Lossy Context Surprisal: Influence of Linearization on Expectation

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The current SPR study investigates whether longer-distance dependencies exhibit attenuated surprisal effects due to an imperfect representation of context in memory, such that the processing of expected words is less facilitated, while unexpected words are less effortful, when the previous context is partially lost due to distance.

Expectation-based sentence processing is supported by a range of behavioral and neurophysiological evidence suggesting that additional input facilitates processing by reducing uncertainty about upcoming words (e.g., Hale, 2001, 2006; Levy, 2008). Studies on long-range dependencies, however, show that increasing the distance between dependent elements of a sentence increases processing difficulty, contradicting expectation-based accounts (for discussion see Futrell et al., 2020). By contrast, memory-based models have attributed such behaviour to working memory limitations (Lewis & Vasishth, 2005). Recent accounts, such as the lossy-context surprisal model, however, incorporate memory effects into an expectation-based framework by formally characterizing how surprisal is determined based on imperfect, or lossy, representations of the preceding context (Futrell et al., 2020; Hahn et al., 2022).

To investigate the interaction of expectation and memory, we conducted a reading time study in German using a 2×2 design based on materials adapted from Aurnhammer et al. (2021). We created 120 items which varied the linear position of an adverbial clause (*bevor der Holzfäller … stapelte*) to manipulate the distance (Long vs Short) between the main verb (*schärfte/aß*) and the object (*Axt*). The expectancy of the object (Expected vs Unexpected) is manipulated by the main verb in the preceding context (*schärfte die Axt vs. aß die Axt*, see Table 1). Cloze and plausibility pretests confirmed the differences in expectancy, but were unaffected by the linearization. In addition to main effects of expectation and distance, the lossy surprisal account crucially predicts an interaction: If the increased distance of the B&D conditions results in a lossy memory representation of the predictive context – namely the main verb (*schärfte/aß*) – surprisal effects are predicted to be attenuated compared to the short distance conditions (A&C). That is, we predict an interaction of expectancy and distance, such that stronger surprisal effects occur in the short distance conditions, and weaker effects in the long distance conditions. In a preliminary analysis of the reading times (N=68), we find precisely the predicted interaction in both the spill-over (*und*) and post-spillover regions (*hackte*), as well as the predicted main effect of expectancy in the post-spillover region (Table 2 and Table 3). We interpret these results as providing both clear support for the predictions of the lossy surprisal account, and broader evidence that linearization decisions influence the online processing effort of alternative encodings beyond offline predictors such as cloze and plausibility.

Conditions	
A Expected Short	Bevor der Holzfäller in den Wald ging und das Holz stapelte, <u>schärfte</u> er die **Axt** und hackte… *(Before the lumberjack in the forest went and the wood stacked, sharpened he the axe and chopped…)*
B Expected Long	Der Holzfäller <u>schärfte</u>, bevor er in den Wald ging und das Holz stapelte, die **Axt** und hackte… *(The lumberjack sharpened, before he in the forest went and the wood stacked, the axe and chopped…)*
C Unexpected Short	Bevor der Holzfäller in den Wald ging und das Holz stapelte, <u>aß</u> er die **Axt** und hackte… *(Before the lumberjack in the forest went and the wood stacked, ate he the axe and chopped…)*
D Unexpected Long	Der Holzfäller <u>aß</u>, bevor er in den Wald ging und das Holz stapelte, die **Axt** und hackte… *(The lumberjack ate, before he in the forest went and the wood stacked, the axe and chopped…)*

Table1. Example of Stimuli.

Fixed effects	Spillover			Post-Spillover		
	$\hat{\beta}$	*SE*	*p*	$\hat{\beta}$	*SE*	*p*
(Intercept)	5.6982	0.0253	0.0000	5.6629	0.0243	0.0000
Expectancy	-0.0021	0.0016	0.2057	**-0.0049**	**0.0017**	**0.0055**
Distance	-0.0003	0.0005	0.5834	0.0005	0.0005	0.3787
Expectancy:Distance	**0.0003**	**0.0001**	**0.0010**	**0.0003**	**0.0001**	**0.0040**

Table2. Summary of the linear mixed effects model of reading times.

Reading time (ms)	Spillover		Post-spillover	
	Short	Long	Short	Long
Expected	*M:* 303.14, *SE:* 1.81	*M:* 302.57 *SE:* 1.81	*M:* 288.59, *SE:* 1.75	*M:* 291.82, *SE:* 1.75
Unexpected	*M:* 308.59, *SE:* 1.93	*M:* 301.22, *SE:* 1.81	*M:* 296.79, *SE:* 1.84	*M:* 294.75, *SE:* 1.82

Table3. Descriptive statistics of reading times.

Selected References

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