

What can ERPs tell us about reading time effects in filler-gap versus ellipsis sentences?

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In filler-gap constructions such as *the intern_i that the researcher looked for _____i*, the filler (*intern*) is maintained in memory until the verb. Evidence of this is that an animacy-matching distractor noun caused reading time slowdowns in filler-gap vs. non-filler-gap (ellipsis) sentences [1]. This slowdown was interpreted as extra memory encoding effort for the similar nouns given the expectation that one of them (the filler) would later be retrieved. An additional finding in [1] was a slowdown at the resolution site in non-filler-gap ellipsis constructions. This slowdown could have been due to interference during memory retrieval because there had been no extra encoding effort for the similar nouns, since there was no expectation that the antecedent would later be retrieved. We ask whether ERPs align with this account of working memory load and reading time slowdowns by examining the SAN (working memory storage; [2,3]), the N400 (lexical retrieval; [4,5]), and the P600 (integration; [5,7]) in separate SPR and ERP experiments using the same stimuli (**Table 1**). We expected to replicate the reading time (RT) results of [1]. We predicted that maintenance of the filler would increase working memory load (larger SAN filler gap > ellipsis). We hypothesised that where RT slowdowns were triggered by retrieval difficulty, we would see an N400; where triggered by integration difficulty and/or additional encoding effort, a P600.

Methods. Design and example item in **Table 1**. Participants reported difficulty with the complex stimuli despite good comprehension (**Table 2**) and showed marked trial-order changes in RTs/ERPs: We therefore report the results of the first half of the experiments where we assume participants were most attentive. **SPR**: 24 sentences, 116 German native speakers. **ERP**: 40 sentences, 58 German native speakers. Evidence from Bayesian linear mixed effects models (detail **Fig. 1**) was evaluated using ratios (Ev) of posterior probability of the effect estimate against an opposite effect. $Ev \geq 3$: moderate evidence for H_1 ; $Ev \geq 10$, strong evidence [6].

Results. SPR. Distractor noun: Filler-gap sentences read faster overall, $\hat{\beta} = -0.04$ [-0.06, -0.01], $P(\beta < 0) = 1.00$, $Ev = 202$; animate condition read slower overall, $\hat{\beta} = 0.02$ [-0.01, 0.05], $P(\beta < 0) = 0.89$, $Ev = 8$. Interaction driven by slower filler gap/animate RTs, $\hat{\beta} = 0.03$ [0, 0.06], $P(\beta > 0) = 0.95$, $Ev = 20$. **Resolution site:** No evidence of animacy effect in either sentence type. **ERP. No evidence for a SAN filler gap > ellipsis in the relativiser or distractor noun regions.** **Distractor noun:** Interaction driven by P600 for filler gap/animate, $\hat{\beta} = 0.65$ [-0.19, 1.47], $P(\beta > 0) = 0.90$, $Ev = 9$, and P600 for ellipsis/inanimate, $\hat{\beta} = -0.99$ [-1.8, -0.18], $P(\beta < 0) = 0.98$, $Ev = 42$. **Resolution site:** Larger N400 for ellipsis/animate, $\hat{\beta} = -0.72$ [-1.71, 0.23], $P(\beta < 0) = 0.89$, $Ev = 8$, and larger P600 for filler gap/animate, $\hat{\beta} = 1.16$ [0.36, 1.97], $P(\beta > 0) = 0.99$, $Ev = 102$.

Conclusions. The absence of a SAN suggests working memory was not detectably impacted by filler maintenance or interference. **Distractor noun:** The animacy interference effect in filler-gap RTs replicates [1], supporting filler maintenance, but may be part of a more general animacy effect (**Fig. 1**). A larger P600 in filler gap/animate suggests the slowdown in RTs may reflect integration attempts and/or extra encoding effort. The P600 for ellipsis/inanimate is difficult to explain and not consistent with RTs. **Resolution site:** The ellipsis/animate effect in [1] was not replicated in RTs but a small N400 in our ellipsis/animate nonetheless suggests retrieval difficulty in this condition, possibly due to similarity-degraded representations. The P600 in filler gap/animate suggests more effortful integration in this condition despite earlier extra encoding effort. ERPs thus aligned somewhat with RTs but appeared more sensitive to processing difficulty.

Table 1. Example experimental item. Both experiments had a 2×2 design identical to [1]: Sentence type (filler gap/ellipsis) and animacy of the filler (animate [match with distractor]/inanimate [mismatch with distractor]). Bold black text indicates the **filler-gap filler / ellipsis antecedent**. The **distractor noun** is underlined in blue. The **resolution sites** are in mustard colour. Commas were deliberately not used to increase similarity between sentence types. A comprehension question appeared after every sentence.

ELLIPSIS, ANIMATE/INANIMATE:

Der Astronaut begutachtet den **Sohn/Bericht**_i des erschöpften Kosmonauten aus der Heimat des Laborpartners während der Mission aber nicht den ______i des **Kommandanten** da er...

*The astronaut assesses the **son/report**_i of the exhausted cosmonaut from the homeland of the lab partner during the mission but not that ______i of the **commander** as he...*

FILLER-GAP, ANIMATE/INANIMATE:

Der Astronaut begutachtet den **Sohn/Bericht**_i den der erschöpfte Kosmonaut aus der Heimat des Laborpartners während der Mission auf der Anlage **gesehen** ______i hatte als wäre...

*The astronaut assesses the **son/report**_i that the exhausted cosmonaut from the homeland of the lab partner during the mission in the facility **saw** ______i as if...*

Table 2. Mean comprehension accuracy.

Experiment	Mean	SD
SPR	83%	6%
ERP	78%	6%

References. [1] Ness & Meltzer-Asscher (2019) Lang, Cog, Neurosci; [1] Phillips et al. (2005) Cog Brain Res; [3] Cruz et al. (2021) Neurobiol Lang [4] Kutas & Federmeier (2011) Ann Rev Psychol; [5] Brouwer et al. (2017) Cog Sci; [6] Lee & Wagenmakers (2013) [7] Kaan et al. (2000) Lang Cog Proc

Figure 1. Reading times and ERPs across the sentence. Reading times were log transformed for analysis. ERP analysis was conducted on amplitudes averaged across electrodes in black shaded scalp areas and time windows in dashed boxes. The choice of regions and windows of interest was theory-driven.

