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The influence of dependency length on expectancy: Evidence from reading times and ERPs

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Abstract

Expectation-based models of sentence processing predict lower processing costs for highly expected words, whereas research on long-distance dependencies consistently shows that greater memory demands increase processing difficulty. The Lossy-Context Surprisal (LCS) framework integrates these approaches, postulating that surprisal is determined on the basis of imperfect memory representations, predicting reduced expectancy effects as dependency length increases. In both a self-paced reading and ERP experiment, we investigated whether the distance between predictive elements of the context and a target word modulates expectancy as predicted by LCS. While the SPR findings revealed an interaction of these factors, providing preliminary support for unified accounts like LCS, neurophysiological responses revealed additive effects of expectancy and memory demands, but not the predicted interaction.

Keywords: Language expectation; Lossy-Context Surprisal; EEG; N400;

Introduction

Language comprehension is widely assumed to be expectation-based, as formalised in surprisal theory which states that processing difficulty increases with the negative log probability of a word given its context (Hale, 2001, 2006; Levy, 2008). However, comprehension is also limited by working-memory constraints (e.g., Gibson, 1998). In an effort to integrate these accounts, Lossy-Context Surprisal (LCS) (Futrell et al., 2020) argues that expectations are derived from imperfect memory representation of the context. This predicts that expectancy effects for a word may be attenuated when previous information is degraded in memory, e.g. over longer distances. In this paper, we report a self-paced reading (SPR) and an ERP study investigating whether the distance between predictive elements of the context and the target modulates expectations as predicted by LCS.

Expectation effects in language comprehension are supported by a substantial body of behavioral and neurophysiological evidence showing increased processing costs for less expected words. Behavioral measures of processing effort, such as reading times, are typically higher for less expected words (e.g., Smith & Levy, 2013). In the neurophysiological domain, two ERP components are most commonly linked to word expectancy: the N400 and the P600. The N400 is a negative-going voltage deflection peaking around 400 ms after stimulus onset, while the P600 is a positive-going deflection typically emerging after 600 ms. While both have been shown to be sensitive to expectancy (see Aurnhammer et al., 2021; Kutas and Federmeier, 2011 and references cited therein), they have been argued to reflect distinct underlying processes. Here we assume the Retrieval-Integration account (Brouwer et al., 2012), under which the N400 reflects lexical retrieval and the P600 reflects semantic integration (see also (Aurnhammer et al., 2023; Delogu et al., 2019).

Language processing also engages other cognitive mechanisms, notably working memory (e.g., Carpenter & Just, 2013). During sentence comprehension, incoming linguistic material must be integrated with previously processed context, which requires the temporary maintenance of to-be-operated information over time. Accordingly, several models of sentence processing emphasize working memory constraints and predict increased processing difficulty when long-distance dependencies must be maintained before integration can occur (e.g., Gibson, 1998; Gibson et al., 2000; Lewis et al., 2006).

These memory-based models predict locality effects, such that increasing the distance between dependent elements leads to greater processing difficulty as demonstrated across a range of behavioral measures in long-distance dependency processing (Gordon et al., 2001; Grodner & Gibson, 2005; J. King & Just, 1991). Importantly, these distance-related effects are not straightforwardly explained by expectation-based models.

Recent models have proposed a unified account of expectation-based and memory-based approaches in terms of Lossy-Context Surprisal (LCS) (Futrell et al., 2020; Hahn et al., 2022). In this framework, linguistic expectations are derived from lossy and imperfect memory representations of the prior context. More precisely, from the LCS perspective, elements that are further back in the input contribute progressively less to determining the expectancy of upcoming words, because memory representations become noisier with distance. As contextual information becomes lossy, comprehenders' expectations increasingly regress toward their prior expectations, reducing the influence of earlier context. As a result, increasing dependency length is predicted to attenuate expectancy effects due to working memory constraints. Such interactions (Expectancy × Distance) have been observed in reaction time studies using the maze task (Hao et al., 2023, 2024), suggesting that surprisal effects during comprehension reflects not only the probabilistic expectations given the linguistic context but also the extent to which the context is fully retained in memory.

While previous studies testing LCS predictions have used

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behavioral measures to examine embedding bias (Hao et al., 2023) and classifier–noun dependency (Hao et al., 2024), we instead test semantic expectancy by comparing verb–object combinations that are either semantically expected or unexpected. In the present study, we investigate whether such semantic expectancy is modulated by distance, as predicted by the Lossy-Context Surprisal framework, in both behavioral and neurophysiological measures. Specifically, we test the hypothesis that increased dependency length attenuates semantic expectancy effects as a consequence of lossy memory representations. As contextual information degrades over longer distances, both facilitation for expected words and difficulty for unexpected words should be reduced.

To test this hypothesis, we developed a 2×2 design manipulating expectancy and distance. Expectancy was manipulated via the semantic plausibility of verb–object combinations (e.g., *sharpened the axe* vs. *weaved the axe*) to maximize the expectancy effect. We varied the dependency length between the main verb (e.g., *sharpened*) and the object (e.g., *axe*) by manipulating the linear position of semantically unassociated material in the context. This unassociated material either preceded the subject or intervened between the verb and the object (Short vs. Long). For an example item see Table 1. Changing the position of this material does not alter the lexical or semantic content of the context and therefore should not differentially affect the expectancy between the verb and the object. In the short condition, semantic violations in verb–object combinations are more salient due to shorter distance, and thus, less expected, which should lead to increased processing difficulty. In the long condition, however, verbs appearing earlier in the sentence may have lossier representations in the comprehender's memory of the context (Futrell et al., 2020). When the object is encountered, the verb information that crucially determines semantic surprisal – and thus processing difficulty – of the object may have partially degraded, thereby reducing the surprisal effect. That is, lossy representations of the verb may result in both reduced expectancy in the expected condition, as well as reduced surprisal in the unexpected condition. We therefore expect behavioral and neurophysiological measures to reflect an interaction between expectancy and distance. We predict a strong expectancy effect in short conditions and an attenuated expectancy effect in long conditions reflected in both reading times and in neurophysiological indices (e.g., N400 and P600 amplitudes).

Methods

Materials

We constructed 120 experimental items adapted from Aurnhammer et al., 2021 according to the design described above. To avoid sentence-final wrap-up effects on the target word, additional material followed the target in all conditions and were kept constant across conditions. In addition, 120 filler items were included to mask the the experimental manipulations.

Cloze Norming

To validate the expectancy manipulation of the verb–target pairs, we collected cloze probabilities for the experimental items using the platform PCIbex (Zehr & Schwarz, 2018). Forty participants were recruited via Prolific Academic Ltd (www.prolific.com). All participants were native speakers of German and reported no language, cognitive, or neurological impairments. Sentences were presented in the center of the screen up to (but not including) the target word, and participants were asked to complete each sentence by filling in the missing word with the best continuation. In the training phase, participants were familiarized with the task by showing them example completions (e.g., "die Axt").

Cloze probability confirmed the expectancy manipulation (Expected Short: $M = 0.445, SE = 0.286$; Expected Long: $M = 0.409, SE = 0.271$; Unexpected Short: $M = 0.007, SE = 0.028$; Unexpected Long: $M = 0.012, SE = 0.088$). To test whether distance influenced cloze completion, we coded each trial as match (1) if the response matched the intended target and missmatch (0) otherwise. We then fitted a binomial generalized linear mixed-effects model using lme4 (Bates, Maechler, et al., 2015) package in R (Team et al., 2016). Distance and expectancy were effects-coded (-.5, .5). Both predictors and their interaction were included as fixed effects, and as random slopes for participant and item. The results showed the expectancy difference between expected and unexpected conditions but not between long and short conditions (Expectancy: $\beta = -9.759, SE = 1.334, z = -7.316, p < .001$; Distance: $\beta = -0.030, SE = 0.252, z = -0.120, p = .904$).

Experiment 1: SPR

Participants

Eighty-three participants (age: $M = 27.6$, Female: 30) were recruited via Prolific Academic Ltd (www.prolific.com). All participants were native speakers of German and reported no history of language, cognitive, or neurological disorders. Participants were excluded if their comprehension accuracy fell below 70%. Data from 80 participants (age: $M = 27.5$, Female: 30) were included in the final analyses.

Procedure

The experiment was conducted as a web-based self-paced reading study using PCIbex (Zehr & Schwarz, 2018). At the beginning of each trial, participants were prompted to press the Enter key to reveal a fixation cross at the center of the screen to indicate the position of upcoming words. Words were then presented one at a time in the center of the screen, and participants were instructed to press the space bar to proceed to the next word. Each trial was followed by a yes/no comprehension question. Comprehension questions were formulated to probe information from all regions of the sentence, thereby discouraging participants from skipping unassociated materials. The experiment began with a practice block consisting of three practice sentences. The main

Table 1: Sample item of the stimuli.

Conditions	Example
Expected Short	Gestern nach dem Hören der Nachrichten und des Wetterberichts **schärfte** der Holzfäller, der ungeduldig war, die Axt in seinem. . . *Yesterday after listening to the news and the weather report* ***sharpened*** *the lumberjack, who impatient was, the axe in his. . .*
Expected Long	Gestern **schärfte** der Holzfäller, der die Nachrichten und den Wetterbericht gehört hatte und ungeduldig war, die Axt in seinem. . . *Yesterday* ***sharpened*** *the lumberjack, who the news and the weather report listened had and impatient was, the axe in his. . .*
Unexpected Short	Gestern nach dem Hören der Nachrichten und des Wetterberichts **webte** der Holzfäller, der ungeduldig war, die Axt in seinem. . . *Yesterday after listening to the news and the weather report* ***weaved*** *the lumberjack, who impatient was, the axe in his. . .*
Unexpected Long	Gestern **webte** der Holzfäller, der die Nachrichten und den Wetterbericht gehört hatte und ungeduldig war, die Axt in seinem. . . *Yesterday* ***weaved*** *the lumberjack, who the news and the weather report listened had and impatient was, the axe in his. . .*

experiment comprised three blocks, with optional breaks of 3–5 minutes between blocks.

Analysis

We analyzed reading times in the target noun phrase region using R (Team et al., 2016). The determiner and noun regions were initially analyzed separately. Single-trial outliers were excluded using the interquartile range (IQR) criterion (Berger & Kiefer, 2021). The IQR was applied separately to each region, and an entire trial was excluded if any region of that trial fell outside the interquartile range. In total, 10.88% of trials were excluded. We conducted an analysis of the reading times of each region using linear mixed-effects models with the MixedModels package in Julia (Bezanson et al., 2017). Expectancy and Distance as well as their interaction were included as fixed effects and as by-participant and by-item random slopes in all linear mixed-effects models. Both predictors were continuous: while Expectancy was introduced as the cloze probability for each target word (collected as described above), Distance was operationalized as the number of syllables between the verb and the target (Long: $M = 22.73, SE = 0.24, min = 16, max = 30$; Short: $M = 9.00, SE = 0.13, min = 6, max = 13$). Both predictors were z-scored. To examine whether participants remained attentive throughout the experiment and whether data quality changed over the course of the web-based study, we conducted a block analysis. Block was contrast-coded as Block 1 vs. Blocks 2 (-2/3, 1/3, 1/3), and Block 2 vs. Block 3 (-1/3 ,-1/3, 2/3). These contrasts were chosen to capture potential changes over time in the effects. To capture such changes, the block contrasts were included as fixed effects and as by-participant random slopes, interacting with the two manipulated factors. Model selection followed the parsimonious mixed-effects modeling strategy recommended by Bates, Kliegl, et al., 2015.

Results

Average reading times of critical regions were plotted in Figure 1. Reading times in the determiner region showed a significant interaction that was most pronounced in the first block (Expectancy × Distance: $\beta = 0.006, SE = 0.003, z = 2.218, p < .05$; Expectancy × Distance × Block contrast 1 [Block 1 vs. Block 2]: $\beta = -0.021, SE = 0.006, z = -3.029, p < .01$), while reading times in the target noun region showed a significant main effect of expectancy most pronounced in Block 1 (Expectancy: $\beta = -0.007, SE = 0.003, z = -2.554, p < .05$; Expectancy × Block contrast 1 [Block 1 vs. Block 2]: $\beta = 0.016, SE = 0.006, z = 2.491, p < .05$) and – similar to the determiner region – a significant interaction in Block 1 (Expectancy × Distance × Block contrast 1 [Block 1 vs. Block 2]: $\beta = -0.013, SE = 0.007, z = -2.009, p < .05$). As the determiner region isolated from the subsequent noun already shows strong effects of our manipulation in the same direction as the noun region, we collapsed the two regions in a post-hoc analysis of the full noun phrase. This was done to further provide direct comparability to the follow-up EEG study, in which the determiner and noun were presented together, based on the findings of this experiment.

The merged target noun phrase region showed effects consistent with the separate analyses above (Expectancy: $\beta = -0.005, SE = 0.003, z = -2.065, p < .05$; Expectancy × Distance: $\beta = 0.006, SE = 0.003, z = 2.392, p < .05$). Both effects in this merged region significantly interact with the block contrast, indicating that they are more pronounced in the first block of the experiment (Expectancy × Block 1: $\beta = 0.013$, SE = 0.006, $z = 2.318, p < .05$; Expectancy × Distance × Block contrast 1 [Block 1 vs. Block 2]: $\beta = -0.019$, SE = 0.006, $z = -2.964$, $p < .01$). Block contrasts are observed as significant main effects (Block contrast 1 [Block 1 vs. Block 2]: $\beta = -0.114$, SE = 0.010, $z = -11.706$, $p < .001$; Block contrast 2 [Block 2 vs. Block 3]: $\beta = 0.050$, SE = 0.009, $z = -5.703$, $p < .001$). The complete model results are reported in Table 2.

Discussion

In the SPR study we found reading times for unexpected objects were overall longer than those for expected objects, consistent with previous findings on expectancy effects. More importantly, we observed reduced reading times for unexpected objects and increased reading times for expected objects in long-distance conditions compared to short-distance conditions, in the predicted direction. Both effects were more pronounced in the first block of the experiment. We interpret this interaction as evidence that expectancy effects are modulated by distance, which is in line with the predictions of LCS.

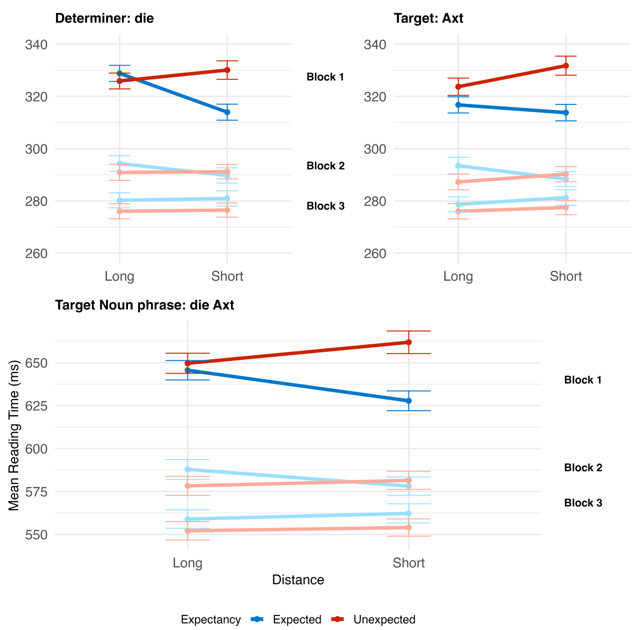

Figure 1: Mean reading times for the target NP; error bars indicate standard errors. For presentation purposes, the continuous factor of Distance was grouped into Long and Short.

As verb-provided information becomes increasingly lossy in comprehenders' memory, both the facilitation associated with expectedness and the processing difficulty associated with unexpectedness are attenuated. Notably, the interaction appears to be strongest in the first block of the experiment. We also observed a block effect indicating that participants' reading speed increased over the course of the experiment, which may account for the attenuation of the effect in later blocks. As reading speed increases, the interaction may no longer be detectable in the SPR measure. Moreover, the interaction emerged as early as the determiner region. One possible explanation is that, because German determiners encode morphosyntactic information such as gender and case, they help narrow the set of possible upcoming nouns. In expected conditions, comprehenders have a specific expectation for both the upcoming noun and its determiner. In unexpected conditions, comprehenders do not anticipate a specific noun and therefore have no strong expectation for the determiner. This suggests that expectancy effects and their interaction with distance, are not restricted to content words, but can also be observed for function words.

Table 2: LMER output Target NP

Region	Fixed Effect	β-Estimate	Std. Error	z value	sig.
	(Intercept)	6.377	0.023	272.219	***
	E	-0.005	0.003	-2.065	*
	D	0.000	0.003	-0.10	.923
	B1	-0.114	0.010	-11.706	***
	B2	0.050	0.009	-5.703	***
	E & D	0.006	0.003	2.392	*
Target NP	E & B1	0.013	0.006	2.138	*
	E & B2	-0.005	0.006	-0.822	.411
	D & B1	0.004	0.005	0.706	.480
	D & B2	0.006	0.005	-1.102	.271
	E & D & B1	-0.019	0.006	-2.964	**
	E & D & B2	0.005	0.006	0.726	.468

. - $p < 0.1$, * - $p < 0.05$, ** - $p < 0.01$, * * * - $p < 0.001$
E - Expectancy , D - Distance , B1 - Block 1 vs. mean of Blocks 2 & 3 , B2 - Block 2 vs. Block 3

Experiment 2: EEG

Participants

Fifty-nine participants (age: $M = 23.92$, Female: 22) were recruited at Saarland University. All participants were native speakers of German and reported no history of language, cognitive, or neurological disorders. Participants were excluded if their comprehension accuracy fell below 70% or if more than 25% of their trials were rejected due to EEG artefacts. After applying these criteria, data from 40 participants were included in the final analyses.

Procedure

Stimuli and fillers were identical to Experiment 1. Sentences were presented using rapid serial visual presentation (RSVP) in E-Prime (Psychology Software Tools, Inc.), with each word displayed for 350 ms followed by a 150 ms inter-stimulus interval in the center of the screen. Determiners were presented together with the nouns, motivated by the emergence of effects in the determiner region in the SPR study, in order to avoid potential baseline-related issues in the EEG study. Participants first completed a practice session with 12 sentences. The main experiment consisted of four blocks of 60 sentences each, presented in pseudorandomized order, with a five-minute break between blocks. After each sentence, participants responded to a yes/no question about sentence content. These included 30 plausibility judgments and 210 comprehension questions. The comprehension questions probed information distributed across the entire sentence. To prevent effects from weakening in later blocks, as observed in the reading-time data, and to ensure that participants read each sentence fully and remained attentive throughout the experiment, the questions were designed to require sentence-level understanding, such that participants had to recall the sentence and infer the correct answer from its meaning rather than answering solely based on whether a particular word had appeared.

EEG Recording and Data Pre-processing

The EEG signal was recorded by 26 Ag/AgCl electrodes (actiCAP Slim, BrainProducts) and amplified with a BrainAmp (BrainVision) amplifier. Electrodes were placed according to the 10–20 system (Lagerlund et al., 1993). The ground electrode was placed at FPz, and the signal was referenced online to FCz. Data were digitized at a sampling rate of 1000 Hz. The EEG signal was re-referenced offline to the average of the mastoid electrodes. The horizontal electrooculogram (EOG) was monitored with two electrodes placed at the right and left outer canthi of each eye and the vertical EOG with two electrodes above and below the left eye. No online filters were used during recording.

EEG data were preprocessed in MATLAB (Inc, 2022) using the EEGLAB toolbox (Delorme & Makeig, 2004) and the ERPLAB extension (Lopez-Calderon & Luck, 2014). The continuous EEG was band-pass filtered between 0.1 and 30 Hz. Independent component analysis (ICA) was applied to identify and correct components associated with horizontal eye movements. Trials containing vertical eye movements or muscle artefacts were rejected using automated artefact detection procedures. Baseline correction was applied using the 150 ms pre-stimulus interval.

Analysis

We conducted an analysis of the mean amplitudes in linear mixed-effects models time locked to the onset of the target noun. All linear mixed effects models utilized Expectancy and Distance as well as their interaction as fixed effects and were also included in the random effects structure as by-participant and by-item random slopes, the same as in the SPR study. Twenty-one electrodes were included in the analysis. Regions of interest were pre-determined as frontal (Fp1, Fp2, F7, F3, Fz, F4, F8), central (C3, Cz, C4, FC5, FC1, FC2, FC6), parietal (P3, Pz, P4, CP5, CP1, CP2, CP6) and contrast coded as frontal vs. central (-2/3, 1/3, 1/3), and central vs. parietal (-1/3, -1/3, 2/3). This sliding contrast was selected because distance effects are reported to be found in more frontal regions, while expectancy effects are usually observed in centro-parietal regions. To account for longitudinal distributions of effects, these ROI contrasts were included as fixed effects and as random slopes, interacting with the two manipulated factors. Model selection followed the parsimonious mixed-effects modeling strategy recommended by Bates, Kliegl, et al., 2015. The averaged ERP waveforms time-locked to the target word for the four experimental conditions at electrodes Fz, Cz, and Pz can be found in Figure 2.

Results

In the N400 window (300–500 ms), an overarching significant effect of Expectancy was observed ($\beta = 0.708, SE = 0.227, z = 3.113, p < .01$), with unexpected target words eliciting larger negative amplitudes than expected targets in both the long- and short-distance conditions (see Figure 3). In addition, a significant interaction between ROI and Distance was found (Distance × ROI contrast [Central vs. Parietal]: $\beta = -0.152, SE = 0.070, z = 2.168, p < .05$). Long-distance conditions showed more negative amplitudes than short-distance conditions, and this distance effect increased from parietal toward frontal regions.

In the 500–1000 ms window, we observed negativities exhibiting a significant main effect of distance ($\beta = -0.526, SE = 0.203, z = -2.590, p < .01$), which was most prominent at frontal electrodes (Distance × ROI contrast [Central vs. Parietal]: $\beta = 0.185, SE = 0.091, z = 2.052, p < .05$). A marginal effect of expectancy was also observed ($\beta = 0.465, SE = 0.238, z = 1.957, p = .05$). No interaction between expectancy and distance was found in either time window. For the full model output, see Table 3.

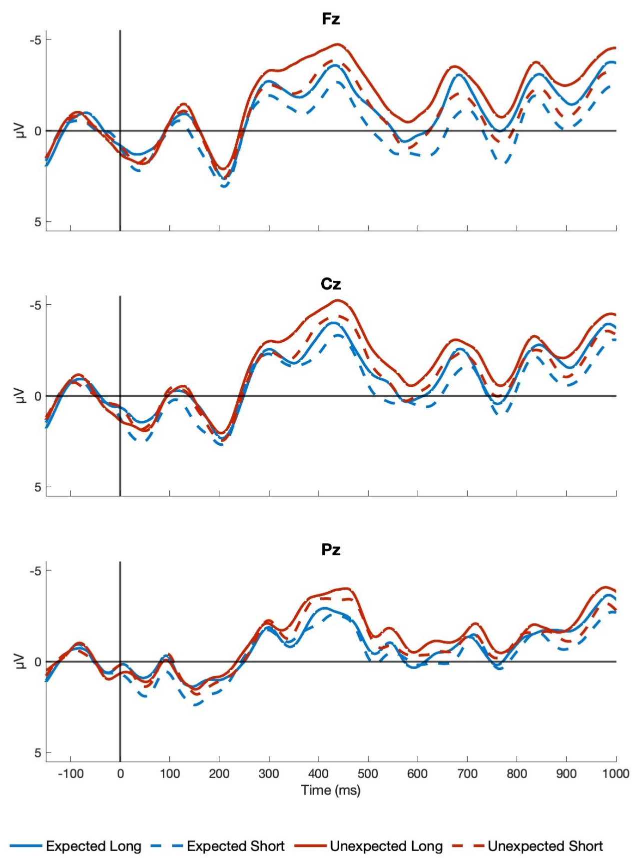

Figure 2: Grand-average EEG waveforms at Fz, Cz, and Pz from -150 to 1000 ms time-locked to the target word, low-pass filtered at 20 Hz for presentation purposes. For presentation purposes, the continuous factor of Distance was grouped into Long and Short.

Discussion

In the ERP data, we observed additive effects of expectancy and distance in the N400 time window, as well as a main effect of distance in the later time window. Negative amplitudes were modulated by the degree of expectancy of the object noun, with less expected objects eliciting more negative amplitudes. The expectancy effect in the N400 time window aligns with previous findings (see Kutas and Federmeier, 2011 for a review). In addition, object nouns in long-distance conditions elicited more negative amplitudes than those in short-distance conditions. The distance effect was more prominent in the frontal region. Importantly, while both expectancy and dis-

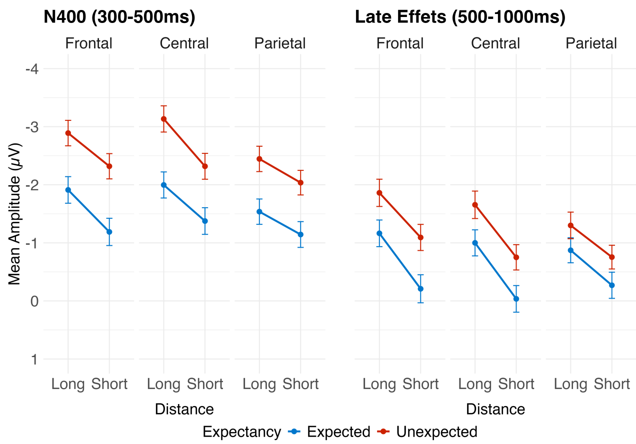

Figure 3: Mean ERP amplitudes in the 300–500 ms and 500-1000 ms time window for frontal, central, and parietal regions of interest. Error bars indicate standard errors. For presentation purposes, the continuous factor of Distance was grouped into Long and Short.

Region	Fixed Effect	β-Estimate	Std. Error	z value	sig.
N400	(Intercept)	-1.952	0.290	-6.727	***
	E	0.708	0.227	3.113	**
	D	-0.389	0.188	-2.071	*
	FC	-0.123	0.134	-0.924	.355
	CP	0.440	0.199	2.208	*
	E & D	-0.048	0.198	-0.242	.809
	E & FC	-0.005	0.106	-0.045	.963
	E & CP	-0.111	0.080	-1.394	.163
	D & FC	-0.029	0.119	-0.241	.809
	D & CP	0.152	0.070	2.168	*
	E & D & FC	0.083	0.107	0.782	.434
	E & D & CP	0.051	0.080	-0.629	.529
Late Effects	(Intercept)	-0.855	0.255	-3.356	***
	E	0.465	0.238	1.957	.
	D	-0.526	0.203	-2.590	**
	FC	0.214	0.132	1.614	.106
	CP	0.054	0.127	0.421	.673
	E & D	-0.114	0.230	-0.493	.622
	E & FC	-0.068	0.094	-0.725	.468
	E & CP	-0.159	0.092	-1.724	.
	D & FC	-0.032	0.108	-0.291	.771
	D & CP	0.185	0.091	2.052	*
	E & D & FC	0.006	0.105	0.053	.957
	E & D & CP	0.024	0.079	0.311	.756

Table 3: LMER output N400 and Late Effects
(. - $p < 0.1$, $*$ - $p < 0.05$, $**$ - $p < 0.01$, $***$ - $p < 0.001$) (E - Expectancy , D - Distance , FC - Frontal vs. Central , CP - Central vs. Parietal)

tance influenced the N400, they did so additively, providing no support for the interaction that would be predicted by LCS. The additive pattern we observed is consistent with both traditional expectancy-based and memory-based models, indicating that processing difficulty is determined by both expectations and working memory. One speculative interpretation of this additive pattern is that it reflects the temporal superposition and partial overlap of the N400 and sustained anterior negativities. Whereas the N400 is thought to reflect expectancy (Kutas & Federmeier, 2011), sustained anterior negativities have been associated with distance-related and task-related memory demands (Cruz Heredia et al., 2022; Fiebach et al., 2002; J. W. King & Kutas, 1995). Both components may therefore contribute concurrently to the observed waveform. The expected P600 effect was not observed. One possible explanation is that the sustained negativities persist over time and mask a potential positive component. An alternative speculative explanation is that the P600 may be sensitive to task relevance: integration-probing tasks are more likely to elicit P600 effects, whereas memory-probing tasks may not (see Schacht et al., 2014 for a discussion). This pattern would suggest that ERP components are differentially sensitive to task demands and reflect distinct aspects of language processing.

Discussion and Conclusion

This study investigated whether increased dependency length attenuates semantic expectancy effects, as predicted by the Lossy-Context Surprisal (LCS) framework. We predicted that memory representation of the context degrades with increasing distances between a predictive verb and its object, thereby reducing the processing advantage for expected words and the penalty for unexpected ones. In the self-paced reading study, we observed a main effect of expectancy and an interaction between expectancy and distance in the direction predicted by LCS. In the ERP study, expectancy and distance showed additive effects, but no interaction. These findings suggest that while behavioral measures like reading times reflect an integrated cost of expectancy and memory decay, neurophysiological indices may index these processes as distinct, concurrent mechanisms that both influence the observable ERPs.

Taken together, the results support accounts in which expectation-based facilitation and memory-based degradation jointly shape real-time language processing, but are reflected differentially across behavioral and neurophysiological measures. While the SPR findings provide at least preliminary support for unified accounts like LCS, neurophysiological responses reveal additive sensitivity to expectancy and memory demands. The findings underscore the importance of combining multiple methological approaches to achieve a fuller understanding the mechanisms underlying sentence processing.

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