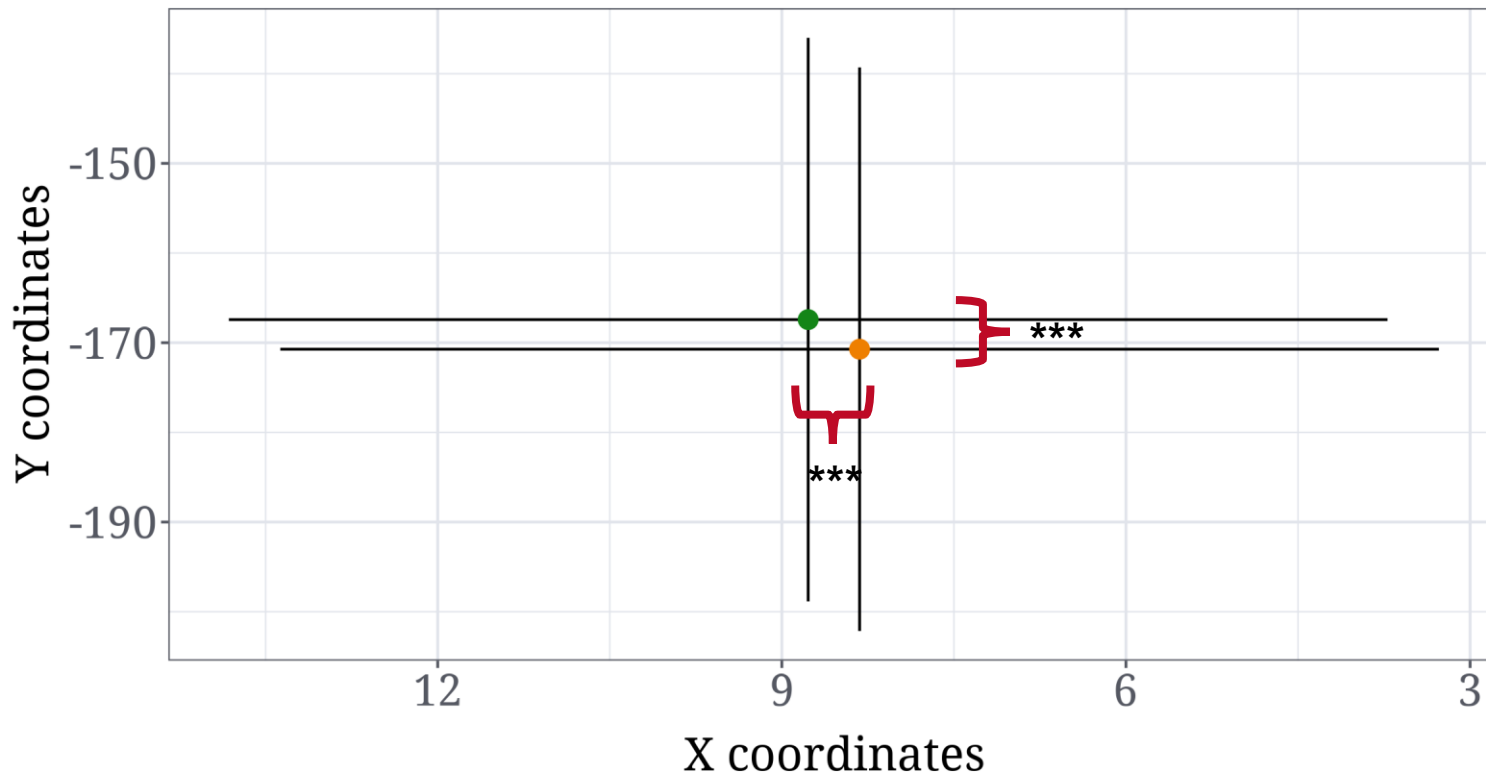
What left/right & higher/lower mean



Results: Example 1

Q 0.7 plural context & *is*-clitic /s/, [glɪps] vs. [glɪps]

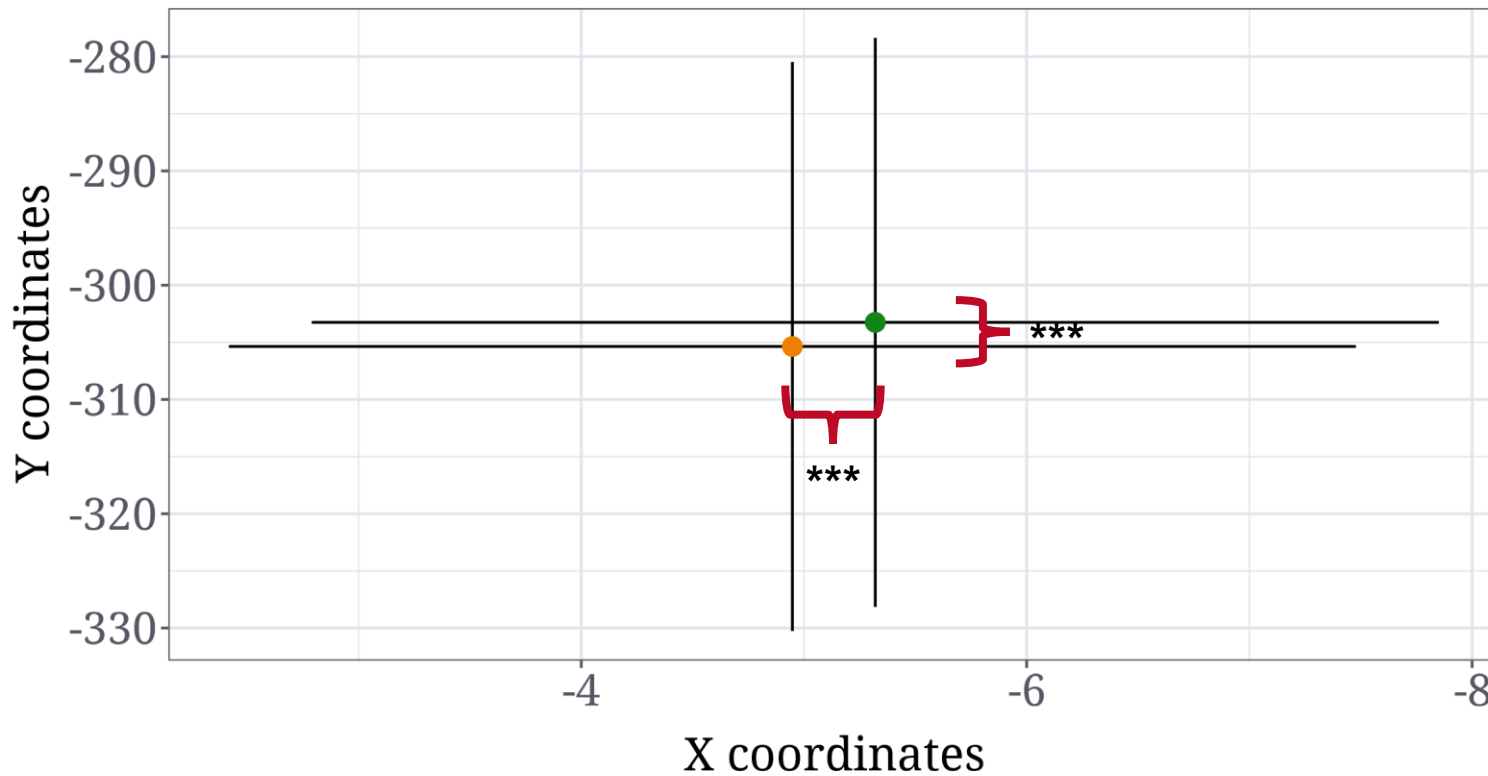
Condition ● matched ● mismatched



Results: Example 2

Q 0.5 plural context & *has*-clitic /s/, [glɪps] vs. [glɪps]

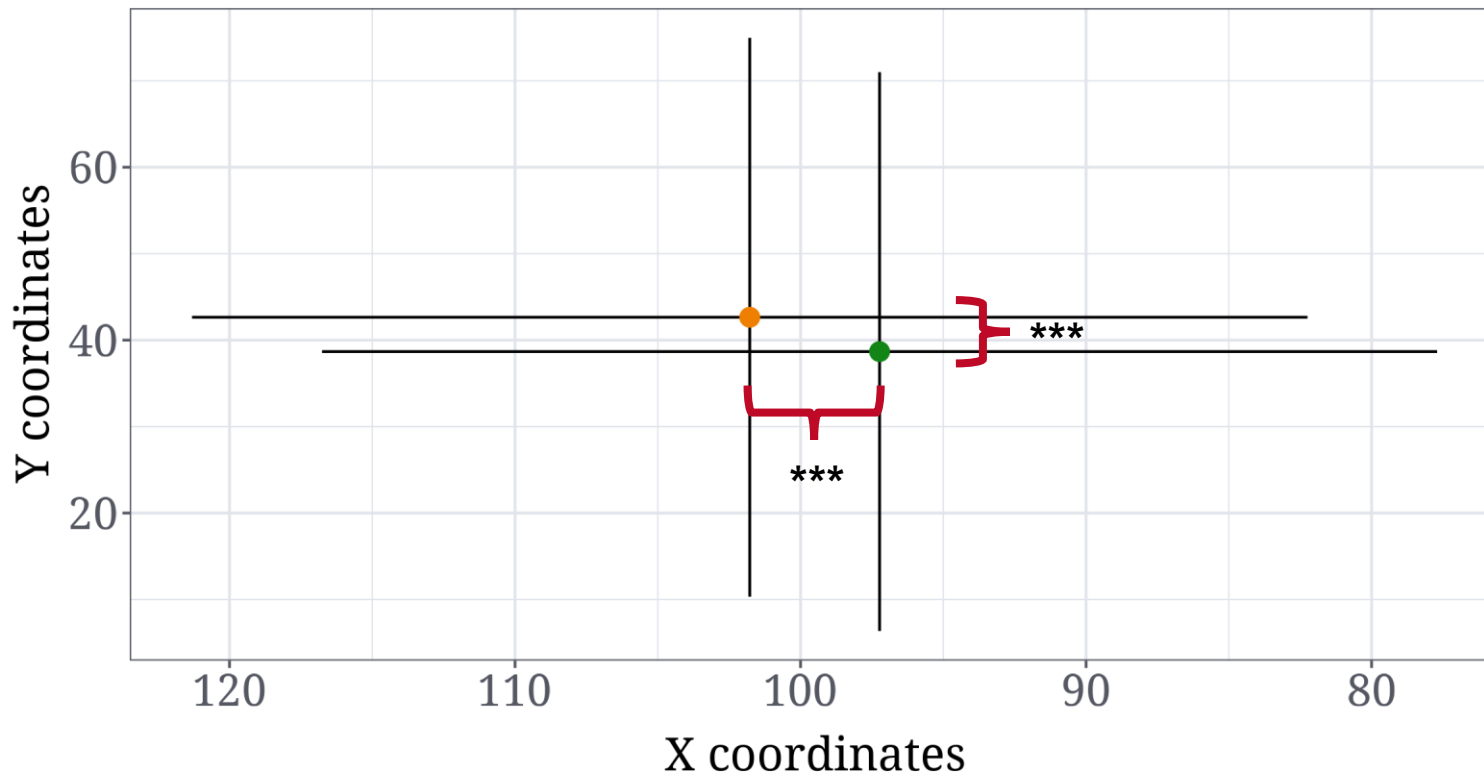
Condition ● matched ● mismatched



Results: Example 3

Q 0.9 *is-clitic context & plural /s/*, [glɪps] vs. [glɪps]

Condition ● matched ● mismatched



Results: Overall Differences

- Where do we find mismatched mouse-tracks?

	plural contexts	clitic contexts
Q		
0.1		
0.3		
0.5		
0.7		
0.9		

Results: Overall Differences

- Where do we find mismatched mouse-tracks?

	plural contexts		clitic contexts	
	plural match vs. <i>is-clitic</i> mismatch			
Q	X	Y		
0.1				
0.3				
0.5				
0.7	←	↑		
0.9	←	↑		

Results: Overall Differences

- Where do we find mismatched mouse-tracks?

	plural contexts				clitic contexts	
	plural match vs. <i>is-clitic</i> mismatch		plural match vs. <i>has-clitic</i> mismatch			
Q	X	Y	X	Y		
0.1			→	↑		
0.3				↑		
0.5				↑		
0.7	←	↑	←	↑		
0.9	←	↑	←			

Results: Overall Differences

- Where do we find mismatched mouse-tracks?

	plural contexts				clitic contexts	
	plural match vs. <i>is-clitic</i> mismatch		plural match vs. <i>has-clitic</i> mismatch		<i>is-clitic</i> match vs. plural mismatch	
Q	X	Y	X	Y	X	Y
0.1			→	↑		↓
0.3				↑		↓
0.5				↑		↓
0.7	←	↑	←	↑	→	↓
0.9	←	↑	←		→	

Results: Overall Differences

- Where do we find mismatched mouse-tracks?

	plural contexts				clitic contexts			
	plural match vs. <i>is-clitic</i> mismatch		plural match vs. <i>has-clitic</i> mismatch		<i>is-clitic</i> match vs. plural mismatch		<i>has-clitic</i> match vs. plural mismatch	
Q	X	Y	X	Y	X	Y	X	Y
0.1			→	↑		↓	←	
0.3				↑		↓	←	↓
0.5				↑		↓	←	↓
0.7	←	↑	←	↑	→	↓		↓
0.9	←	↑	←		→			↓

Summary

Summary

- CONDITION shows a significant effect across most quantiles and across all sets of QGAMs

Summary

- CONDITION shows a significant effect across most quantiles and across all sets of QGAMs
- that is, participants overall show significantly different mouse-trajectories for **matched** vs. **mismatched** items

Summary

- CONDITION shows a significant effect across most quantiles and across all sets of QGAMs
- that is, participants overall show significantly different mouse-trajectories for **matched** vs. **mismatched** items
 - plural contexts with mismatched clitic /s/ durations come with **higher** Y coordinate values

Summary

- CONDITION shows a significant effect across most quantiles and across all sets of QGAMs
- that is, participants overall show significantly different mouse-trajectories for **matched** vs. **mismatched** items
 - plural contexts with mismatched clitic /s/ durations come with **higher** Y coordinate values
 - clitic contexts with mismatched plural /s/ durations come with **lower** Y coordinate values

Summary

- CONDITION shows a significant effect across most quantiles and across all sets of QGAMs
- that is, participants overall show significantly different mouse-trajectories for **matched** vs. **mismatched** items
 - plural contexts with mismatched clitic /s/ durations come with **higher** Y coordinate values
 - clitic contexts with mismatched plural /s/ durations come with **lower** Y coordinate values
 - for X coordinates, no such clear pattern is found

Summary

- CONDITION shows a significant effect across most quantiles and across all sets of QGAMs
- that is, participants overall show significantly different mouse-trajectories for **matched** vs. **mismatched** items
 - plural contexts with mismatched clitic /s/ durations come with **higher** Y coordinate values
 - clitic contexts with mismatched plural /s/ durations come with **lower** Y coordinate values
 - for X coordinates, no such clear pattern is found
- this is clear evidence for an influence of word-final /s/ duration on comprehension

Theoretical Implications

Theoretical Implications

- subtle morpho-phonetic differences need to be taken seriously in both production and comprehension!

Theoretical Implications

- subtle morpho-phonetic differences need to be taken seriously in both production and comprehension!
- 1. abstractionist models assume abstract phonological representations to be the unit of comprehension (e.g. Klatt, 1979; McClelland & Elman, 1986; Norris, 1994; Norris & McQueen, 2008)
 - no subphonemic information is retained

Theoretical Implications

- subtle morpho-phonetic differences need to be taken seriously in both production and comprehension!
- 1. abstractionist models assume abstract phonological representations to be the unit of comprehension (e.g. Klatt, 1979; McClelland & Elman, 1986; Norris, 1994; Norris & McQueen, 2008)
 - no subphonemic information is retained
- 2. feature based models assume that only marked information is retained for comprehension (e.g. Massaro, 1987; Lahiri & Marslen-Wilson, 1991)
 - are subphonemic durational differences marked information?

Theoretical Implications

- subtle morpho-phonetic differences need to be taken seriously in both production and comprehension!
- 1. abstractionist models assume abstract phonological representations to be the unit of comprehension (e.g. Klatt, 1979; McClelland & Elman, 1986; Norris, 1994; Norris & McQueen, 2008)
 - no subphonemic information is retained
- 2. feature based models assume that only marked information is retained for comprehension (e.g. Massaro, 1987; Lahiri & Marslen-Wilson, 1991)
 - are subphonemic durational differences marked information?
- 3. exemplar-based models can account for our findings as they assume fine phonetic detail to be stored in the lexicon (e.g. Goldinger, 1998)
 - however, they cannot account for the emergence of such differences in the first place (cf. Schmitz et al., 2021)

Thank you!

References

- Caselli, N. K., Caselli, M. K., & Cohen-Goldberg, A. M. (2016). Inflected words in production: Evidence for a morphologically rich lexicon. *Quarterly Journal of Experimental Psychology*, *69*(3), 432–454. <https://doi.org/10.1080/17470218.2015.1054847>
- Fasiolo, M., Wood, S. N., Zaffran, M., Nedellec, R., & Goude, Y. (2021). Fast Calibrated Additive Quantile Regression. *Journal of the American Statistical Association*, *116*(535), 1402–1412. <https://doi.org/10.1080/01621459.2020.1725521>
- Gahl, S. (2008). Time and Thyme Are not Homophones: The Effect of Lemma Frequency on Word Durations in Spontaneous Speech. *Language*, *84*(3), 474–496. <https://doi.org/10.1353/lan.0.0035>
- Goldinger, S. D. (1998). Echoes of Echoes? An Episodic Theory of Lexical Access. *Psychological Review*, *105*(2), 251–279. <https://doi.org/10.1037/0033-295X.105.2.251>
- Klatt, D. H. (1976). Linguistic uses of segmental duration in English: Acoustic and perceptual evidence. *The Journal of the Acoustical Society of America*, *59*(5), 1208. <https://doi.org/10.1121/1.380986>
- Klatt, D. H. (1979). Speech perception: a model of acoustic–phonetic analysis and lexical access. *Journal of Phonetics*, *7*(3), 279–312. [https://doi.org/10.1016/S0095-4470\(19\)31059-9](https://doi.org/10.1016/S0095-4470(19)31059-9)
- Lahiri, A., & Marslen-Wilson, W. (1991). The mental representation of lexical form: A phonological approach to the recognition lexicon. *Cognition*, *38*(3), 245–294. [https://doi.org/10.1016/0010-0277\(91\)90008-R](https://doi.org/10.1016/0010-0277(91)90008-R)
- Massaro, D. W. (1987). *Speech perception by ear and eye: A paradigm for psychological inquiry*. Psychology Press. <https://doi.org/https://doi.org/10.4324/9781315808253>
- McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology*, *18*(1), 1–86. [https://doi.org/10.1016/0010-0285\(86\)90015-0](https://doi.org/10.1016/0010-0285(86)90015-0)
- Norris, D. (1994). Shortlist: a connectionist model of continuous speech recognition. *Cognition*, *52*(3), 189–234. [https://doi.org/10.1016/0010-0277\(94\)90043-4](https://doi.org/10.1016/0010-0277(94)90043-4)
- Norris, D., & McQueen, J. M. (2008). Shortlist B: A Bayesian model of continuous speech recognition. *Psychological Review*, *115*(2), 357–395. <https://doi.org/10.1037/0033-295X.115.2.357>
- Plag, I., Homann, J., & Kunter, G. (2017). Homophony and morphology: The acoustics of word-final S in English. *Journal of Linguistics*, *53*(1), 181–216. <https://doi.org/10.1017/S0022226715000183>
- Plag, I., Lohmann, A., Ben Hedia, S., & Zimmermann, J. (2020). An <s> is an <s'>, or is it? Plural and genitive-plural are not homophonous. In L. Körtvélyessy & P. Štekauer (Eds.), *Complex Words*. Cambridge University Press.
- Schmitz, D., Baer-Henney, D., & Plag, I. (2021). The duration of word-final /s/ differs across morphological categories in English: evidence from pseudowords. *Phonetica*, *78*(5–6), 571–616. <https://doi.org/10.1515/phon-2021-2013>
- Seyfarth, S., Garellek, M., Gillingham, G., Ackerman, F., & Malouf, R. (2017). Acoustic differences in morphologically-distinct homophones. *Language, Cognition and Neuroscience*, *33*(1), 32–49. <https://doi.org/10.1080/23273798.2017.1359634>
- Tomaschek, F., Plag, I., Ernestus, M., & Baayen, R. H. (2019). Phonetic effects of morphology and context: Modeling the duration of word-final S in English with naïve discriminative learning. *Journal of Linguistics*, *2019*, 1–39. <https://doi.org/10.1017/S0022226719000203>
- Wightman, C. W., Shattuck-Hufnagel, S., Ostendorf, M., & Price, P. J. (1992). Segmental Durations In The Vicinity Of Prosodic Phrase Boundaries. *Journal of the Acoustical Society of America*, *91*(3), 1707–1717. <https://doi.org/10.1121/1.402450>