The Complex Structure of Errors and The Independent Visibility of φ-features: Evidence from Agreement Attraction in Arabic

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Unresolved issues with Agreement

1. Are Simple Agreement Errors Uniform?

➔ Evidence from Self-Paced Reading times

- **Assumption:** Errors simply shift the *means* of conditions
- **But:** Agreement Attraction (1) shifts *right tails* of RT distributions[1,2]

    (1) The key to the cabinets are on the table.

➔ Problem:

- I. The *mean* is a *non-robust* measure of central tendency
- II. Shifts in right tails are *positively correlated* with shifts in *means*
- ?? *Changes in means:* Central tendency or Shape of RT distribution?

2. Are All φ-Features Equipotent? Two views:

- a) Bundled for syntax[3]; equally weighted for the parser[4].
- b) Differentially visible for syntax[5]; weighted differently for the parser.

➔ Evidence from Self-Paced Reading times

- Unclear: **timing** and **effect sizes** for [Num(ber)] and [Gen(der)] agreement, especially on Agr. Atttraction contexts, is underexplored

Two Experiments to Tackle these Questions

1. Are Simple Agreement Errors Uniform?
- **Large N (=330) studies:** Analyze RT distributions (means vs shape?)

2. Are all φ-Features Equipotent?
- **[Num]** and **[Gen]** agreement in Modern Standard Arabic
    ➔ Timing, Effect Size, Susceptibility to Agr. Attraction effects
- ❖ Design: 2x2x2 manipulation:
    1. Subject φ
    2. Match (Subject φ == Distractor φ?)
    3. Grammaticality (Subject φ == Verb φ?)
- Experiments: (1) Gender [Masc, Fem] (2) Number [Sg, Pl]

المرض الذي عالج المريض بعنايةٍ يدرس في المستشفى الجامعة.

al-mumarrid	allati	ʕaaladʒ	al-mariid	bɪ-ʔanaajat-in	ja-drus	...
the-nurse	who	treated	the-patient	with-care-GEN	3MS-studies	

"The nurse who cared for the patient carefully studies ... (at the university hospital)."

Participants & Procedure

- 330 participants in each experiment (φ-feature) (660 total)
- All 18-23 yrs./students at UAE University
- Self-paced reading with Linger

Refs & Thanks

References. [1] Lago et al. (2015) JML 82:133–49. [2] Staub (2010) Cognition 114: 447–454 [3]Chomsky (1995). The Minimalist Program [4] Badecker & Kuminiak (2007) JML 56: 65–86. [5] Béjar & Rezac (2009) LI 40:35–73. [6] Matzke & Wagenmakers (2009) PBR 16:798–817 [7]Verde et al. (2016), IEEE transactions on cybernetics 46:344–355. [8]Wagers et al. (2009) JML 61:206–237.

Are Simple Agreement Errors Uniform?

Mean RT, Gender

Raw RT in All Conditions, Number
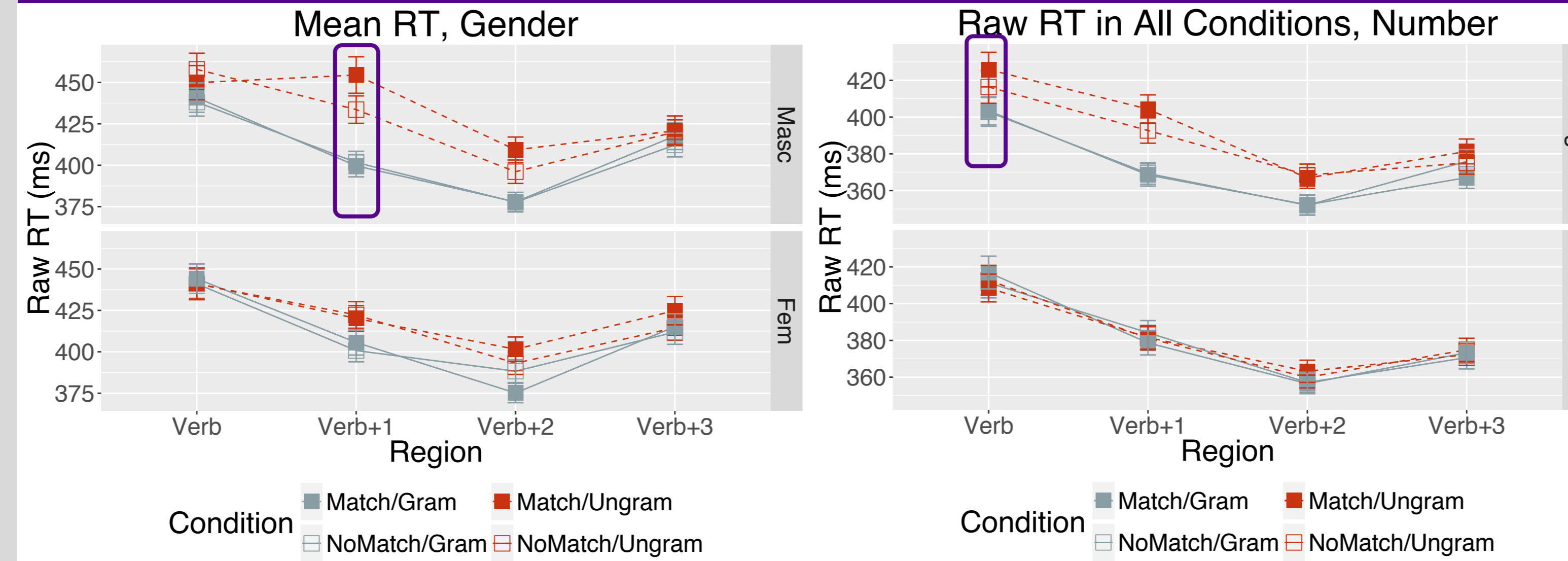
◉ **Agr. Attraction:** Change in **Central tendency** or **Shape of distribution**?

- **Shape** analysis of **RT distribution:** usually rely on **distributional assumptions**
    - E.g., **ExGaussian:** Summarize distribution into a few **parameters** (μ, σ, τ)
    - Parameters not easily interpretable as **cognitive processes**[6]
- **Non-parametric** techniques are available, like **Vincentiles**[1,2]. Downsides:
    - Quantiles are highly correlated
    - Multiple comparison problem (poor summary of data)

◉ New technique: **Principal Components Analysis** (PCA) on RT quantiles (deciles)[7]

➔ Optimal **summary** of distributional information considering **quantile correlations**

➔ Finds orthogonal dimensions of most **variability** in the quantile data; **orders** them

➔ PCA on average RTs from every Subject, for every Region in SPR experiments

➔ Largest variation in RT distribution: **PC1** (93% variance)

➔ Right tail of distribution (esp. 8th, 9th, Max deciles)
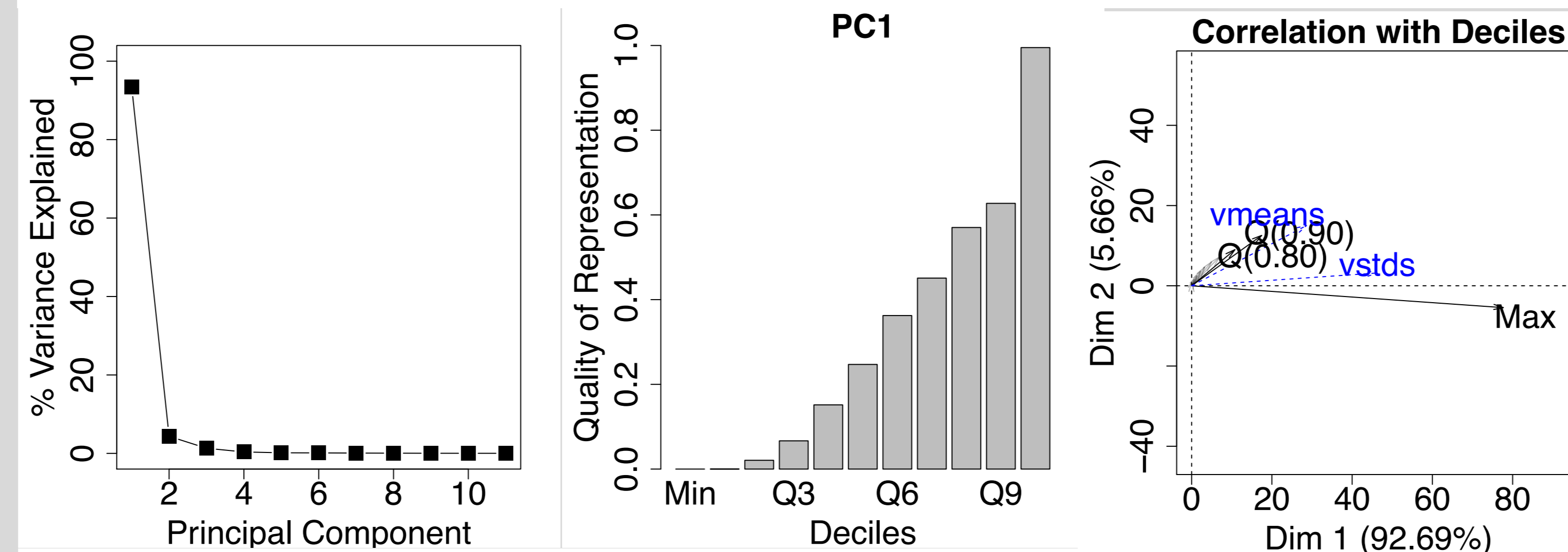
- How does PC1 vary in our SPR data?

PC1: Right Tail of RT distribution

- **Agreement Errors:** *Average* right tails
- ➔ *Exception: Subject is [Masc] or [Sg]*
    ➔ Right tail is lengthened!
- **Anatomy of Agreement Attraction:**
    1) Agreement error **lengthens** right tail
    2) Attractor **shortens** right tail
    ➔ Step (1) depends on unmarked φ-features on the subject

Are All Φ-Features Equipotent?

- If **φ-Features** are equipotent/bundled for processing
    - similar rates of agreement attraction
- From Dillon, *et al.* (2013): measure attraction by Intrusion Effect Size:

$$\mu_{\phi/Match/Ungram} - \mu_{\phi/NoMatch/Ungram}$$

- Predictions:
    - **Equipotence:** Identical effect sizes for [Gen] & [Num]
    - **Differential Activity:** Different effect sizes

Intrusion Effect Size by Subject φ
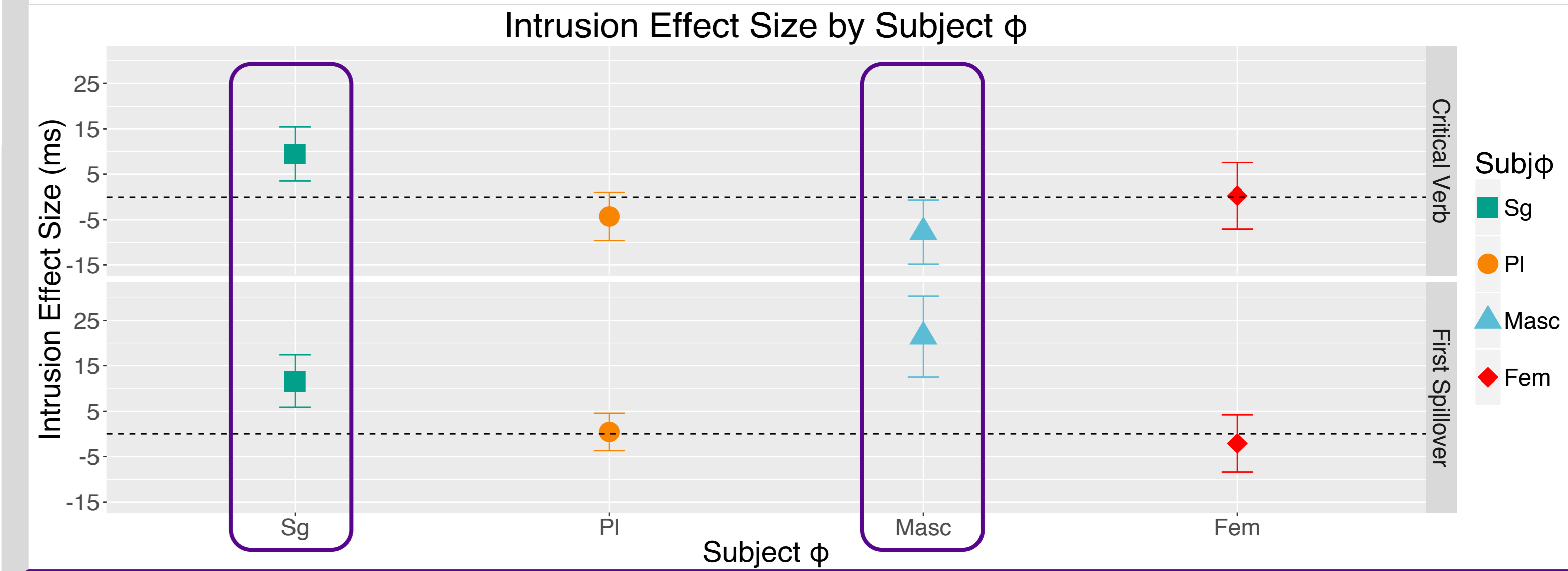
➔ Phi-features cause attraction at different strengths.

- Suggestive of differential visibility of agreement features for cue weighting.

Methodological Conclusions

- **Right tail of RT distribution is really important**

- i. Most of the RT shape variation is there, and yet
- ii. Shifts in right tail **directly correlated with** shifts in **means**, meaning that
- iii. Shifts in **RT means** are **ambiguous**, and may have two different sources

➔ In order to discern the source, one needs to be able to quantify the right tail
    ➔ Can only do that with **large sample sizes!**

➔ Data transformations that interfere with right tail are a bad idea:
    ✘ Heavy trimming/winsorizing of outliers
    ✘ Log-transforming RTs

Conclusions

1. Simple agreement errors are not uniform: sometimes Mean sometimes Right Tail

- **Errors** affecting **right-tail** tied to **Markedness** of Subject φ-feature
➔ Error-driven models of agreement attraction[8]: **Grammatical Asymmetry**
➔ **Markedness** as another error-gating mechanism: explains **Markedness Asymmetry**

2. φ-Features are not equipotent:

- **Effect size** and **timing difference** in susceptibility to Agreement Attraction:
➔ **φ-features** are differentially visible for cue-weighting algorithms/syntax

3. Larger picture:

- Agreement errors do not seem to trigger simple on/off error signals
- Explaining **Agreement Attraction** requires not only a model of memory search but also a model of how grammatical information is represented in memory.

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