Convergence, covariation, and individual differences

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Handout (slides as text) for a talk presented at Michigan State University Linguistics Colloquium on October 31st, 2025

Where we're going

Joint work

Everything presented in this talk based on joint work with Chelsea Sanker (almost everything presented here is joint work with Chelsea Sanker, as equal contribition), Lee Edelist, and Emily Gleason.

Introduction

The puzzle of convergence

Convergence is widely documented

Speakers become more similar to their interlocutors

- Observed across many speech characteristics
  - VOT, speech rate, pitch, ~~formants~~, *uh*:*um* ratio
    (Pardo 2006; Babel 2010; Babel 2012; Cohen Priva and Sanker 2020)
  - Lexical choices, syntactic structures (Branigan et al. 2000)
- Humans mirror each other in many ways (Chartrand and Bargh 1999)
- Even newborn infants imitate facial expressions (Meltzoff and Moore 1983)
- Speech is no exception to this phenomenon

The traditional view

Traditional measurements show widespread convergence

- Speakers converge across numerous characteristics
- Individual differences in "tendency to converge"
  (Natale 1975; Bilous and Krauss 1988; Yu 2010)

Some issues (← the focus of this talk)

- Possible conflation of distinct phenomena (convergence vs. covariation)
- Few attempts at testing across multiple characteristics
- Few attempts to test and retest individuals
- Possible methodological shortcomings

Problems

Two distinct phenomena

When conversation partners become more similar, two things might be happening

True convergence

- Speaker A shifts toward Speaker B's baseline patterns
- Measured using B's productions from *other* conversations
- Requires influence from interlocutor

Covariation

- Both speakers produce similar values
- Due to shared contextual factors
- Topic, emotion, style, lexical choices
- No direct influence needed

However: Many studies cannot distinguish between these**

Convergence across multiple characteristics

Are there natural convergers ("followers")?

- Why: it would indicate that there are underlying mechanisms (social, cognitive) that predict this behavior
- Proof: likelihood to converge in one property should predict convergence in other properties
- Evidence: surprisingly little evidence for anything like it

Test-retest

- Standard practice in psychometric evaluation
- Intuition: if people differ, that difference should be estimated reliably (consider a personality test that yields completely different results when used multiple times)
- But test-retest studies are very rare in linguistics

Methodological shortcomings

More on that later!

The linear combination method

The linear combination method (Cohen Priva et al. 2017)

The key insight (Cohen Priva et al. 2017)

To measure true convergence, we need:

- Speaker's baseline: productions with *other* interlocutors (or pre-exposure)
- Interlocutor's baseline: productions with *other* speakers (same)
- Compare to their shared conversation
- This rules out conversation-level effects

Notation:

- S_I: Speaker with Interlocutor in shared conversation
- $S_{\neg I}$: Speaker with everyone *except* Interlocutor
- $I_{\neg S}$: Interlocutor with everyone *except* Speaker

The model

Linear combination of consistency and convergence:

$$S_I \approx \beta_{S_{\neg I}} \cdot S_{\neg I} + \beta_{I_{\neg S}} \cdot I_{\neg S} + \epsilon$$

- $\beta_{S_{\neg I}}$: Self-consistency (how much speakers maintain their baseline)
- $\beta_{I_{\neg S}}$: Convergence (how much speakers shift toward interlocutor's baseline)

The model

Advantages

- Separates convergence from conversation-level effects
- Controls for speaker and interlocutor baselines
- Allows testing for individual differences properly

Shortcomings

It's difficult to assign a value to a specific individual at a specific time

Switchboard as a natural testing site

Using the Switchboard Corpus

Data from the Switchboard corpus (Godfrey and Holliman 1997)

- Repeated conversational interactions
- Multiple speakers with multiple interlocutors

Advantages

- Naturally provides test-retest
- Easy to calculate baselines from other conversations

Cross-characteristics test-retest study (2020)

Transition to multiple measures

Cohen Priva et al. (2017)

- Found convergence to the baseline in speech rate
- Speakers are mostly consistent (about 0.8 correlation)
- But also converge (about 0.05 correlation)

Something to keep in mind: the effect of convergence is **much** smaller than consistency

Cohen Priva and Sanker (2018), Cohen Priva and Sanker (2020)

Extend this approach to six different measures to detect cross-measure convergence

Multiple measures at once

Measures examined

- F0 median and variance
- Speech rate (Cohen Priva et al. 2017)
- uh:um ratio
- Lexical information rate (mean unigram entropy, Cohen Priva 2017)
- Sentential conjunction (tendency to conjoin sentences)

Every conversation contributes one point per speaker $\times$ the different measures

Single-measure results (Cohen Priva and Sanker 2020)

Consistency estimates

	β	SE	df	t	p
F0 median	0.971	0.0039	3434	248	<0.00001
F0 variance	0.675	0.0119	3622	57	<0.00001
Speech rate	0.800	0.0086	4336	93	<0.00001
uh:um ratio	0.787	0.0090	4501	87	<0.00001
Lexical information rate	0.645	0.0095	4490	68	<0.00001
Sentential conjunction	0.391	0.0131	4677	30	<0.00001

Single-measure results (Cohen Priva and Sanker 2020)

Convergence estimates

	β	SE	df	t	p
F0 median	0.0179	0.0049	181	3.7	0.00033
F0 variance	0.0929	0.0140	143	6.6	<0.00001
Speech rate	0.0477	0.0097	219	4.9	<0.00001
uh:um ratio	0.0320	0.0110	147	2.9	0.00433
Lexical information rate	0.0612	0.0110	224	5.5	<0.00001
Sentential conjunction	0.0405	0.0148	152	2.7	0.00699

Combined model

Predict performance by speakers across measures (all z-transformed to scale) using:

- Speaker baseline (measures *consistency*)
  Their mean performance in **other** conversations
- **Interlocutor baseline (measures *convergence*)**
  Their mean performance in **other** conversations
- Random intercept per conversation, per characteristic
  (attempts to explain away conversation-specific effect)
- Random slopes for the **interlocutor baseline**:
  - Per speaker (if there are "natural followers")
  - Per interlocutor (if there are "natural leaders")

and many more!

Combined model

```
performance ~
    speaker.baseline +                                    ## consistency
    interlocutor.baseline +                               ## convergence
    (0 + interlocutor.baseline | speaker) +               ## natural followers
    (0 + interlocutor.baseline | interlocutor) +          ## natural leaders
    (0 + interlocutor.baseline | speaker:characteristic) + ## characteristic-specific followers
    (0 + speaker.baseline | interlocutor:characteristic) + ## characteristic-specific leaders
    (1 | conversation:characteristic) +                   ## conversation-specific difference
    ...
```

Results

- Speakers are very consistent (but not in the same way in each characteristic)
- Speakers converge (but not to the same extent in each characteristic)
- **No people with a tendency to converge**
  (Though some people converge more along specific characteristics)
- **There are leaders**: people which are likely to cause more convergence
  - Some of them are likely to cause *divergence*
  - No clear correlation with any demographics property the corpus provided

Variance estimates for and model comparison *p* values for random effects

	SD	Model comparison *p*
Per-characteristic and conversation intercept	0.2473518	<0.0001
Per-characteristic and interlocutor slope for convergence	0.0143233	0.86616
Per-characteristic and interlocutor intercept	0.0714960	0.00053
Per-characteristic and speaker slope for convergence	0.0459992	0.04416
Per-characteristic and speaker intercept	0.0000000	1.00000
Conversation slope for convergence	0.0000315	1.00000
Interlocutor slope for convergence	**0.0453861**	**0.00160**
Speaker slope for convergence	**0.0000000**	**1.00000**
Per-characteristic and topic intercept	0.2010929	<0.0001
Per-characteristic slope for convergence	0.0226591	0.00123
Per-characteristic slope for consistency	0.1942646	<0.0001

And so

- We should find who the leaders are
- Convergence seems socially driven
- But likely has no universal cognitive underpinnings

How come several previous studies found individual differences among speakers?

The problem with previous methods

Systematic biases in DID

The issue with previous studies

There's a problem: previous studies did find individual differences in who's likely to converge.

- Some didn't check across characteristics: perhaps they found individual differences in convergence for a specific property
- Most didn't test-retest: what they did find may not have been an individual difference but a random trend
- **And some used difference-in-difference** (← this part next)

The DID method (Cohen Priva and Sanker 2019)

Difference-in-Difference (DID)

How it works:

1. Measure distance between speaker and interlocutor *before* an exposure
2. Measure distance between speaker and interlocutor *after* an exposure
3. Convergence = reduction in absolute distance

Widely used in convergence research

Sounds reasonable, but...

The baseline problem

DID systematically biases results based on starting distance:

Close baselines

- Small starting distance
- Any change may look like divergence

Extreme baselines

- Large starting distance
- Regression to mean looks like convergence

Spurious individual differences

- Speakers with underlying extreme productions would seem as convergers
- And people who are close to the population modes would not

Verification

What if people with extreme baseline performance really do converge more?

Sampling study

- We sampled fake data that explicitly does not include convergence
- We ran both DID and linear combination

Results

- DID found individual difference based on starting difference, and absolute distance from mode
- Linear combination did not

Consequences of DID biases

- Many reported individual differences are artifacts
- Inconsistent results across studies
- Cannot reliably compare across speakers
- Effects of gender may be artifacts
- Misidentification of who converges

Linear combination doesn't have these biases

Linear combination method

- No bias from starting distance
- Regression to mean controlled by baseline predictors
- Reliable individual estimates
- Can meaningfully compare across speakers and measures

Vowel formants: A case study

No convergence, but clear covariation

Recap

- There really is convergence to interlocutors' baseline across multiple measures
- We even found some characteristic-specific individual differences for speaker
- But cross-characteristic individual differences found only for interlocutors, not speakers
- Possible causes for previous findings
  - No test retest
  - No pooling across characteristics
  - Used difference-in-difference
  - **Did not contrast convergence and covariation** (← this part next)

Vowel formants in Switchboard (Cohen Priva & Sanker, submitted)

Why formants?

- Strong evidence for convergence in some studies (Babel 2010; Delvaux and Soquet 2007)
- But inconsistent findings across studies
  (Pardo et al. 2010; Uluşahin et al. 2023)
- Sensitive to many factors (Fourakis 1991; Fletcher et al. 2015)
- Important cues to vowel identity (Johnson 1997)

Vowel formants in Switchboard

Our approach

- Normalized F1 and F2 measurements
- Large-scale analysis across vowels
- Separate tests for convergence vs. covariation
- Switchboard corpus (Godfrey and Holliman 1997)

Advantage

- With many vowels $\times$ two formants, there are many possible studies
- Multiple studies, but not pooled this time
- Should allow to find convergence and its effect size

Formants study 1: Is there convergence?

Method

- Linear combination model (Cohen Priva et al. 2017)
- Interlocutor's formants from *other* conversations as predictor
- Speaker's formants from *other* conversations as baseline
- Controls for conversation-level effects

This means that for every vowel and every formant we ran a single linear combination model

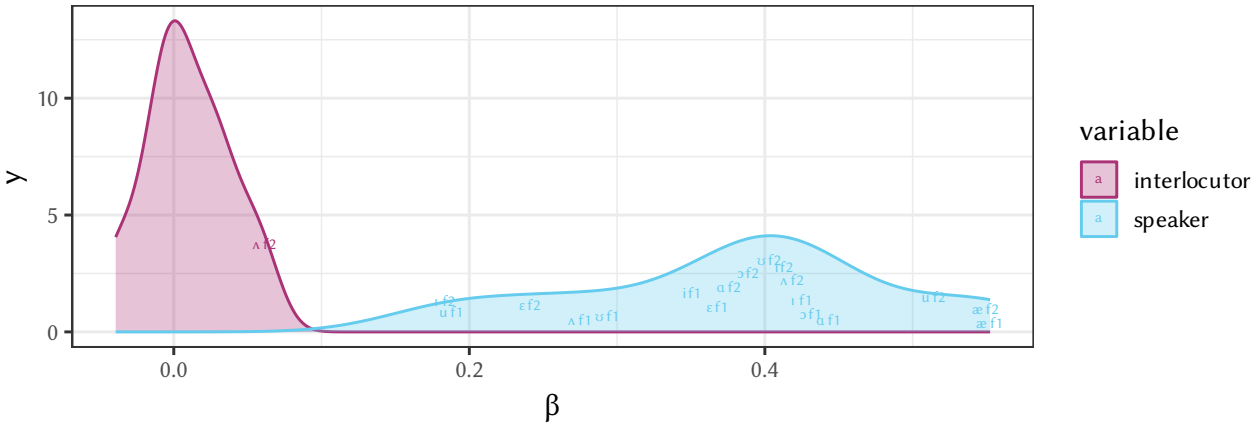
Formants study 1: Is there convergence?

Results

- Mode of convergence estimates at zero
- No clear evidence for formant convergence
- Strong evidence for self-consistency
- Contrasts with some previous findings (Babel 2010; Delvaux and Soquet 2007)
- But consistent with null results (Pardo et al. 2010; Ostrand and Chodroff 2021)

Formants study 1: Is there convergence?

Results



Speaker (consistency) and interlocutor (convergence) betas. The one "significant" result for convergence does not withstand correction for multiple comparisons.

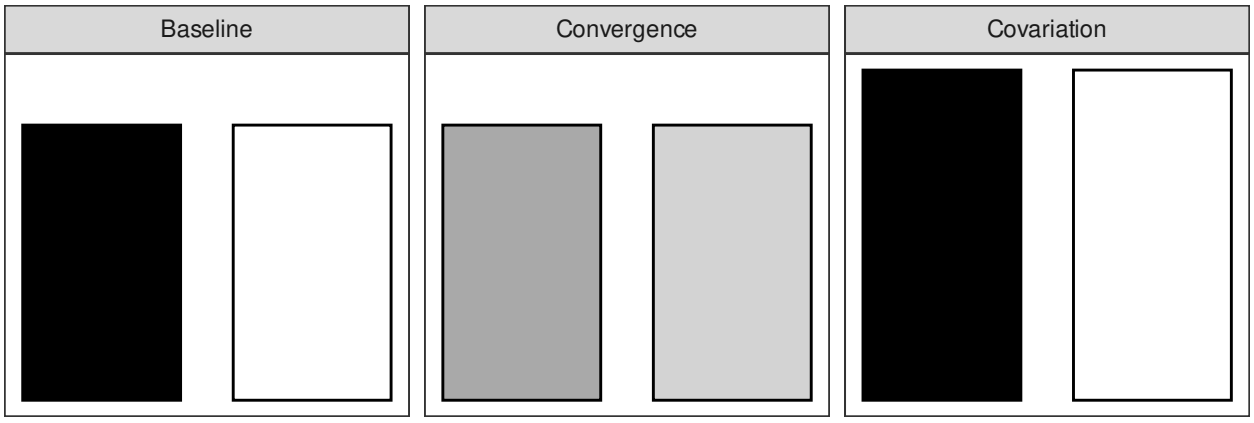
Formants study 2: Is there covariation?

Some previous studies did find convergence, but possibly did not distinguish between convergence and covariation. Is there covariation?

Method

- Same data, different predictor
- Interlocutor's formants from *same* conversation
- Tests similarity within conversation
- Rather than use interlocutor's **baseline** use interlocutor **performance**
- Similar to approaches in Levitan and Hirschberg (2011), Edlund et al. (2009)

Two distinct phenomena



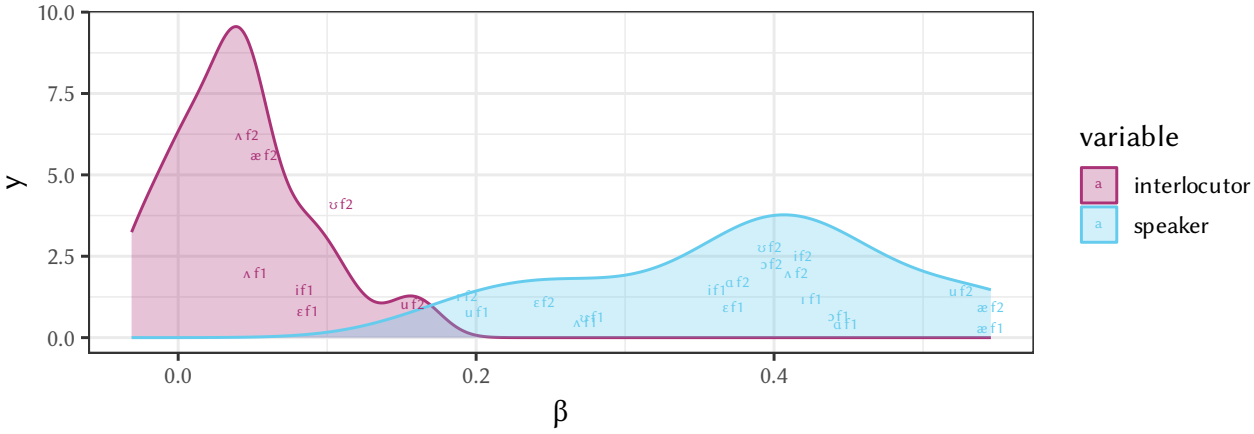
Formants study 2: Is there covariation?

Results

- Strong evidence for covariation
- Speakers are more similar to interlocutors in shared conversations
- But this is NOT convergence: could be conversation effects
- Both speakers adapting to same contextual factors

Formants study 2: Is there covariation?

Results



Speaker (consistency) and interlocutor (convergence) betas. The mode clearly shifted.

Formants study 3: What causes the covariation?

Question: If not convergence, what makes partners similar?

Perhaps lexical effects / phonetic environments?

Method

- Control for lexical effects
- Remove variation due to specific words
- Test whether covariation remains
- Related to findings on lexical effects (Goldinger 1998) and phonetic environment (Cohen Priva and Strand 2023)
- Remove lexical effects
  - Train a model: `formant-value ~ vowel-identity + (1 | word-specific-bias)`
  - Remove the contribution of `(1 | word-specific-bias)`

Formants study 3: What causes the covariation?

Results

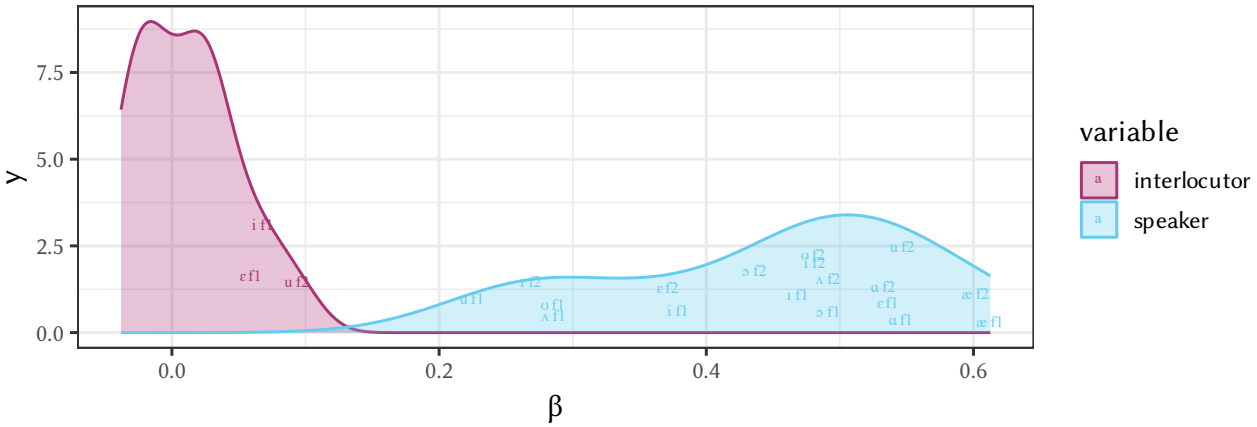
Covariation disappears when controlling for words

Which means:

- Partners use the same words in conversation
- Shared words have shared formant values
- Could follow from shared conversation topics or lexical convergence (Branigan et al. 2000)

Formants study 3: What causes the covariation?

Results



Speaker (consistency) and interlocutor (convergence) betas. The "significant" results for convergence do not withstand correction for multiple comparisons

The lexical explanation

Why do conversation partners show similar formant values?

Not because

- They're converging to each other's vowel spaces
- They're aligning their articulation

But because

- They discuss specific topics
- Topics require specific vocabulary (Branigan et al. 2000)
- The same words have similar acoustic properties (Johnson 1997)
- This creates covariation without convergence
- Lexical frequency effects are well-documented (Goldinger 1998)
- Word-specific phonetic targets (Munson and Solomon 2004)

Why no convergence in formants?

Possible explanations

Phonetic factors

- Many sources of formant variation (Johnson 1997)
  - Vocal tract length (Simpson and Weirich 2020)
  - Coarticulation (Summers 1987; Moreton 2004)
  - Speech rate (Fourakis 1991; Fletcher et al. 2015)
- Creates ambiguity about "target" formant values
- Listeners adjust for speaker differences (Joos 1948; Nordström and Lindblom 1975)

Possible explanations

Linguistic factors

- Dense vowel inventory in English
- Convergence risks reducing contrasts (Nielsen 2011)
- Contrast preservation may inhibit convergence
- May differ in languages with fewer vowels

Possible explanations

Methodological factors

- Switchboard: short conversations, phone quality (Godfrey and Holliman 1997)
- But formants well within transmitted frequency range
- Previous work also suggests formant convergence is weak (Pardo et al. 2017)

Prior evidence for weak formant convergence

Many studies find

- No formant convergence (Pardo et al. 2010; Pardo et al. 2013; Uluşahin et al. 2023; Ostrand and Chodroff 2021)
- Marginal effects (Pardo et al. 2017)
- Convergence in some vowels but not others (Babel 2012; Pardo 2009)
- Depends on dialect distance (Babel 2010; Delvaux and Soquet 2007; Clopper et al. 2024)

Other reasons

- Many formant studies use DID
- Some "convergence" may be DID artifacts (Cohen Priva and Sanker 2019; MacLeod 2021)
- Our study avoids DID biases
- Uses more conservative baseline method

Implications and conclusions

What we've learned

Summary of findings

Convergence is not as ubiquitous as thought

- No evidence for general convergence tendency (Cohen Priva and Sanker 2018)
- No cross-characteristic consistency (Bilous and Krauss 1988; Pardo et al. 2012)
- Formants show covariation but not convergence
- Interlocutor effects more consistent than speaker effects

Summary of findings

Covariation is easily confused with convergence

- Shared lexical items create similarity
- Conversational topics drive word choice and other properties
- This looks like alignment but isn't

Methodological lessons

Pay attention!

- Distinguishing convergence from covariation
- Using appropriate baselines from other conversations
- Avoiding DID biases
- Testing with appropriate controls for lexical effects
- Test-retest

The linear combination method

- Separates convergence from covariation
- Provides unbiased estimates
- Allows meaningful comparisons
- Successfully applied across multiple measures

Theoretical implications

About convergence

- Not as unified a phenomenon as assumed
- Measure-specific, not trait-based
- Socially mediated (interlocutor effects)
- May depend on perceptual salience

About covariation

- Can arise without any convergence
- Driven by conversational content
- Important to distinguish from true alignment
- Lexical and phonetic alignment are separate

I’ve seen the future

Future directions

Many remaining questions

- Which measures do show true convergence?
- What makes some interlocutors “natural leaders”?
- How does convergence vary across languages/vowel systems?
- When and why do speakers converge?
- Role of attention and cognitive load (Abel and Babel 2017; Heath 2017)

Future directions

Methodological needs

- Reanalysis of prior studies with better methods
- Testing across diverse conversational contexts
- Examining convergence in languages with fewer vowels

Conclusion

Take-home messages

1. **Convergence ≠ Covariation**
    - Traditional methods conflate distinct phenomena
    - This conflation has led to misunderstandings
2. **No general tendency to converge** (Cohen Priva and Sanker 2018; Cohen Priva and Sanker 2020)
    - Individual differences are measure-specific
    - Social factors (interlocutor) matter more
3. **DID produces systematic artifacts** (Cohen Priva and Sanker 2019)
    - Spurious individual differences
    - False evidence for convergence

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Additional

Cohen Priva and Sanker (2020)

Single characteristic formula

lme4 syntax	explanation
speaker ~	Speaker's performance in a conversation (S_I)
1	Intercept, expected to be zero (β_0)
+ speaker.baseline	Speakers' baseline: captures consistency ($\beta_{S_b} S_b$)
+ interlocutor.baseline	Interlocutors' baseline: captures convergence ($\beta_I I$)
+ (1 | speaker)	Differences in speakers (expected to be close to 0)
+ (1 | interlocutor)	Differences based on interlocutor (possibly not due to convergence)
+ (1 | conversation)	Differences by conversation
+ (1 | topic)	Differences by topics
+ (0 + interlocutor.baseline | speaker)	Per-speaker slope for convergence
+ (0 + interlocutor.baseline | interlocutor)	Per-interlocutor slope for convergence

Multiple characteristics formula

lme4 syntax	explanation
performance ~	Speaker's performance in a conversation
1	Global intercept (expected to be 0)
+ speaker.baseline	Speaker's baseline performance for the characteristic
+ interlocutor.baseline	Interlocutor's baseline performance for the characteristic
+ (0 + speaker.baseline | char)	Per-characteristic slope for consistency
+ (0 + interlocutor.baseline | char)	Per-characteristic slope for convergence
+ (0 + interlocutor.baseline | char:speaker)	Within-characteristic per-speaker slope for convergence
+ (0 + interlocutor.baseline | char:interlocutor)	Within-characteristic per-interlocutor slope for convergence
+ (1 | char:topic)	Within-characteristic per-topic differences
+ (1 | char:speaker)	Within-characteristic per-speaker differences
+ (1 | char:interlocutor)	Within-characteristic per-interlocutor differences
+ (1 | char:conversation)	Within-characteristic per-conversation differences
+ (0 + interlocutor.baseline | speaker)	Per-speaker slope for convergence (characteristic agnostic)
+ (0 + interlocutor.baseline | interlocutor)	Per-interlocutor slope for convergence (characteristic agnostic)
+ (0 + interlocutor.baseline | conversation)	Per-conversation slope for convergence (characteristic agnostic)