Does reading unexpected words lead to engagement of cognitive control?

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When a sentence ends unexpectedly, readers must make adjustments to successfully integrate the unexpected word in the previous sentence context. A previous self-paced reading ERP study by Payne and Federmeier [1] suggested that readers have two mechanisms available to cope with expectancy violations. For highly constraining sentences ending unexpectedly, they found a late anterior positivity (LPC) previously argued to reflect suppression of the anticipated word and/or the revision of the sentence message [2]. Importantly, they found the LPC only for fast final-word reading trials. For slow trials, they instead found an anterior N2, previously linked to domain-general cognitive control [3]. The authors argued that the N2 acts to inhibit the prepotent motor response to move forward, giving readers time to resolve the conflict between the expected and presented word. This suggests that reading relies on cognitive control and that slow trials are actually trials of successful employment of control. In situations where readers are too late to exert cognitive control and move on quickly, they instead have to rely on a late semantic revision process as reflected by the LPC.

To test the hypothesis that reading unexpected words may rely on cognitive control, we used a cross-task paradigm interleaving self-paced reading trials with cognitive control trials, a paradigm used successfully to show ambiguity resolution engages cognitive control [4]. We presented, word-by-word, 136 highly constraining sentences from [5], half ending expectedly and the other half unexpectedly. Each sentence was followed by a Flanker trial. Adler et al. [6] showed that Flanker performance was modulated by prior reading of a cognitively demanding code-switch sentence: subjects were faster on incongruent Flanker trials that followed a code-switch compared to a non-switch sentence, but no prior sentence effect was found for congruent trials. This reflects conflict adaptation: cognitive control engagement facilitates subsequent conflict resolution [the Gratton effect, 7]. If reading an unexpected word engages cognitive control, we should see better performance on a subsequent incongruent Flanker trial.

The reading-Flanker task was performed online. To ensure participants read the sentences, a block of 34 trials was followed by 6 old/new memory questions. Only individuals with memory performance above 70% were included (48 out of 61). We used a linear mixed effects model for Flanker RTs and mixed effects logistic regression for Flanker accuracy, as [6]. Both models included prior sentence ending, current Flanker trial, and their interaction as fixed effects and subject as a random intercept. For a second analysis, we sorted Flanker responses into four separate bins based on final-word reading times, separately for each participant and condition [1]. We tested if including the three-way interaction Expectancy x Congruency x Bin improved model fit to investigate if reading speed influences control adjustments.

Results indicated a typical Flanker effect both in RTs and accuracy (Table 1): responses were faster and more accurate overall on congruent trials than incongruent trials. Did the prior sentence ending modulate this pattern? We found no such evidence as there was no significant interaction for RT nor accuracy (Table 2). Performance on incongruent trials was not enhanced after unexpected endings compared to expected endings. Instead, neither congruent nor incongruent trials were influenced by the previous final word. Including the three-way interaction with bin did not improve model fit (RT; $\chi^2(3) = 4.46$, $p = .22$; ACC: $\chi^2(3) = 2.24$, $p = .52$). Thus, there was no evidence that slow trials in particular exhibited enhanced cognitive control (Fig. 1).

To conclude, we found no evidence for cognitive control adjustments when readers encountered an unexpected word. Employment of control, previously evidenced by an N2 for slow reading trials [1], did not appear to sustain long enough to impact a subsequent Flanker trial. Whereas ambiguity resolution or code-switching [4,6] may require continued control spanning several words, reading an unexpected word may instead engage control only briefly to slow down reading for the current word, with control lifted instantly to resume normal reading.

Table 1. Response time and accuracy performance on Flanker trials*, dependent on the previous sentence ending type (as determined by cloze probability ratings).

Previous Sentence Ending	Current Flanker Trial Type	Flanker RT** (ms)	Flanker Accuracy (%)
Expected	Congruent	514 (*SD* = 166)	98.6 (*SD* = 11.7)
Unexpected	Congruent	510 (*SD* = 172)	98.7 (*SD* = 11.1)
Expected	Incongruent	689 (*SD* = 220)	91.9 (*SD* = 27.3)
Unexpected	Incongruent	694 (*SD* = 237)	93.0 (*SD* = 25.4)

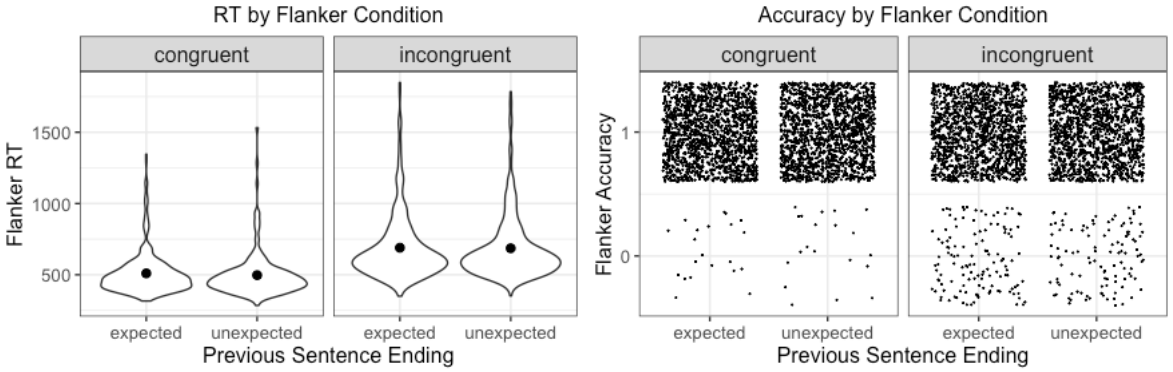
* Excludes trials with final-word reading times at 99.7th percentile within person and within condition (1.5%) [1], and with Flanker RTs beyond 2.5SDs from the overall mean (1.4%) [5].
** Excludes incorrect trials (4.2%).

Table 2. Results of mixed model analyses for Flanker RT and Flanker accuracy.

	Fixed effects*	Estimate	Std. Error	*T/Z* value	*P* value**
RT***	Intercept	6.350	0.028	224.33	<.0001
	Expectancy	0.005	0.005	1.05	0.29
	Congruency	-0.293	0.005	-58.14	<.0001
	Exp * Con	0.013	0.010	1.31	0.19
Accuracy	Intercept	4.75	0.289	16.44	<.0001
	Expectancy	-0.178	0.181	-0.98	0.33
	Congruency	2.328	0.193	12.05	<.0001
	Exp * Con	0.135	0.361	0.37	0.71

* Sum-to-zero contrast coding.
** Computed using Satterthwaite's approximation for denominator degrees of freedom.
*** RTs were log-transformed to correct for non-normal distribution.

Figure 1. Flanker RTs and Flanker Accuracy for slow reading trials (bin 4) only, separated by congruency type. Previous sentence type* did not appear to influence either Flanker trial type.



*There was no main effect of sentence ending (i.e., similar RTs for expected and unexpected words). This however does not entail that unexpected words do not require control: [6] found no main effect for code-switching, yet did find an influence on subsequent incongruent Flankers.

References

[1] Payne & Federmeier, 2017, J Cogn Neurosci, 29:5; [2] Van Petten & Luka, 2012, Int J Psychophysiol, 83:2; [3] Folstein & Van Petten, 2008, Psychophysiolog, 45:1; [4] Kan et al., 2013, Cognition, 129:3, [5] Federmeier et al., 2007, Brain Res, 1146; [6] Adler et al., 2020; J Exp Psychol Learn Mem Cogn, 46:4; [7] Gratton et al., J Exp Psychol; 121:4.