



Can we integrate that?

Anaphor resolution effects of high boundary tones in
German adverbial and factive embedded clauses

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Introduction

Final falls and low boundary tones at the end of clause-length chunks of speech have long been associated with *finality and completeness*; their absence with *incompleteness*

Specifically, **high tones, rises, or level pitch** at such boundaries have been taken to cue *continuation or incompleteness*

Does that mean that given two clauses, a high tone at an interclausal boundary will always cue more integration between the two clauses than a low tone?



turns out, not really...

Questions

How do prosodic cues (esp. boundary tones) at interclausal boundaries contribute to an integrated vs. separating representation **at the level of discourse units/referents?**

→ as reflected in anaphor resolution preferences

Does prosody simply contribute additively to integration/separation cues from other formal domains (syntax, typography, connectives)?

- OR more complex interaction with syntax?

CAVEAT: The research here does not tell us directly about how natural or frequent the combinations between +/- prosodic integration and +/- syntactic integration are (they are at least natural enough for me and other native speakers); I can just show you something about discourse effects on their combination

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- Prosodic Exp 3 on Factives

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Background: what tonal boundary cues contribute to large speech unit chunking

low boundary tones / boundary falls associated with “closedness” or “finality”;

their absence or presence of **level or high boundary tones / boundary rises** associated with “openness”, “non-finality”, “continuation”

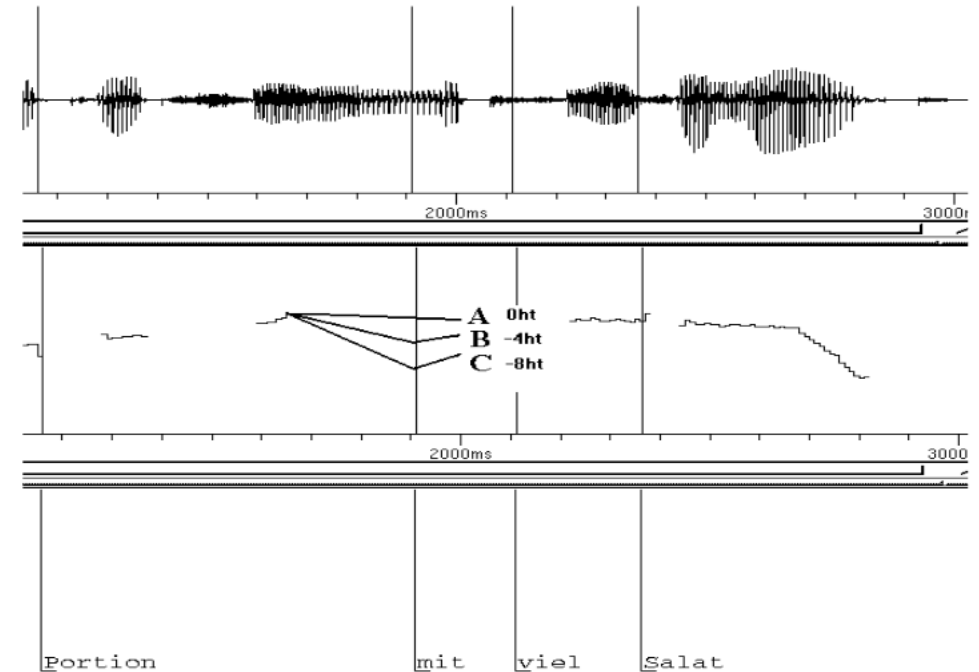
(Cruttenden 1981, Gussenhoven 2004, many others)

- *period intonation* (fall) vs. *comma intonation* (rise, level) (Chafe 1988)
- crosslinguistically, final rises associated with smaller Intonation Phrases or Intonation Units, final falls with larger Utterances or prosodic Sentences (Gordon 2025)
 - absence of final fall associated with non-finality
- similar observations for German (B. Peters 2005; Grice & Baumann 2007; J. Peters 2018, amongst others)

Boundary pitch movement cues perceived prosodic integration/separation

Peters (2005) on spontaneous German:

- perceived degree of phonetic separation based on boundary contour: strong falling > slightly falling > level
- speaker change predicted at turn end: strong falling > slightly falling > others (incl. rising)
- syntax no effect; pauses much stronger



positive closure shift (indicative for prosodic boundary) detected via EEG (Holzgreffe-Lang et al. 2016)

Peters (2005: 231)

- for boundaries cued by pitch and preboundary lengthening in absence of pauses in German
- correlates with behavioural data

Prosodic integration / separation in German causal adverbial clauses

Volodina (2011): prosodic corpus study on causal clauses:

strongly falling *or* strongly rising boundary movement seen as separating;
rising or level integrating

- *weil*-clauses: high degree of prosodic integration correlated with content-level reading, low degree with epistemic- and speech act-level reading (cf. Sweetser 1990)

Er kommt ↓/ ↑↑ weil ich ihn gefragt habe.

integrating; content-level

Er kommt ↑ /→ weil ich ihn gefragt habe.

separating; non-content-level

he comes because I asked him

Prosodic integration / separation in German causal adverbial clauses

Volodina (2011): prosodic corpus study on causal clauses:

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rising or level integrating

- *denn*-clauses: only instances found of low prosodic integration and epistemic- or speech act-level readings (but cf. Wöllstein et al. 2022 for *denn* in content-level readings)

Die Heizungsrohre sind geplatzt (↑ /→ ?) denn es hat Frost gegeben *content-level*

the heating pipes burst *because there's been a freeze*

Es hat Frost gegeben ↓/ ↑↑ denn die Heizungsrohre sind geplatzt *non-content-level*

there's been a freeze *because the heating pipes burst*

Prosodic integration / separation in German causal adverbial clauses

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- *weil*-clauses: high degree of prosodic integration correlated with content-level reading, low degree with epistemic- and speech act-level reading (cf. Sweetser 1990)
- *denn*-clauses: only instances found of low prosodic integration and epistemic- or speech act-level readings (but cf. Wöllstein et al. 2022 for *denn* in content-level readings)
- parallel to syntax: correlation between more > less integration and content > epistemic > speech act-level readings for *weil*- and other adverbial clauses; *denn*-clauses (V2) always less integrated than postposed *weil*-V-final clauses (Antomo & Steinbach 2010; Scheffler 2013; Frey 2016; Wöllstein et al. 2022)

What follows?

given this general background and the observed parallel between syntactic and prosodic integration for making the different levels of reading available

can we assume that cues for prosodic integration will add to cues for integration from other domains (syntax, typography, connectives) towards an overall construction of integration?

e.g. in the construction and selection of discourse referents?

one way to test this: anaphor resolution

Anaphor resolution experiments on cues to clause-combining with adverbial clauses

- written cues (syntax, typography, connectives)
- spoken cues (prosody)



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Structural differentiation at the RF

The **Right Frontier Constraint**:

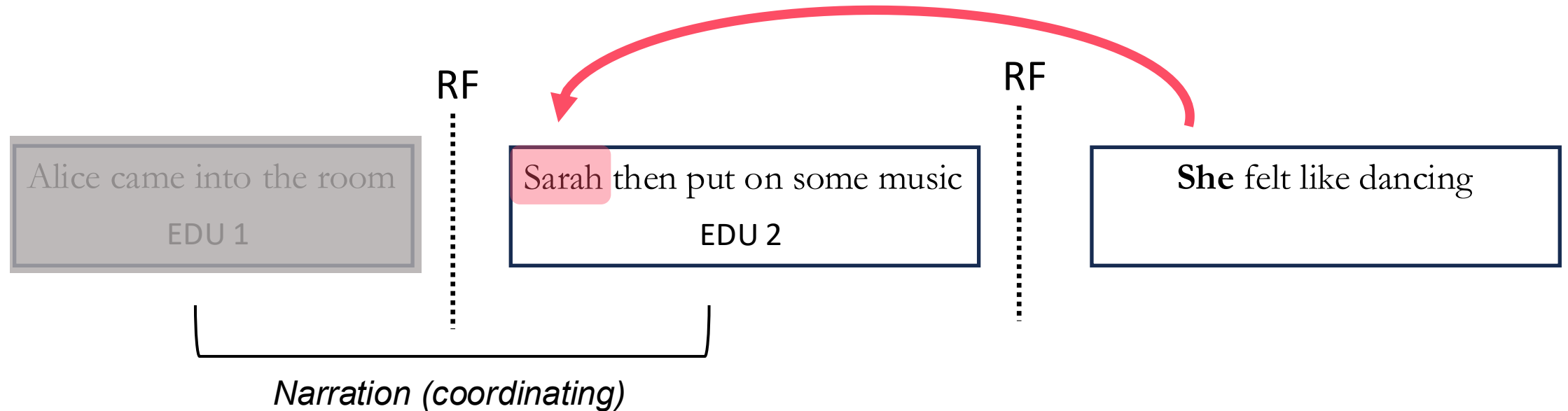
Only content that is at the **Right Frontier** (RF) of discourse is available for subsequent attachment via anaphors

A new discourse-*coordinated* discourse unit forms a queue with the preceding discourse → moves RF forward

A new discourse-*subordinated* discourse unit forms a stack → does not move RF forward

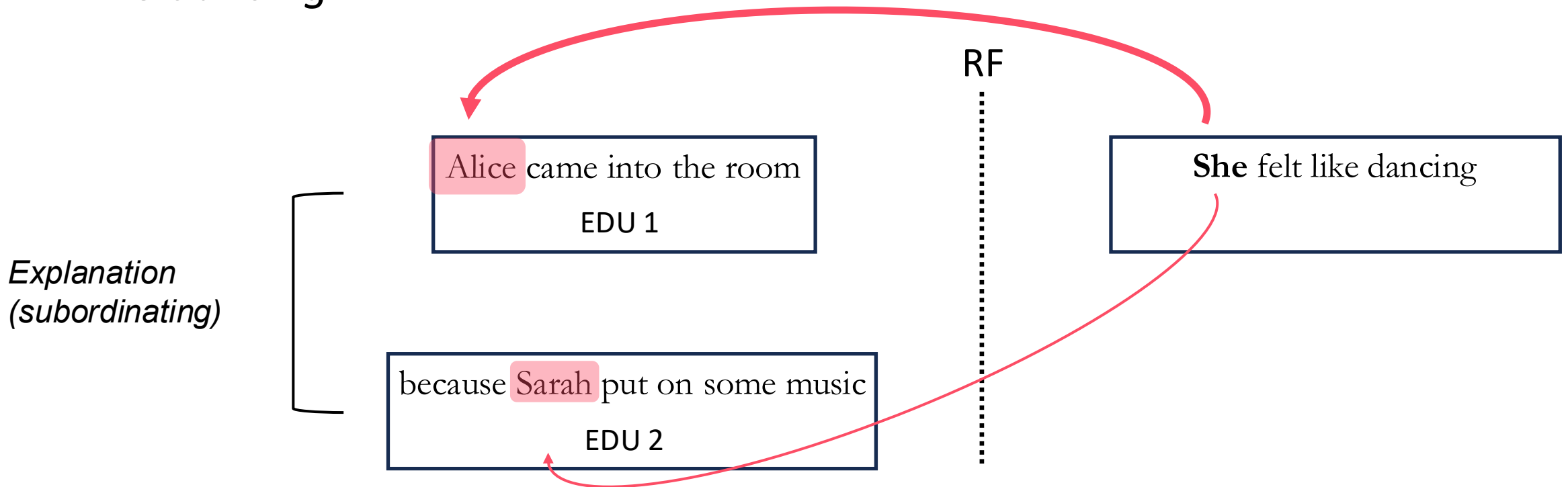
DS-Coordination moves the RF forward

Alice came into the room. Sarah then put on some music. She felt like dancing.



DS-Subordination does not move the RF

Alice came into the room, because Sarah put on some music. She felt like dancing.



But...

*Explanation
(subordinating)*

Christoph hat viele Snacks gekauft
Christoph bought lots of snacks

,

weil Raphael einen Filmabend vorgeschlagen **hatte**
because Raphael had proposed a movie night

*Explanation
(subordinating)*

Christoph hat viele Snacks gekauft
Christoph bought lots of snacks

.

Raphael **hatte** einen Filmabend vorgeschlagen
Raphael had proposed a movie night

RF

Er...
he... ?

But...

There are lots of cases where two discourse units / clauses are available at the RF - but they can have different (formal) properties

- different (subordinating) rhetorical relations
 - often explicitly cued e.g. via adverbial clauses with connectives
 - or implicitly cued without connectives
- *syntactic* subordination vs coordination
 - clauses with verb-final vs. verb-second word order (e.g. *weil* vs. *denn*)
- typographic differences
- *prosodic boundary cues*

How do these influence anaphoric attachment?

What's the contribution of discourse structure, and what's the contribution of formal properties of the clauses and their linking?

- ... can these all be modeled as contributing to a weaker/stronger degree of integration between the two clauses?

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- *more* structural integration → more likely perceived as a single sentence / discourse unit with high discourse prominence (von Heusinger & Schumacher 2019)

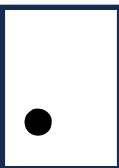
Christoph hat viele Snacks gekauft
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- ... can these all be modeled as contributing to a weaker/stronger degree of integration between the two clauses?
- *less structural integration* → second clause more likely perceived as a separate discourse unit with corresponding higher relative prominence

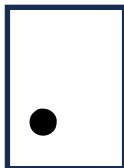
Christoph hat viele Snacks gekauft
Christoph bought lots of snacks



Raphael **hatte** einen Filmabend vorgeschlagen
Raphael had proposed a movie night

- ... can these all be modeled as contributing to a weaker/stronger degree of integration between the two clauses?
- less structural integration → second clause more likely perceived as a separate discourse unit with corresponding higher relative prominence
- prominence relations between clause-level units get "inherited" by their subject referents (Buchholz et al. 2025)
- → affect resolution patterns of anaphoric personal pronouns

Christoph hat viele Snacks gekauft
Christoph bought lots of snacks



Raphael **hatte** einen Filmabend vorgeschlagen
Raphael had proposed a movie night

Experiments on written German

Christoph hat viele Snacks gekauft
Christoph bought lots of snacks

syntactic sub-
/coordination

comma/
full stop

connective
+/-

• weil Raphael einen Filmabend vorgeschlagen **hatte**
H%/L% *because Raphael had proposed a movie night*

• weil Raphael **nämlich** einen Filmabend vorgeschlagen **hatte**
because Raphael had proposed a movie night

• denn Raphael **hatte** einen Filmabend vorgeschlagen
H%/L% *because Raphael had proposed a movie night*

• Raphael **hatte nämlich** einen Filmabend vorgeschlagen
because Raphael had proposed a movie night

• Raphael **hatte** einen Filmabend vorgeschlagen
Raphael had proposed a movie night

Christoph hat viele Snacks gekauft
Christoph bought lots of snacks

› **weil** Raphael einen Filmabend vorgeschlagen **hatte**

› **denn** Raphael **hatte** einen Filmabend vorgeschlagen
because Raphael had proposed a movie night

• Raphael **hatte** einen Filmabend vorgeschlagen
Raphael had proposed a movie night

backward causality

Raphael hat einen Filmabend vorgeschlagen
Raphael has proposed a movie night

› **so dass** Christoph viele Snacks gekauft **hat**

› **also hat** Christoph viele Snacks gekauft
so Christoph bought lots of snacks

• Christoph **hat** viele Snacks gekauft
Christoph bought lots of snacks

forward causality

Er...

(Das...)

Christoph hat viele Snacks gekauft
Christoph bought lots of snacks

› **obwohl** Raphael einen Ausgehabend vorgeschlagen **hat**
even though Raphael suggested going out for the evening

› **aber** Raphael **hat** einen Ausgehabend vorgeschlagen

• Raphael **hat aber** einen Ausgehabend vorgeschlagen
but Raphael suggested going out for the evening

violation of expectation

Parameters

Syntax

- subordination vs coordination (verb-final vs. verb-second)
- presence or absence of a connective

Typography:

- comma (weak) or full stop (strong) at interclausal boundary

Discourse structure:

- backward causality / Explanation (subordinating)
- forward causality / Result (SDRT: coordinating, RST: not necessarily)
- violation of expectations (SDRT: coordinating, RST: not necessarily)

Prosodic boundaries (next step)

- Propositional anaphors

Brief experimental setup

Ref1

Nadja hat vegane Burger gekauft
Nadja bought vegan burger

Ref2

, denn Sabine isst kein Fleisch.
because Sabine doesn't eat meat

nonce verb

Sie plaugte.
She plauged

Wer plaugte?
Who plauged?

Sabine

Nadja

forced-choice,
randomized order

- 2 subjects, 1 per clause
- both plausible as subjects of ambiguous 3rd clause
- content-level interpretation aimed at
- nonce verb predicates
- 4 experiments with 3 conditions each (+ 3 exps on propositional anaphors)
- 24 experimental items, 16 fillers, 8-16 catch fillers
- ~20 participants per condition after exclusion, web-based

Hypotheses and Predictions (Formal properties)

Typography: weaker boundary (*comma*) → 2nd clause more integrated than with stronger boundary (*full stop*)

Connector: *with* connector → 2nd clause more integrated than *without*

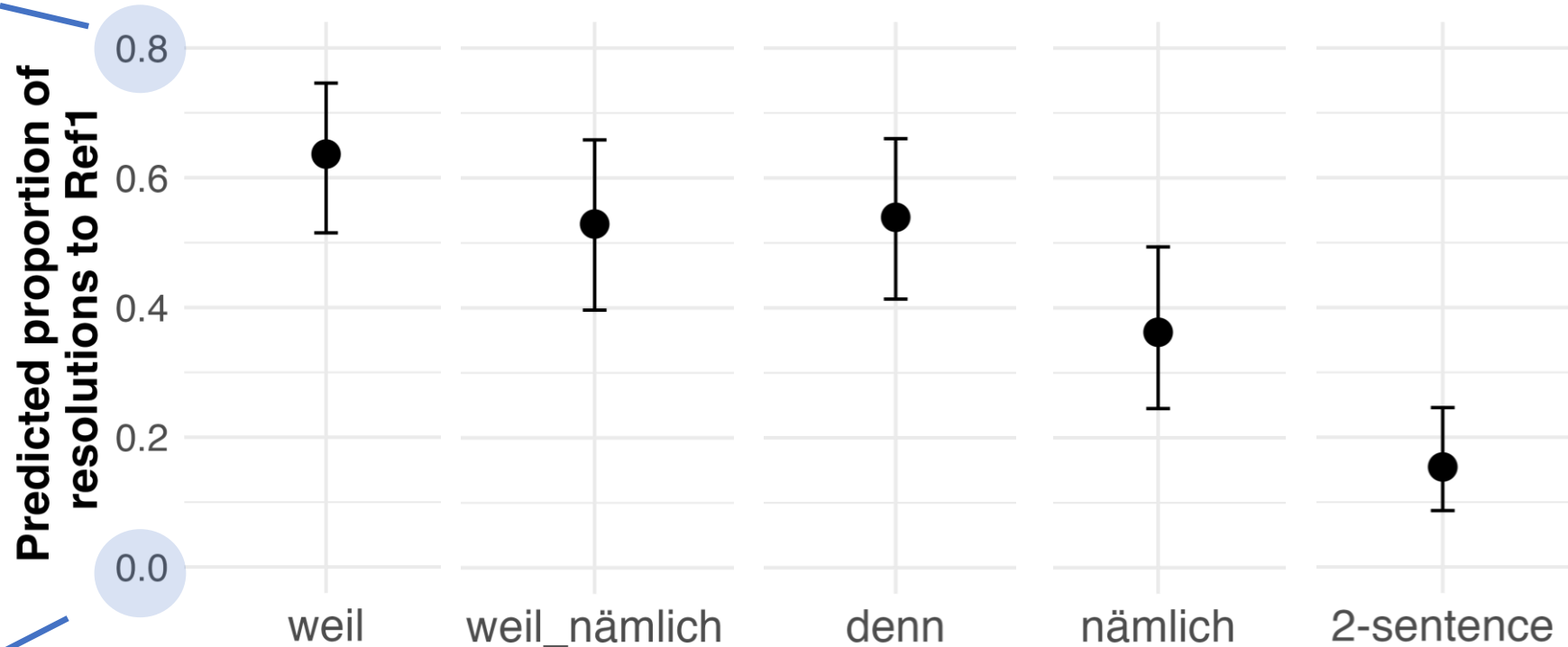
Syntax: *V-final* (subordinate clause) word order → 2nd clause more integrated than with *V-2nd* (main clause)

Clausal prominence:

- main clause > subordinate clause
- more independent > more integrated (typography, connector)
- more recent > less recent

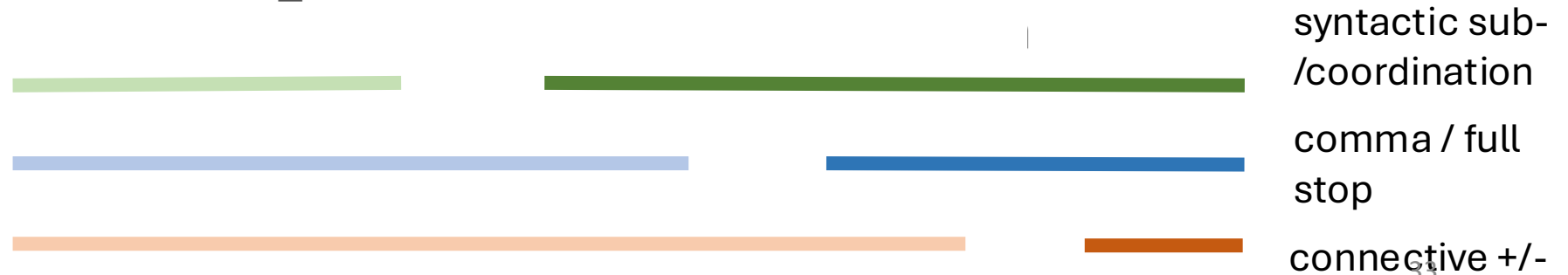
Results formal properties (written)

“80% resolution to Ref1, 20% to Ref2”

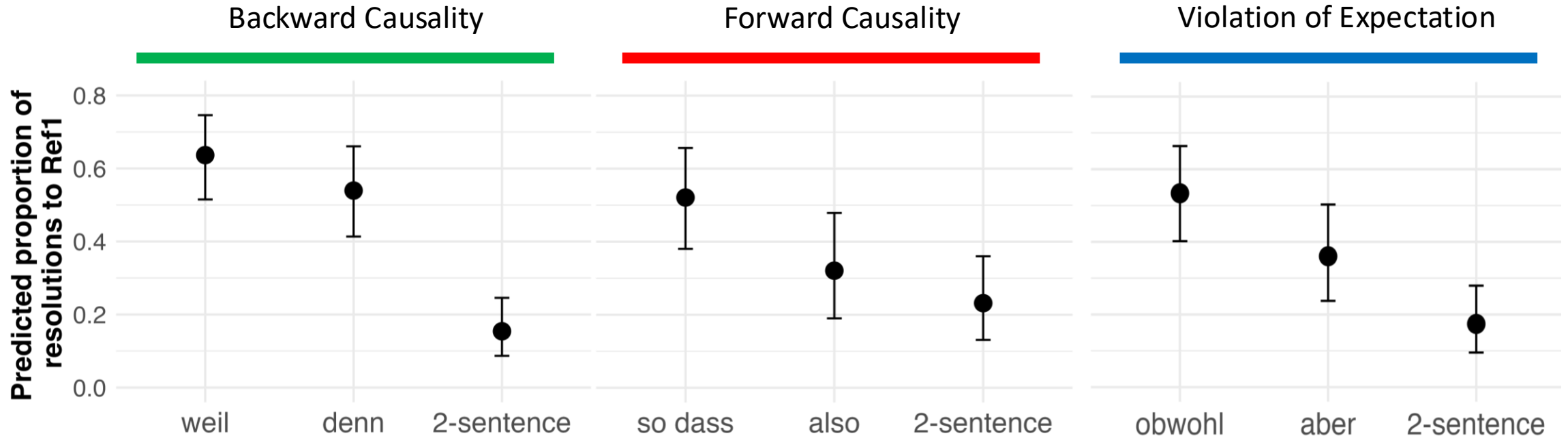


Predicted proportion of resolutions to Ref1

“0% resolution to Ref1, 100% to Ref2”



Across coherence relations (written)



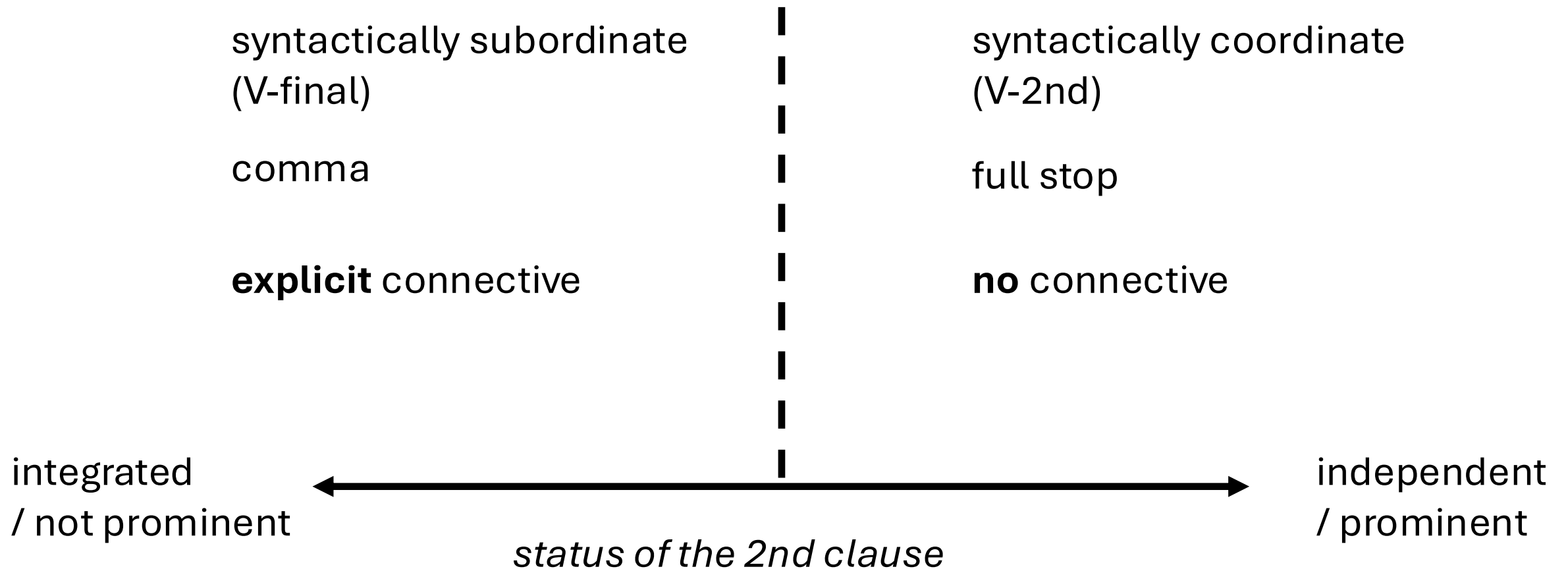
(very comparable results for propositional anaphors, with some exceptions for VIOLATION OF EXPECTATION)

Summary results written cues

Formal properties:

- syntactic sub/coordination, typographic boundary (comma/full stop), connective +/-
→ **independently** and **additively** contribute to
 integration \leftrightarrow independence / prominence
- under same DS-condition (Explanation, subordinated)
- pattern repeats across DS-conditions

Summary results written cues



Can we integrate prosody into this picture?

2 more experiments on similar materials, this time in spoken modality with manipulation of interclausal boundary

Anaphor resolution experiments on cues to clause-combining with adverbial clauses

- written cues (syntax, typography, connectives)
- spoken cues (prosody)



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Sounds also at:

https://osf.io/r5jtk/?view_only=70308cb0c5554ed789359cf7f4759e8d

Buchholz, Hoek & von Heusinger (2026)

Prosodic Experiment 1: 2x3 design

H%  Ø  L% 

Christoph hat viele Snacks gekauft $\begin{cases} H\% \\ \emptyset \\ L\% \end{cases}$ weil Raphael einen Filmabend **vorgeschlagen hatte** L% **Er tummte.**

Christoph bought many snacks, because Raphael had suggested a movie night. **He** tummed.

Christoph hat viele Snacks gekauft $\begin{cases} H\% \\ \emptyset \\ L\% \end{cases}$ denn Raphael **hatte** einen Filmabend **vorgeschlagen** L% **Er tummte.**

Christoph bought many snacks, because Raphael had suggested a movie night. **He** tummed.

Wer tummte? Christoph Raphael

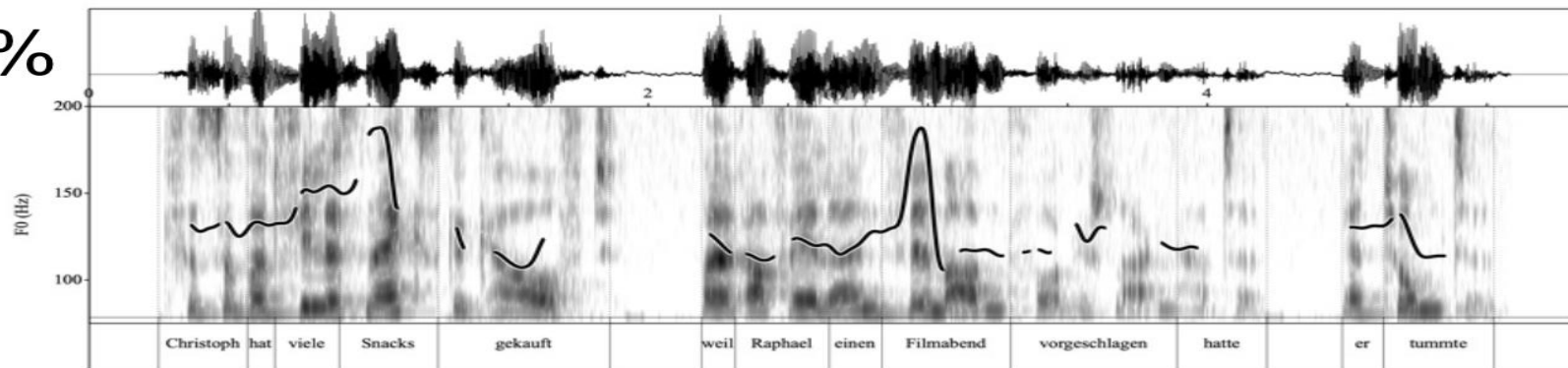
H%  Ø  L% 

Prosodic Experiment 1 – Conditions

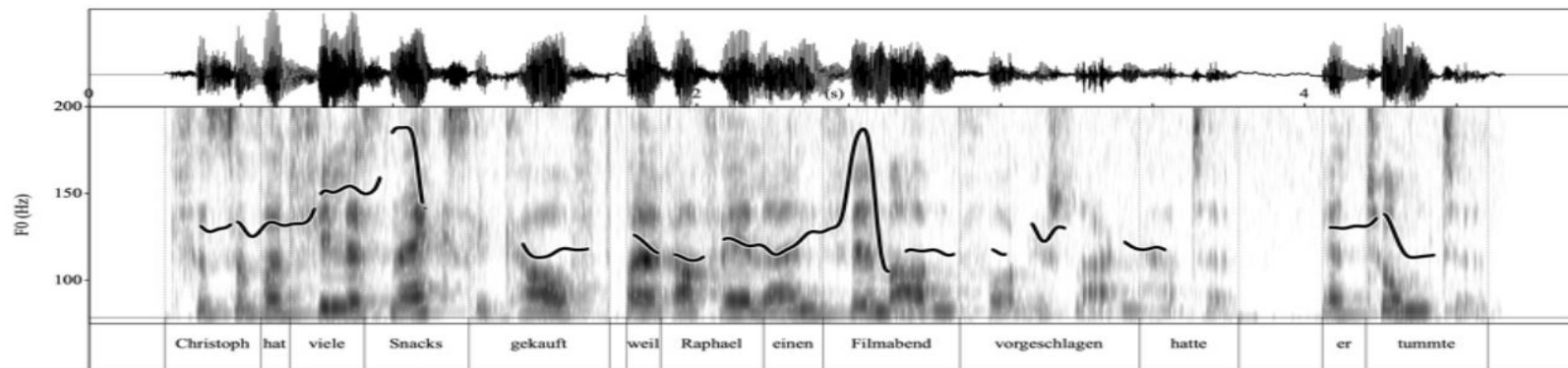
boundary type: H% (250 ms + **rise**) vs. L% (250 ms + **fall**) vs. \emptyset (30 ms + level, less preboundary lengthening)

- final word with rise/fall spliced into same recording of first clause, only one pitch accent per clause, always on non-subject argument
- \emptyset : causal clause does not necessarily form its own IP; H% + L% : causal clause probably forms its own IP

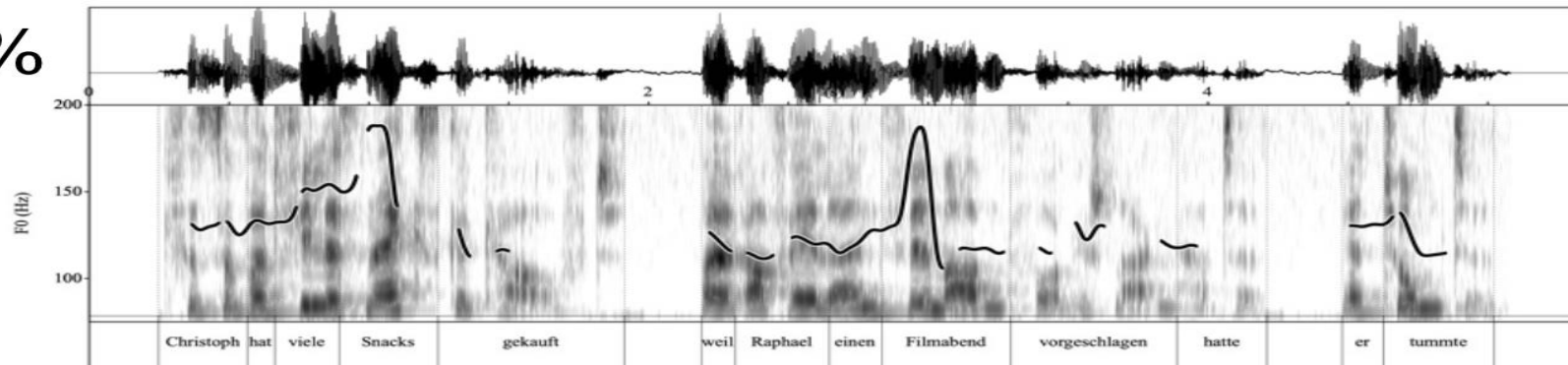
H%



Ø



L%



Prosodic Experiment 1 – Hypotheses

H1: weak vs. strong boundary: \emptyset interpreted as as no or lower-level boundary \rightarrow more integration (i.e. resolution to Ref1) than L%/H%

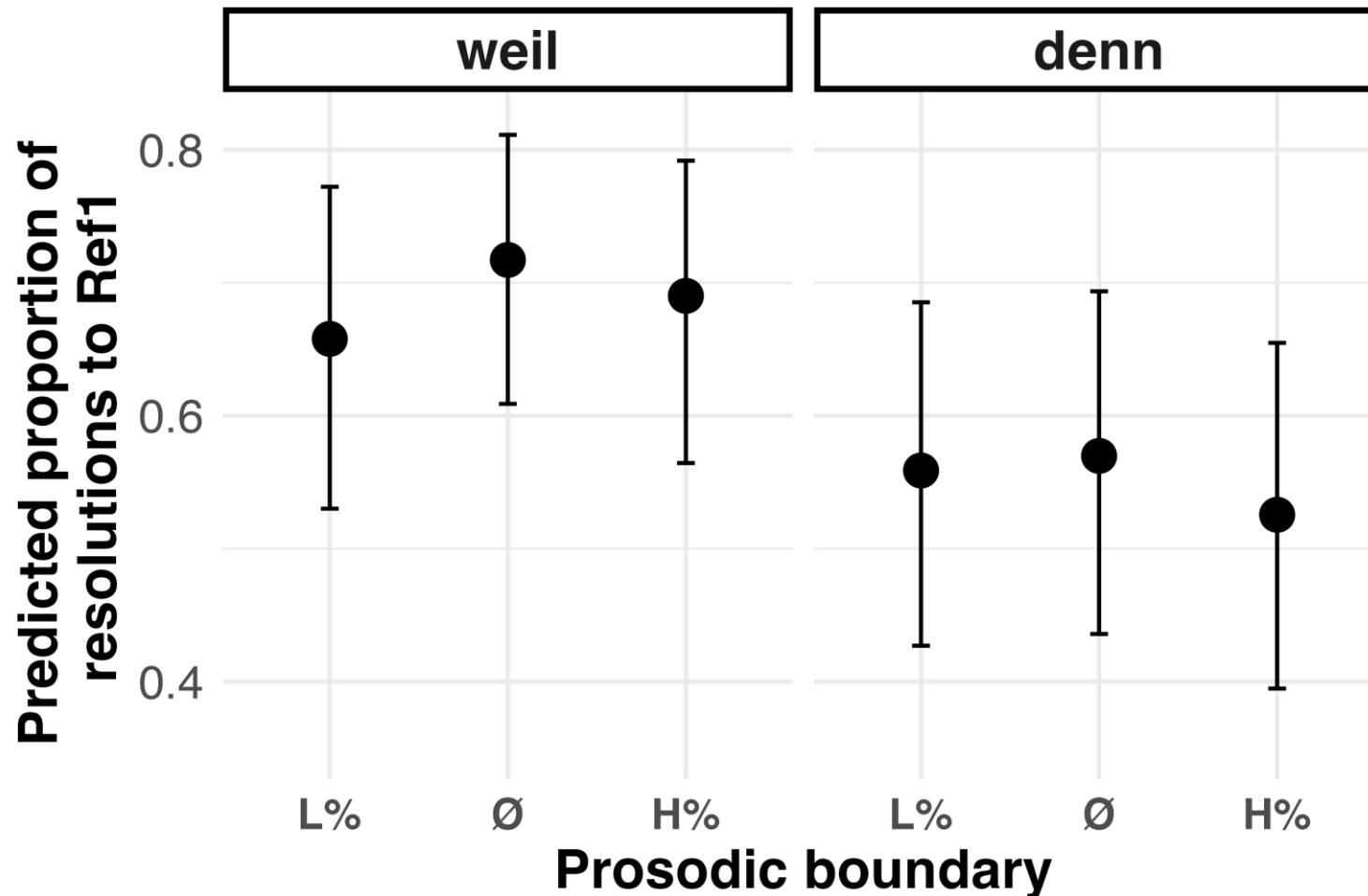
H2: L% cues separation/independence, H% cues integration/continuation

\rightarrow H% more integration (i.e. res. to Ref1) than L%

prediction: $\emptyset > H\% > L\%$ in terms of resolution to Ref1

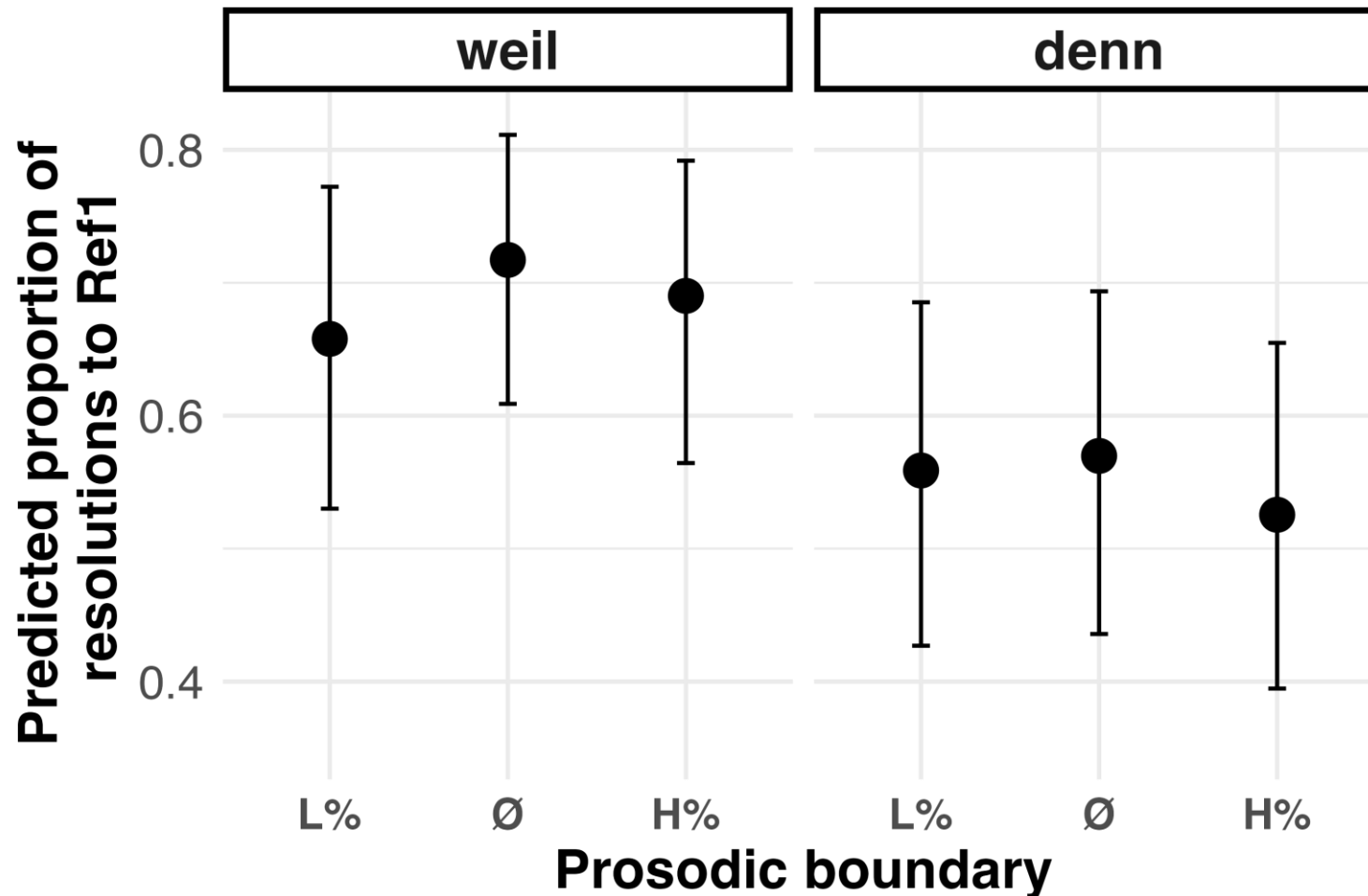
\rightarrow **additive effects with syntax**

Results Prosodic Exp 1



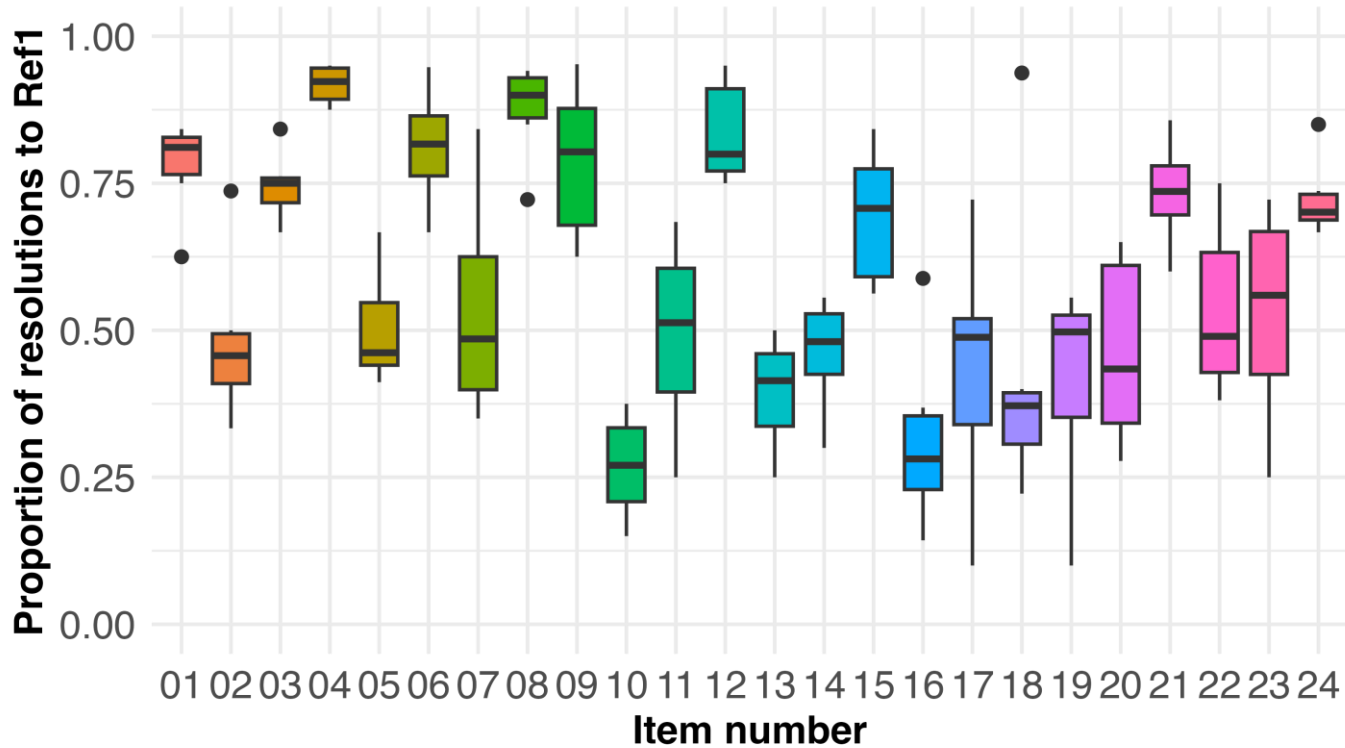
- effect of *syntax* from previous exps replicated
- **no** independent effect of *prosody* (such that H%, Ø, or L% → more resolution to Ref1 across *syntax* conditions)

Results Prosodic Exp 1



- **marginal** crossing interaction effect *pros x syntax*
- such that with *weil* + H% → more Ref1 than L%; *denn* + L% → more Ref 1 than H%
- ∅ patterns with H% in *weil* but L% in *denn*

→ **unexpected**
→ **too weak to be certain here**



- range of variation due to conditions very variable across items
- some items not at all affected by conditions
- meaning perhaps makes it implausible to continue with one of the refs, blocking an effect of prosody

Anna hat kalte Spaghetti gegessen weil Gabi die Mikrowelle kaputt gemacht hat. Sie...
Anna ate cold spaghetti because Gabi broke the microwave. She...

For the next experiment...

- replace all items where IQR of variation due to conditions is <0.125 for next experiment (12 of 24 items)
- since *no boundary* condition seems inconclusive, we drop it to concentrate on the difference between L% and H% and the potential interaction

Anna hat kalte Spaghetti gegessen weil Gabi die Mikrowelle kaputt gemacht hat. Sie...
Anna ate cold spaghetti because Gabi broke the microwave. She...

Anna hat den Ball angenommen weil Gabi nicht mehr dran gekommen ist. Sie...
Anna took the ball because Gabi couldn't reach it anymore. She...

Prosodic Experiment 2 – 2x2 design



Can we reproduce the interaction effect between prosody and syntax with better items and new participants?

[weil]

Christoph hat viele Snacks gekauft $\begin{cases} H\% \\ L\% \end{cases}$ weil Raphael einen Filmabend **vorgeschlagen hatte** L% **Er tummte.**



*Christoph bought many snacks, because Raphael had suggested a movie night. **He** tummed.*

syntactic subordination x high / low interclausal boundary



Christoph hat viele Snacks gekauft $\begin{cases} H\% \\ L\% \end{cases}$ denn Raphael **hatte** einen Filmabend **vorgeschlagen** L% **Er tummte.**

[denn]

*Christoph bought many snacks, because Raphael had suggested a movie night. **He** tummed.*

syntactic coordination x high / low interclausal boundary



Wer tummte? Christoph Raphael

Prosodic Experiment 2 – Conditions & Hypotheses

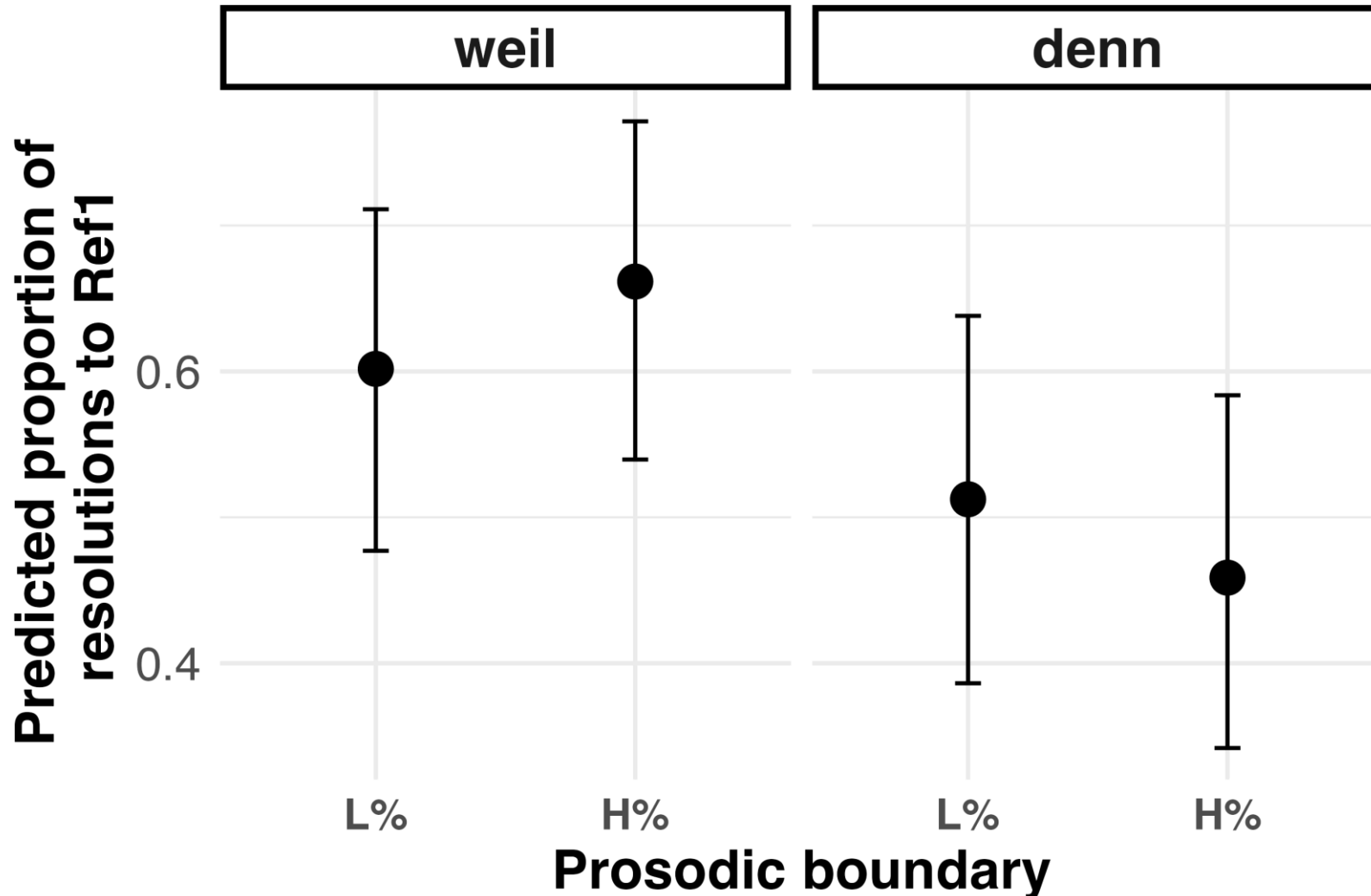
2 x 2: weil/denn x H%/L%

boundary type: H% (250 ms + **rise**) vs. L% (250 ms + **fall**)

H1 (based on literature): L% cues independence, H% cues integration → additive effects with syntax

H2 (based on Exp1): crossing interaction *prosody x syntax*

Results Prosodic Exp 2

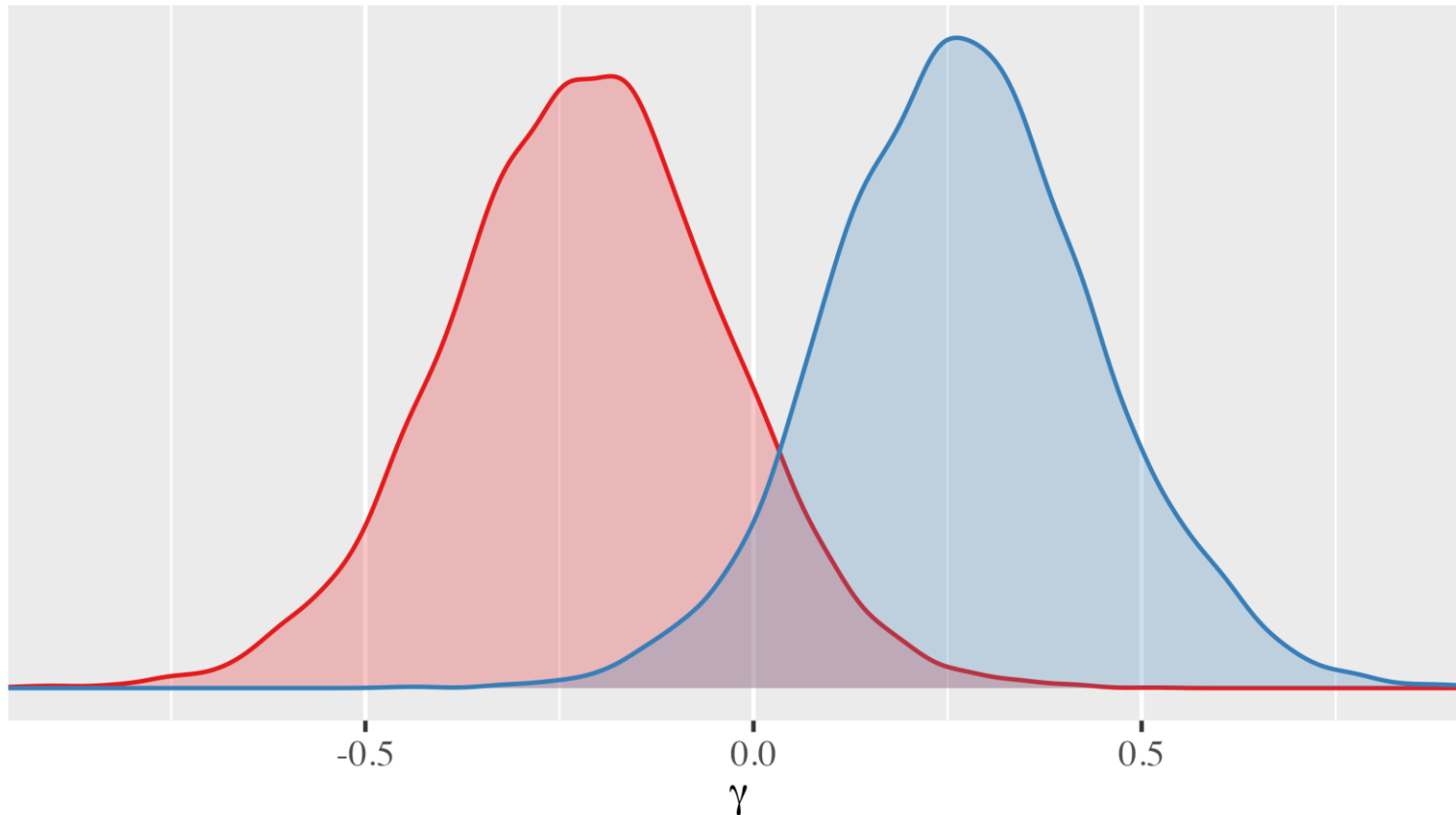


- effect of syntax again reproduced
- again no *independent* effect of *prosody* (against *H1*)
- crossing interaction effect *prosody x syntax* now reliable (for *H2*)

Results Pros. Exp 2

Prosodic Effect from L% to H% (logit scale)

Red = Denn, Blue = Weil



change **L% -> H%**
avg. *positive* effect for *weil* (more res. to Ref 1)
avg. *negative* effect for *denn* (less res. to Ref 1)

draw-wise comparison of posteriors:
in 98.4% of draws,
 $L\% \rightarrow H\% (weil) > L\% \rightarrow H\% (denn)$

Discussion prosodic experiments on adverbial clauses

no strong effect for *no boundary*

tonal boundary cues interact with syntax in an unexpected way:

- with *weil*, $H\% > L\%$ in terms of resolution to Ref1 (more “integration”)
- with *denn*, $L\% \geq H\%$ in terms of resolution to Ref1 (more “integration”)

small effect size but comparable to effects of antecedent pitch accenting in similar designs (Itzhak 2013; Hert 2023)

no independent effect of prosody: H% increases effect in the “direction” of the syntactic structure: more integrated with *weil*, less integrated with *denn*

also no simple correspondence to typography:

- *weil* + L% > *denn* + L% > *connective* + full stop
- H% ≠ comma; L% ≠ full stop
- typographic boundary markers have their own grammar (Kirchhoff 2016, Bredel 2008)

An explanation? High boundary tones direct attention

rather than contributing directly to an integrating/separating construction of discourse referents, prosodic boundary cues might serve to direct attention to the (structure of the) referents constructed by the other domains

- high tones in pitch accents and boundary tones found to orient attention via EEG and pupillometry (Lialiou et al. 2024a, b; Lialiou 2025)
- high boundary tones improve serial recall of demarcated groups, high pitch accents only that of individual units (Roehr et al. 2022, Grice et al. 2024)

with *weil*, H% directs attention to integrated structure → more res. to main clause subject

with *denn*, H% directs attention to separate structure → more res. to most recent clause subject

BONUS Experiment:

Another experiment where high boundary tones attract attention

Prosodic Exp 3 on *factives*

Test anaphoric accessibility of embedded clause content of factive constructions in German via **propositional** anaphora

Explore the effect of continuations and prosody **matching** vs. mismatching presupposition status

- prosody determined via pretest

surprise prosody

obvious prosody

neutral prosody

Jonas **bedauert**
Jonas deploras

dass Sören selten Bier trinkt
that Sören rarely drinks beer

Das war bekannt
that was known

Das ist bizarr
that is bizarr

Sounds



neut



surp



obv

Das war bekannt
that was known

Jonas **bedauert**
Jonas deplores

dass Sören selten Bier trinkt
that Sören rarely drinks beer



neut

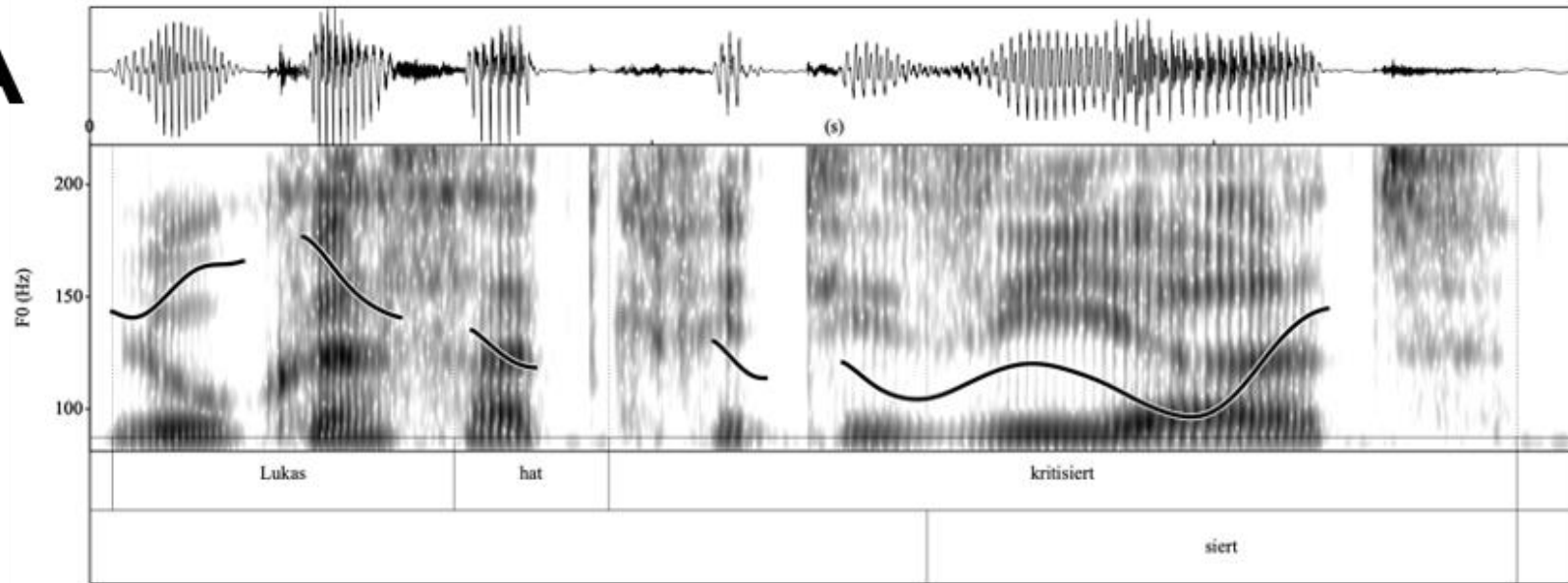


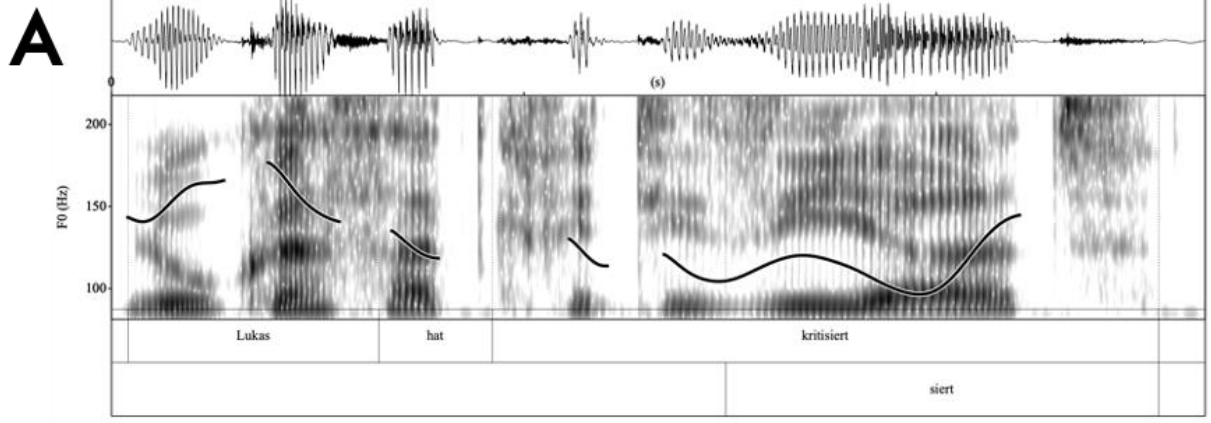
surp



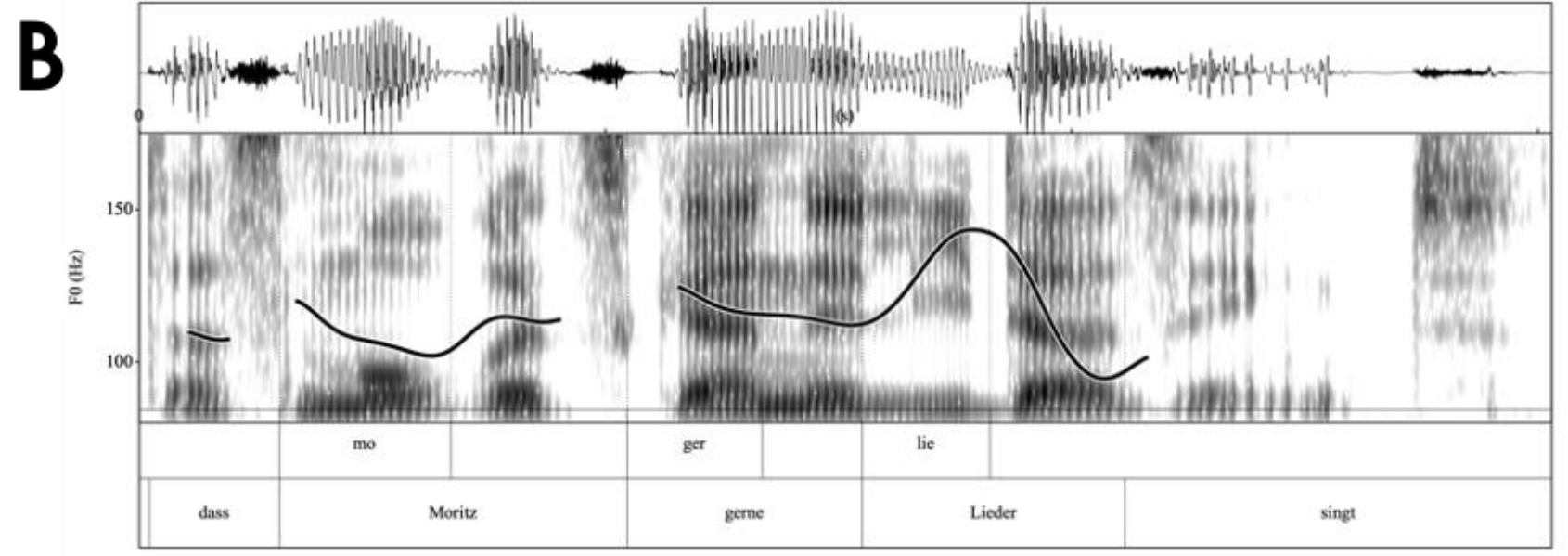
obv

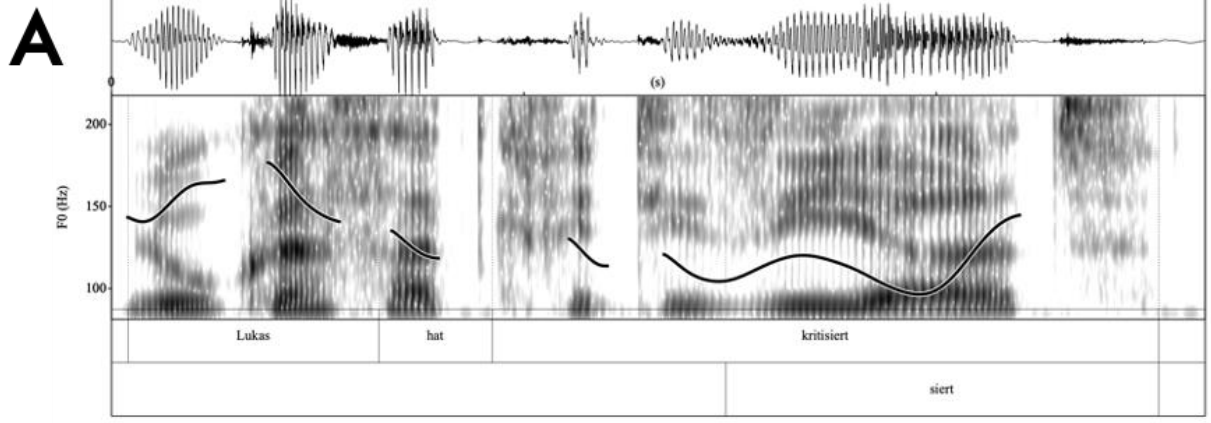
Das ist überraschend
that is surprising

A

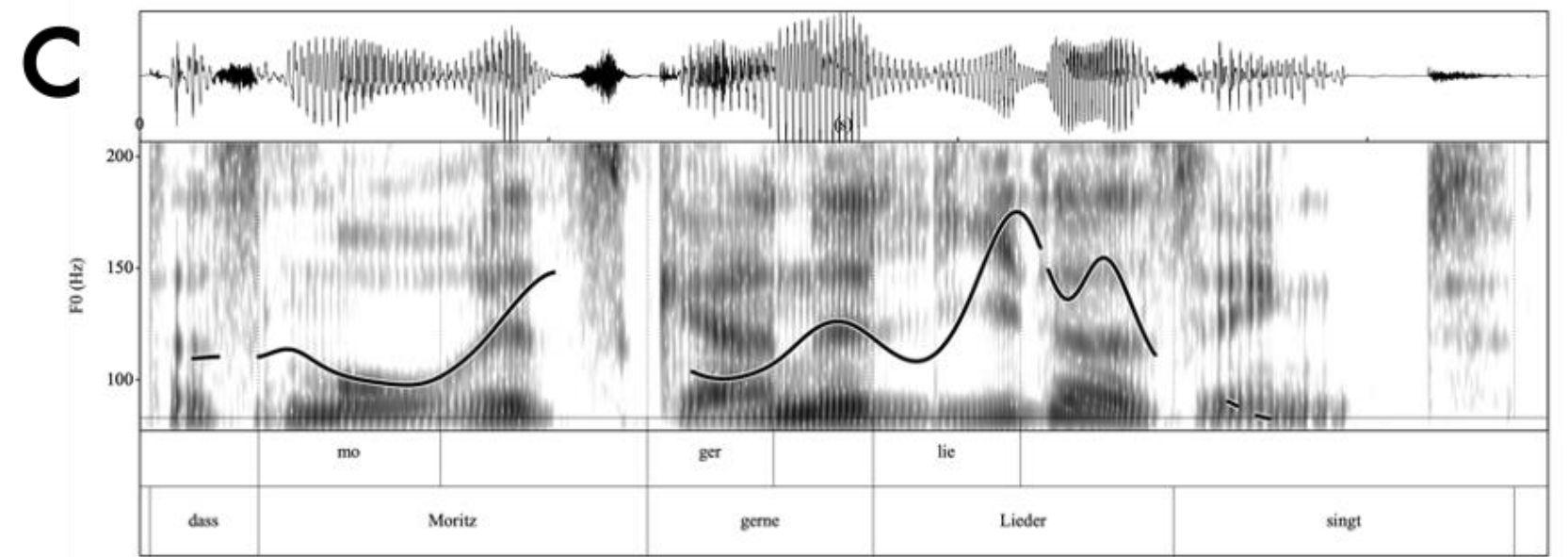


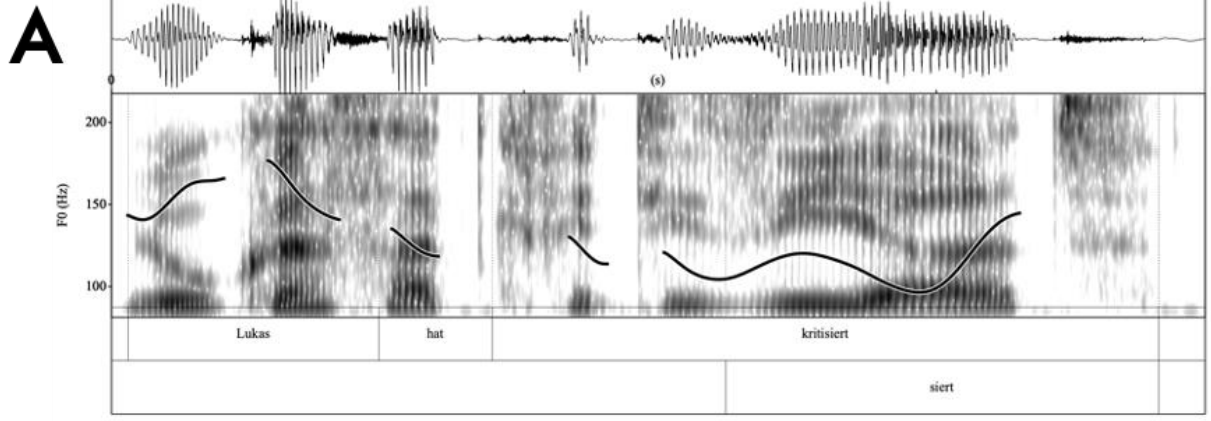
neutral



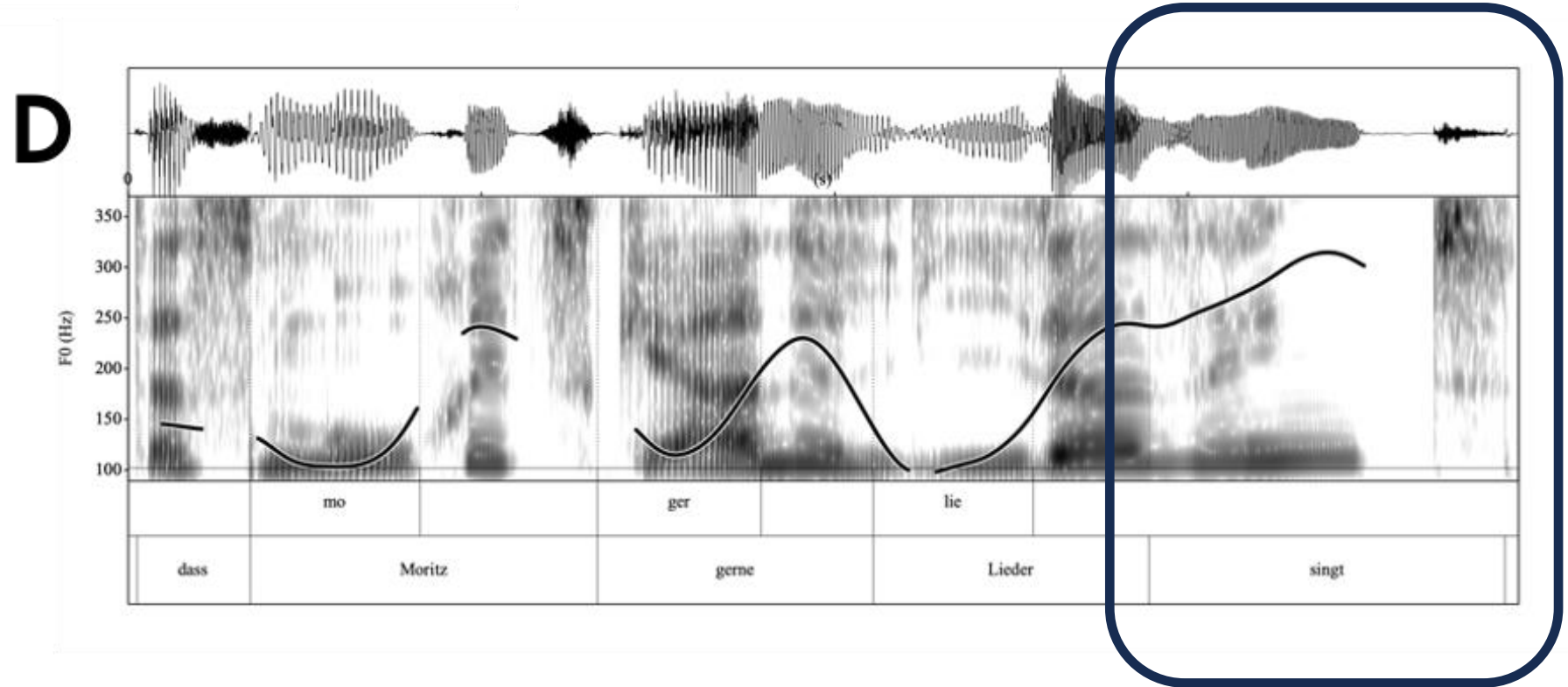


obvious





surprise



Items

12 factive matrix verbs (based on list in Bonke & Repp 2022)

6 negative, 6 positive

adverbs like *gerne* ‘like to’, *häufig* ‘often’, *selten* ‘rarely’, to add sites for prenuclear accents

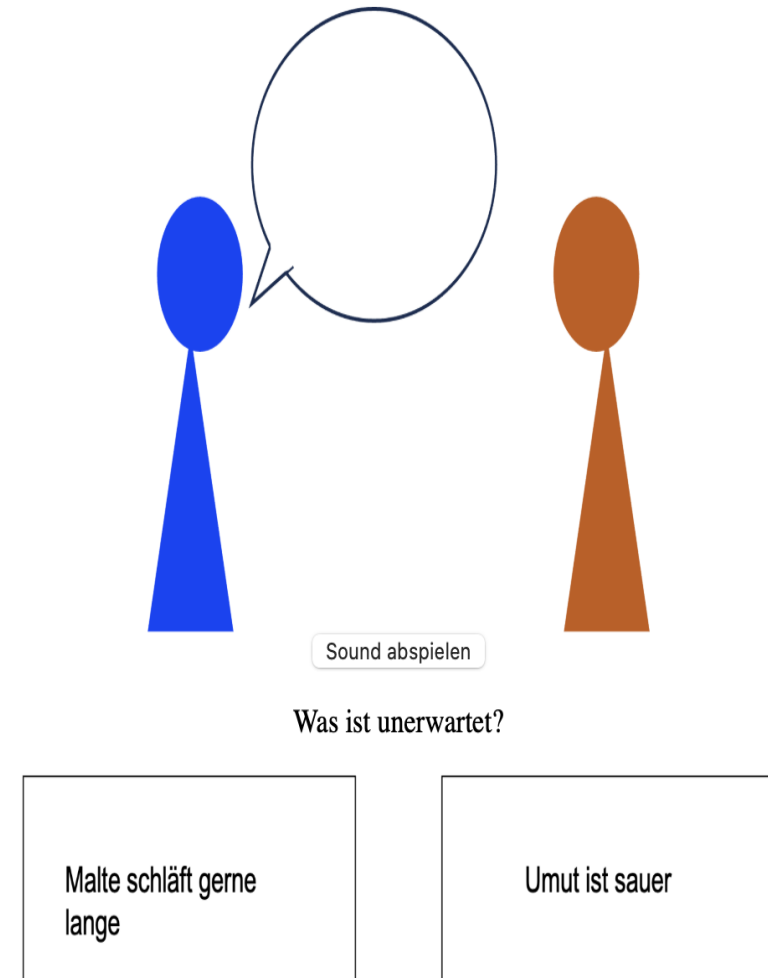
3 realizations on the embedded clause:

- *obvious*
- *surprise*
- *neutral*

2 continuations: **Matching** vs. Mismatching

Method

- ❖ Conditions: 2 x 3
 - neutral* vs. *obvious* vs. *surprise* prosody
 - matching* vs. *mismatching* continuation
- ❖ 6 lists (incl. 16 fillers & 8 catch fillers)
- ❖ forced-choice (e.g. *Was war bekannt?*):
 - **matrix clause** vs. **embedded clause**
- ❖ reaction times (inconclusive)
- ❖ 180 participants, 153 after exclusion
- ❖ PCIBex
 - sounds could only be played once
- ❖ Bayesian mixed-effects models



Hypotheses & Predictions (*Prosody*)

H2 (Prosodic meaning matching): prosody whose meaning matches with presupposition status (*obvious*) strengthens matching/mismatching effect of continuation, mismatching prosody (*surprise*) weakens it compared to neutral

Prediction: crossing interaction: obv-match > neut-match > surp-match > surp-mismatch > neut-mismatch > obv-mismatch in terms of resolution to embedded clauses

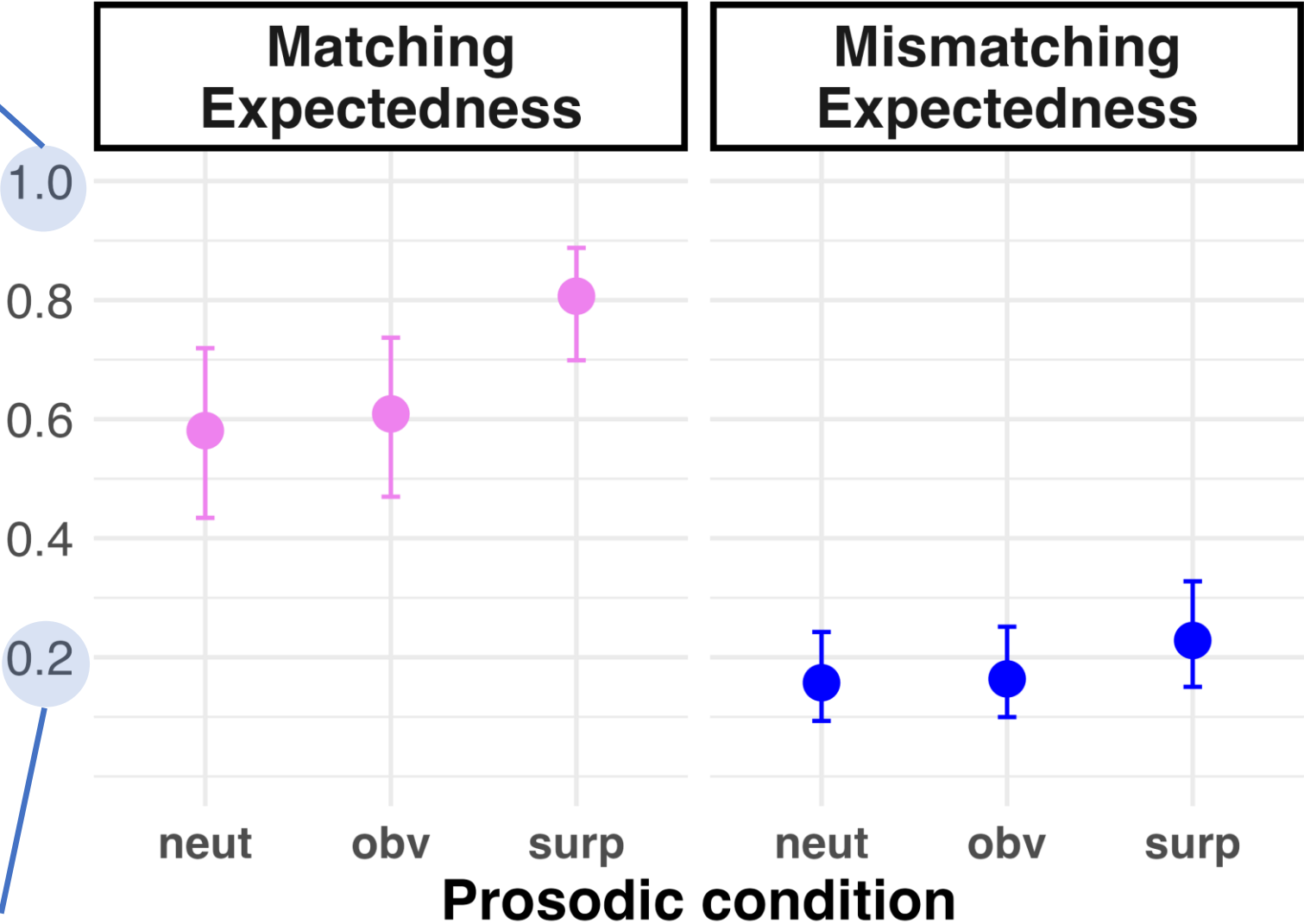
H3 (Prosodic prominence): in terms of acoustic & prosodic prominence, *surprise* > *obvious* > *neutral* (number and type of pitch accents, boundary tones, cf. Baumann & Roehr 2015)

Prediction: affects resolution to embedded clause in this order and independent of continuation

(i.e., **overall** prosodic prominence attracts attention)

“100% resolution to embedded clause”

Predicted proportion of resolutions to embedded clause



“20% resolution to embedded clause, 80% to matrix clause”

N = 153 participants after exclusion

Results

- **continuation** switches reference:
 - *Matching* continuation clearly > 50% resolution to embedded clause on average; *mismatching* < 30% on average
- **prosody** interacts unexpectedly:
 - **only** *surprise* boosts resolution to embedded clause, more with *matching* continuation than with *mismatching*
 - **H2 X H3 (?)**

Discussion Prosodic Exp 3

Effect of prosody:

- neither prosodic meaning account (H2) nor prosodic prominence account (H3) fully hit the mark
 - prosodic “meaning” not used for the construction of reference
- striking difference in final boundary movement:
 - high / rising for *surprising*
 - low / falling for *neutral* and *obvious*
- high boundary tone directs attention toward embedded clause content, domain-specifically?
- such that only final H% in *surprise*, but not high pitch accents in *obvious* attract attention to whole demarcated group = IP \approx embedded clause proposition (cf. Grice et al. 2024)

General discussion: open questions and future work

more systematic exploration of non-tonal integration cues

- no effect on discourse referent integration at all?
- if also crossing interaction: attention-directing account of tonal cues in doubt

same goes for pitch reset cues

General discussion: open questions and future work

if we buy into account of domain-specific attention direction effect of boundary tones (Grice et al 2024):

- manipulation of only boundary tones of embedded clause (Exp 3)
- manipulation of final boundary tone of adverbial clause (Exps 1 & 2) and interclausal boundary tone (Exp 3) (position of “relevant” H% different in Exps 1&2 vs. 3)
- manipulation of only pitch accents on referents → no effect on prop. anaphor predicted, but effects found for personal pronouns (Itzhak 2013, Hert 2023)
- but we get effect of boundary tones on individual referents in Exps 1 & 2 → “prominence inheritance” only in direction from larger to smaller discourse referents, not the other way round? (cf. Buchholz et al. 2025)

General discussion: open questions and future work

Differences between observed prosodic effects for *weil* and *denn* (Exps 1 & 2) partly due to differing frequencies between the constructions?

- similar crossing interaction if we use e.g. *weil*-V2 with H%/L%?
- predicted to produce similar results if H% directs attention at more/less integrated structure

Final Discussion

prosody interacts with syntax in unexpected ways in the construction and selection of discourse referents for anaphoric uptake

at least for reference establishment, boundary prosody does not seem to count towards a more integrated or separated representation

- instead, it might act at the level of attention orienting towards referents of a certain size

Thank you very much for your attention!

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