Resolving illusions of plausibility: Competition between syntax and semantics over time?

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Can readers resolve semantic illusions?

- The N400 semantic illusion arises when an unexpected word does **not** elicit an N400 relative to an expected word.
- The illusion is typically observed at the underlined verb in role reversal sentences[1;9]:

Canonical: The thief that the cop <u>arrested</u>
Roles reversed: The cop that the thief <u>arrested</u>   ⎫ Same N400 amplitude

- The illusion may arise because thematic roles are misassigned and so the verb seems plausible (SG model[10]) or because roles have not yet been assigned and verb prediction is delayed (slow prediction hypothesis[8]).
- Delaying the verb can resolve the illusion, even when no disambiguating information is presented[8,9]:

Canonical: The thief that the cop *yesterday evening* <u>arrested</u>
Roles reversed: The cop that the thief *yesterday evening* <u>arrested</u>   ⎫ Different N400 amplitude

Our study aims to:

- Replicate the delay finding[8] in a language with rich subject/object morphological marking (German).
- Examine the contribution of syntactic and semantic cues in three conditions: <u>no delay</u>, <u>syntactically consistent but semantically neutral delay</u>, and <u>syntactically consistent + semantically informative delay</u>.

Potential outcomes:

- **i)** The delay allows syntax to better constrain interpretation and verb predictions, so any delay resolves the illusion, regardless of semantic content.
- **ii)** The delay allows facilitatory interaction between syntactic and semantic cues to constrain interpretation/prediction, so resolution of the illusion is improved when both types of cues are present.
- **iii)** Syntactic and semantic cues compete over time, so syntactic cues work towards resolving the illusion, while semantic cues strengthen it so that it reappears.

Design and methods

Example item:
Jeder im Zug hat gesehen, ...
Everyone in the train has seen...

	Delay	Target	Spillover
(a) Canonical/no delay			
welchen.ACC Schwarzfahrer der.NOM Ticketkontrolleur		**erwischt**	hat
which.ACC fare evader the.NOM ticket controller		*caught*	*had*
(b) Reversed/no delay			
welcher.NOM Schwarzfahrer den.ACC Ticketkontrolleur		**erwischt**	hat
which.NOM fare evader the.ACC ticket controller		*caught*	*had*
(c) Canonical/ neutral delay			
welchen.ACC Schwarzfahrer der.NOM Ticketkontrolleur	<u>weiter vorne</u>	**erwischt**	hat
which.ACC fare evader the.NOM ticket controller	*further up*	*caught*	*had*
(d) Reversed/ neutral delay			
welcher.NOM Schwarzfahrer den.ACC Ticketkontrolleur	<u>weiter vorne</u>	**erwischt**	hat
which.NOM fare evader the.ACC ticket controller	*further up*	*caught*	*had*
(e) Canonical/ informative delay			
welchen.ACC Schwarzfahrer der.NOM Ticketkontrolleur	<u>ohne Fahrausweis</u>	**erwischt**	hat
which.ACC fare evader the.NOM ticket controller	*without a ticket*	*caught*	*had*
(f) Reversed/ informative delay			
welcher.NOM Schwarzfahrer den.ACC Ticketkontrolleur	<u>ohne Fahrausweis</u>	**erwischt**	hat
which.NOM fare evader the.ACC ticket controller	*without a ticket*	*caught*	*had*

- **Sample size determined via Bayesian stopping rule:** Bayes factor ≥ 6 for the 2×2 interaction of role order and delay (none/neutral; replication of [8]). **Current sample size: 62.**
- **Main analysis:** simple difference contrasts comparing informative vs. neutral and neutral vs. no delay in interaction with role order (sum contrast coded).
- Maximal Bayesian linear mixed effects models.
- DV: mean N400 amplitude.
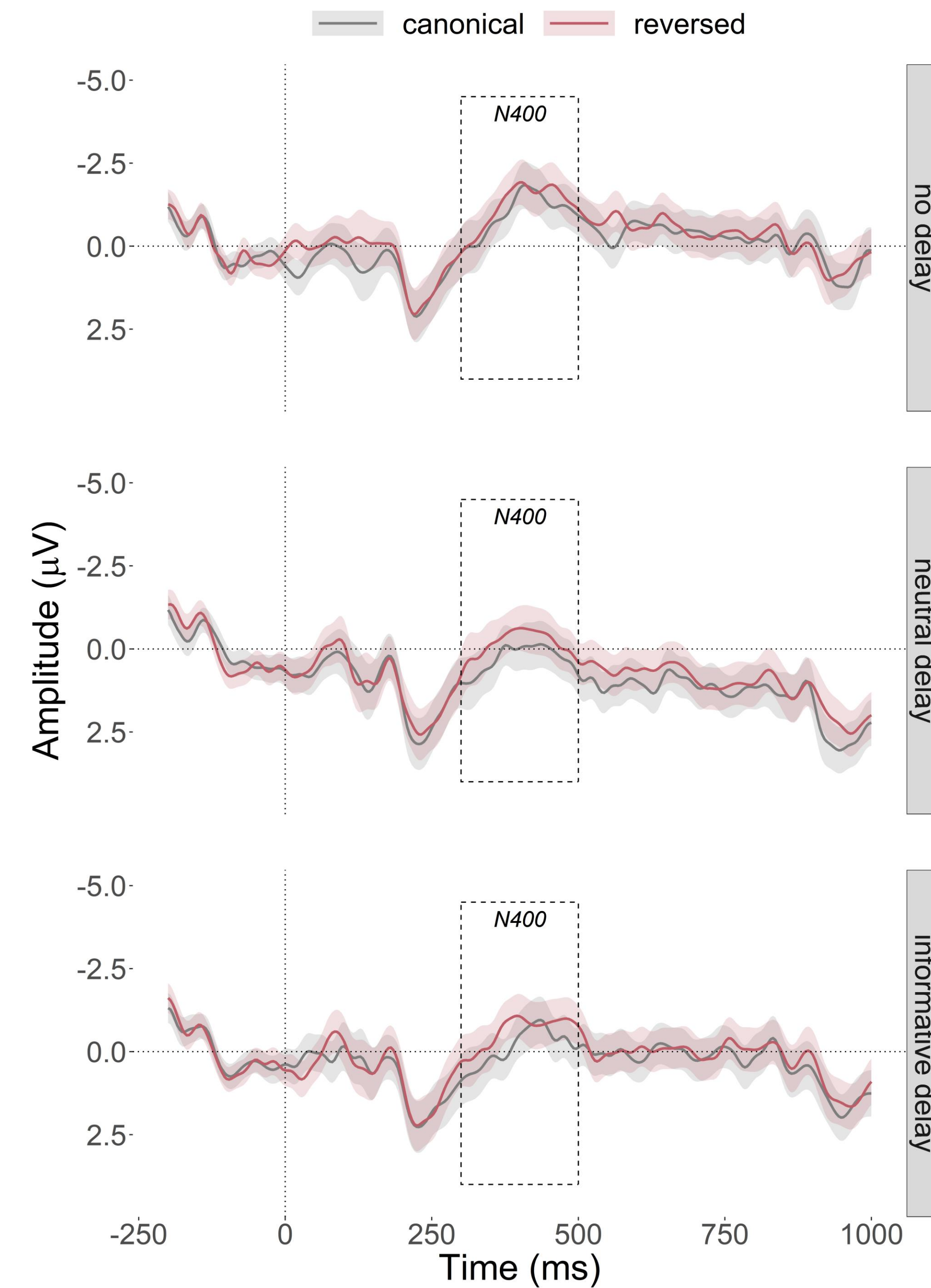- IVs: role order (canonical/reversed), delay (none/neutral/informative)

Figure 1. Main analysis. ERPs at the target verb in the canonical (grey) and reversed (red) conditions, split by delay type.
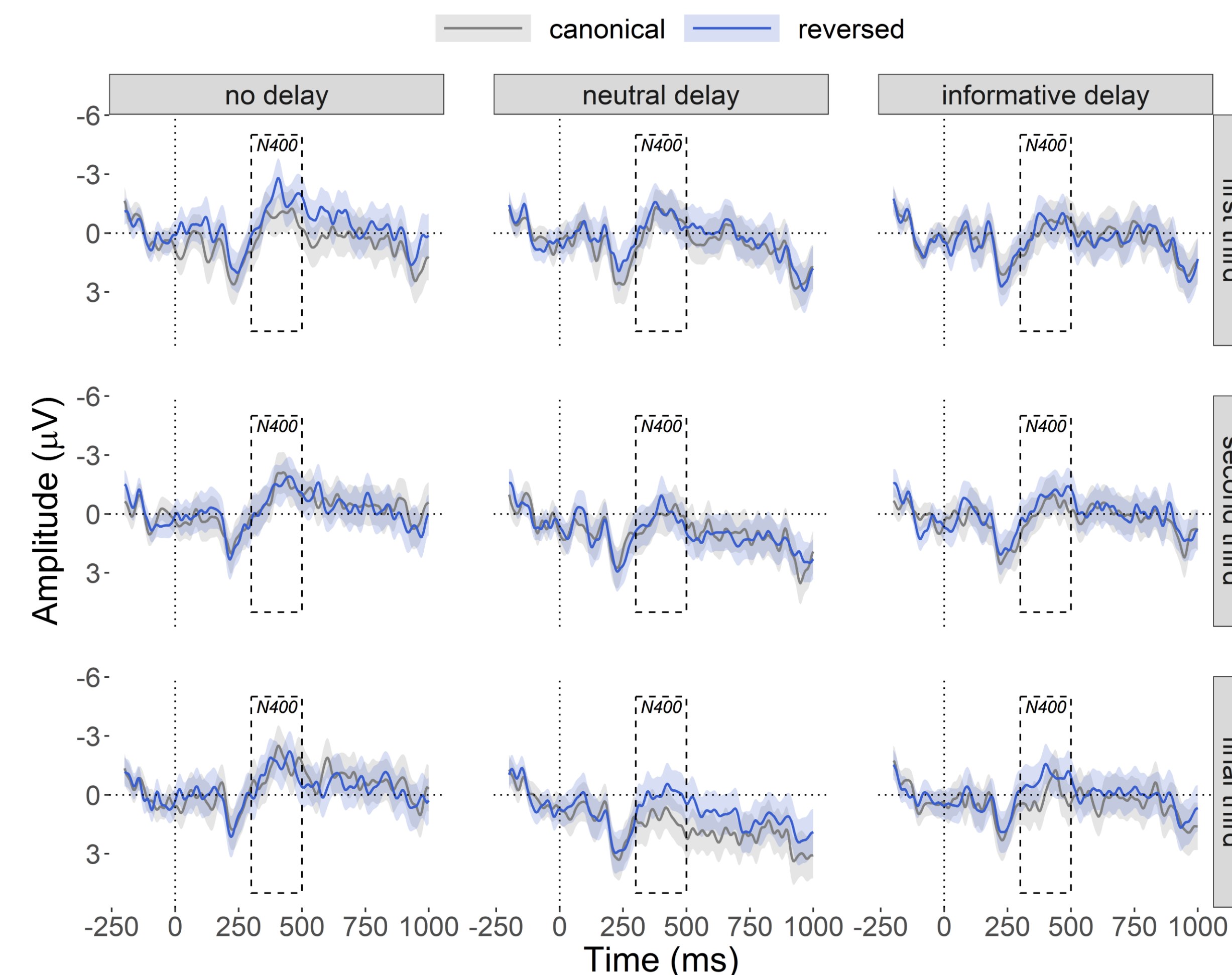

Figure 2. Exploratory analysis: Trial order effects. ERPs at the target verb in the canonical (grey) and reversed (blue) conditions in the neutral condition in the first, second and final thirds of the experiment.

Preliminary conclusions

- N400 semantic illusion in no-delay condition consistent with readers making quick, surface-based semantic interpretations and predictions (see **Fig. 1**).
- Unclear whether the illusion is resolved by delaying the verb, although the interaction coefficient in the neutral condition was numerically consistent with the effect observed in a previous experiment[8] (see **Fig. 1**).
- Interestingly, readers appeared to get better at using the *neutral* delay to resolve the illusion as the experiment progressed, but not the informative delay (see **Fig. 2**).
    - Hypothesis: Experience with the experiment allows use of syntactic cues to resolve the illusion, but competition from semantic cues blocks this effect?
- The delay effect may be true but small: A design analysis suggested that even hundreds of participants would not yield conclusive evidence either for or against the effect.

Results

Sample size determination

- Current ratio of evidence H_1:H_0 (BF_{10}) is 1:1, recruitment is ongoing.

Main analysis

- Inconclusive evidence for the interaction of role order and delay type for neutral vs. none, $\hat{\beta} = -0.16$, $95\%\ CrI = [-0.43, -0.01]$, $BF_{10} = 1$, and for informative vs. neutral, $\hat{\beta} = -0.29$, $95\%\ CrI = [-0.83, -0.01]$, $BF_{10} = 1$ (see **Fig. 1**).

Meta-analysis

- We fit the 2x2 model to the combined data from the current and published study [8], increasing sample size to 86. The interaction effect was larger but more variable and evidence was still inconclusive, $\hat{\beta} = -0.40$, $95\%\ CrI = [-0.96, -0.03]$, $BF_{10} = 1$.

Design analysis

- Assuming the current data adequately represent true values, we used them to simulate new datasets with 100, 150, 200 and 300 participants. None of the simulated datasets yielded a conclusive Bayes factor for either the null or alternative hypotheses.

Exploratory analysis: Trial order effects

- Most participants noticed the role reversals and reported a change in strategy over the experiment. The interaction of role order and neutral delay differed significantly as trials progressed, $\hat{\beta} = -0.90$, $SE = 0.44$, $t = -2.03$ (see **Fig. 2**). Pairwise comparisons indicated a significant difference in amplitude for reversals vs. canonical sentences in the neutral condition of the final third of the experiment, $\hat{\beta} = -1.25$, $SE = 0.51$, $t = -2.45$.

Bibliography

[1] Chow et al. (2015) *Lang, Cog, Neurosci* [2] Chow et al. (2016) *Lang, Cog, Neurosci* [3] Kuperberg et al. (2003) *Cog Brain Res* [4] Kim & Osterhout (2005) *JML* [5] Hoeks et al. (2004) *Cog Brain Res* [6] Kolk et al. (2003) *Brain & Lang* [7] Van Herten et al. (2005) *Cog Brain Res* [8] Chow et al. (2018) *Lang, Cog, Neurosci* [9] Momma et al. (2015) *CUNY Conference* [10] Rabovsky et al (2018) *Nat Hum Behav* [11] Kim & Osterhout (2005) *JML* [12] Kuperberg et al. (2003) *Cog Brain Res* [13] Brouwer et al. (2017) *Cog Science* [14] Bornkessel-Schlesewsky & Schlesewsky (2008) *Brain Res Rev*