Cognitive Control and Ambiguity Resolution: Beyond Conflict Resolution

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Cognitive control is a multi-layered function involved in highly demanding, goal-oriented behaviours, including the processing of garden path sentences. In the ambiguous version of (1), cognitive control is argued to facilitate the switch from the preferred main clause interpretation of **'fed the hot dogs'** to the less preferred relative clause interpretation at the disambiguating '*got a stomach ache'*.

(1) The sunburned boys (that were) **fed the hot dogs** *got a stomach* ache.

Causal evidence for this has been provided with the visual world paradigm [1]. Participants completed a Stroop task (congruent/incongruent) before hearing a sentence like (2) (ambiguous/unambiguous) that they acted out with objects in the visual display.

(2) Put the frog (that is) on the napkin into the box.

In the ambiguous condition, there were fewer incorrect goal actions and less looks to the incorrect goal when the sentence was preceded by an incongruent Stroop condition (compared to congruent). For unambiguous sentences, there was no effect of the preceding Stroop condition. Hsu and Novick [1] argue that the incongruent Stroop condition activates a conflict resolution mechanism that is sustained and facilitates syntactic reanalysis.

To generalise this finding to syntactic processing that is independent of a visual context we used a similar interleaved Stroop-Sentence design, but with self-paced reading and sentences like (1). Fine and Jaeger [2] found an ambiguity effect (ambiguous > unambiguous) in self-paced reading times at both ambiguous **'fed the hot dogs'** and disambiguating *'got a stomach'* regions. Based on [1], we predicted the incongruent Stroop condition would reduce the ambiguity effect at the disambiguating region, but not the ambiguous region, where all information is compatible (i.e., not conflicting) with the preferred interpretation of the verb.

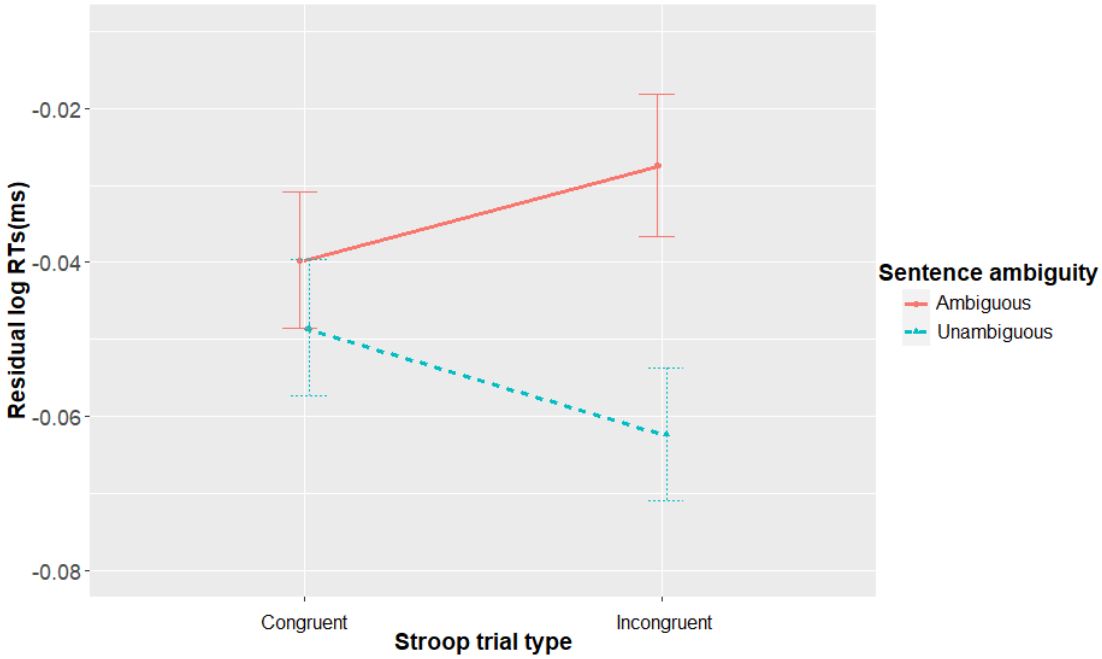
Method & Results: Stroop (congruent, incongruent) and Ambiguity (ambiguous, unambiguous) were crossed in 36 items (N= 96 native English speakers recruited via prolific.co). A Stroop task was followed by self-paced sentence reading and a yes/no comprehension question (see Figure 2). These were presented with filler items (54 sentence-Stroop and 18 Stroop-sentence) in a pseudorandomised order. Data was analysed using linear mixed effects models.

We replicated the ambiguity effect at ambiguous and disambiguating regions [2] (see Table 1). Contrary to expectation, we did not observe a Stroop x Ambiguity interaction at the disambiguating region (p=.64). Potentially the lag between Stroop completion and disambiguation was too long for sustained cognitive control [3]. Critically, however, we observed an interaction at the ambiguous region (t=-2.15, p<.05; see Figure 1, Table 1), where the standard ambiguity effect was present when the preceding Stroop was incongruent (t=4.29, p<.001), but eliminated when congruent (p=.275).

Conclusions:

This is the first study to demonstrate that congruent, or low conflict, trials can eliminate the ambiguity effect standardly observed at the ambiguous region. Contrary to previous findings [1], Stroop did not affect processing of directly conflicting parses at disambiguation, but the consideration of potential parses at the ambiguous region. While a conflict resolution mechanism seems necessary, it is insufficient to explain this transfer effect at ambiguous region. Like work outside language processing, that has also found processing adaptation from a congruent Stroop condition [4], we suggest attentional mechanisms to underlie our transfer effect. This gives rise to interesting new avenues to explore the interaction between attentional mechanisms and sentence processing in future work.

Figure 1. *Residual log reading times at ambiguous region.*



Note: The figure illustrates mean residual log reading times with 95% confidence intervals.

Figure 2. *Trial dynamics.*

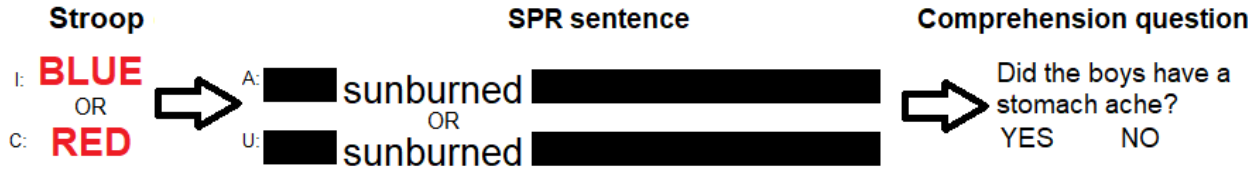


Table 1. *Results of fixed effects at the three regions of analysis.*

	Ambiguous region RT		Ambiguous verb only RT		Disambiguating region RT	
Fixed effects	*β*	*t*	*β*	*t*	*β*	*t*
Ambiguity	**0.014**	**2.95**	**0.034**	**6.69**	**0.018**	**4.21**
Stroop	0.001	0.31	-0.003	-0.75	-0.002	0.62
Stroop x Ambiguity	**-0.006**	**-2.15**	**-0.012**	**-2.69**	-0.001	-0.47

Note: significant effects (p<.05) are marked in **bold**.

References

[1] Hsu, N. S., & Novick, J. M. (2016). *Psychological science*, *27*(4), 572-582.

[2] Fine, A. B., & Jaeger, T. F. (2016). *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *42*(9), 1362.

[3] Egner, T., Ely, S., & Grinband, J. (2010). *Frontiers in psychology, 1,* 154.

[4] Lamers, M. J., & Roelofs, A. (2011). *Quarterly Journal of Experimental Psychology, 64*(6), 1056-1081.