Dissociating constraint and predictability in ERP: Evidence from German

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Are unexpected words more difficult to process in strongly constraining contexts?

- Intuitively, a low predictability word should be more difficult to process in a highly constraining than a weakly constraining context:[1]

  Strong constraint: The children went outside to... *look*
  Weak constraint: Joy was too frightened to... *look*

- Yet constraint effects are difficult to demonstrate in online measures.[1,2,4,5]
- Several studies report an anterior post-N400 positivity (PNP) larger to unexpected words in high- vs. low-constraint.[1,4,6]
- But PNP findings are inconsistent.[7–12]
- We are attempting a conceptual replication of [1] and [4] with Stage 1 registered report approval from *Neurobiology of Language*.

Design and methods

Example item:	Predictability Cloze probability [95% CI]	Constraint Entropy (bits) [95% CI]
Strong constraint:		
Auf Annetts Terrasse schien zu viel Sonne […]. Daher kaufte sie sich einen großen... *On Annett's terrace shone too much sun […]. So bought she herself a large...*		
(a) Schirm *umbrella*	0.80 [0.50, 1.00]	1 [0, 2]
(b) Hut *hat*	0.05 [0.03, 0.18]	1 [0, 2]
Weak constraint:		
Annett mag es gerne gemütlich […]. Daher kaufte sie sich einen großen... *Annett likes it really cozy […]. So bought she herself a large...*		
(c) Schirm *umbrella*	0.07 [0.03, 0.34]	2 [1, 3]
(d) Hut *hat*	0.05 [0.04, 0.15]	2 [1, 3]

Critical comparisons: PNP and N400 at low probability word in strong vs. weak constraint (b vs. d)

Other comparisons: PNP and N400 as high vs. low predictability word in strong constraint (a vs. b)

Sample size: Recruit until Bayes factor is ≥ 10 for critical comparisons or N = 150 (current N = 60)

- 224 items
- Comprehension questions after 50% of sentences
- RSVP 190 ms/word + 20 ms/letter; target noun 700 ms; 300 ms ISI

Bayesian models, critical comparisons:

N400 ~ entropy + *log*2 cloze probability + (1|item) + (1 + entropy + *log*2 cloze probability | subject)

PNP ~ entropy + *log*2 cloze probability + (1|item) + (1 + entropy + *log*2 cloze probability | subject)

Results:
Evidence that strong probabilistic commitments are more difficult to update than weaker commitments

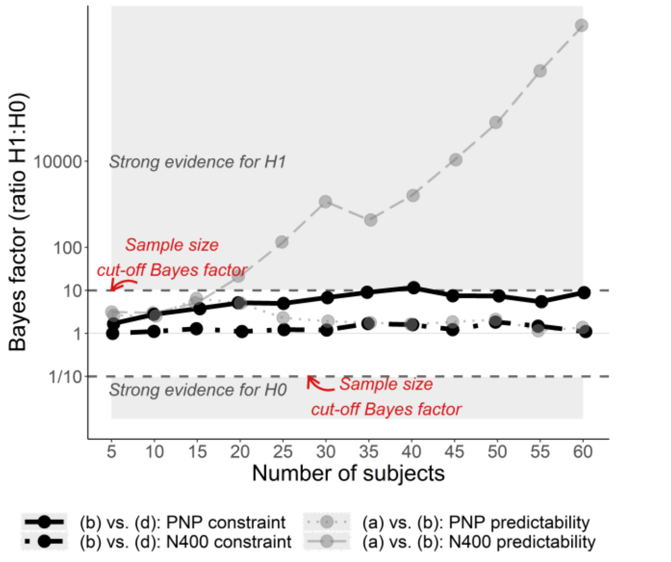

Figure 1. Ratio of evidence for H1:H0 (Bayes factor) as sample size increases. Critical comparisons are black. The sample size cut-off for strong evidence for a PNP constraint effect was reached at 40 subjects, although evidence weakened with increasing sample size. Data collection continues as the cut-off for the N400 and PNP constraint effect has not yet been reached.

Comparison	$\hat{\beta}$	95% credible interval	Current Bayes factor (BF_{10})	Prior
(b) vs. (d): PNP constraint	−0.25	[−0.48, −0.04]	9	$N_{-}(0,0.2)$
(b) vs. (d): N400 constraint	−0.13	[−0.34, 0.09]	1	$N(0,0.2)$
(a) vs. (b): PNP predictability	−0.11	[−0.25, 0.01]	1	$N_{-}(0,0.2)$
(a) vs. (b): N400 predictability	0.53	[0.37, 0.68]	14400773	$N_{+}(0,0.2)$

Table 1: Model estimates at the current sample size of 60 participants. Bayes factors indicate the ratio of evidence for the alternative (H1) vs. the null hypothesis (H0) at the priors specified. Priors indicate a priori hypotheses; for example, that as entropy increases (constraint decreases), PNP amplitude will decrease by 0 to $-4\,\mu V$ with 95% probability. A sign on the prior (e.g. N_{-} or N_{+}) indicates a one-sided prior.

- First pre-registered replication of the PNP constraint effect.
- **But:** The effect appears to be driven by a P600 constraint effect in the posterior region: $\hat{\beta} = -0.45\ [-0.68, -0.21], BF > 900$ (see Figure 2).
- Inconclusive evidence about an N400 constraint effect (P600 overlap?).
- Inconclusive evidence about a PNP predictability effect.
- Classic N400 predictability effect replicated.

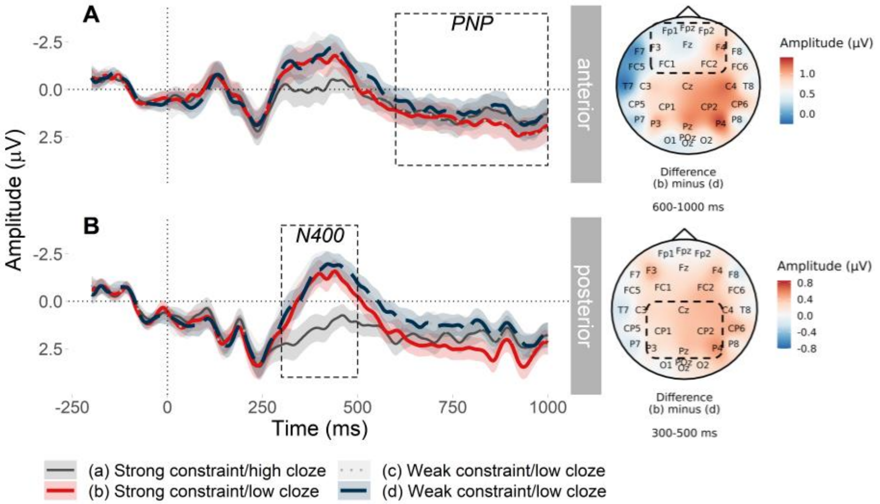

Figure 2. LEFT PANEL: Grand average amplitude for each of the four conditions in the anterior (A) and posterior (B) regions of interest. The critical comparisons are between red (b) and blue (d). RIGHT PANEL: Topography of the difference between conditions (b) and (d) in the PNP window (top) and the N400 window (bottom). Regions of interest are marked with a dotted line.

Bibliography

[1] Federmeier et al. (2007) Brain Res; [2] Frisson et al. (2017) JML; [3] Kutas (1993) Lang Cog Proc; [4] Kuperberg, Brothers & Wlotko (2020) J Cog Neurosci; [5] Kutas & Hillyard (1984) Nature; [6] Brothers et al. (2020) Neurobiol Lang; [7] Federmeier & Kutas (1999) JML; [8] Thornill & Van Petten (2012) Int J Psychophys; [9] Wlotko & Federmeier (2007) Neuropsychologia; [10] Szewczyk & Schriefers (2013) JML; [11] Lai, Rommers & Federmeier (2021) Brain Res. [12] Rommers & Federmeier (2018) NeuroImage.