Getting to the Truth is More Cognitively Demanding – Another Look at the Role of Working Memory in Negation Processing

For negative sentences, the results of visual probe recognition task [1] show that participants may take longer to respond to images that match the true states of affairs (soas) than mismatch images, which depict the positive argument of negation. [2-4] argues that attention to the positive soa soon after reading a negative sentence is the outcome of normal parallel language processes which compute both the content and the relevance of the utterance (QUD) given the same linguistic source and discourse information. [2-4] maintain that sentential negation alone can trigger a strong cue to a type of context where the positive soa is entertained as a live possibility. Therefore, preference for an image consistent with the positive soa after reading simple negative sentences suggest inferences about context may be stimulated first. Our idea is simply that, participants' expectations about visual probes are influenced by inferences based on the interpretation of the linguistic stimulus in context. In 'the banana is not peeled', parsing the subject and predicate ('peeled') directly promotes inferences about the denied state of the banana, while inferences about the asserted state would draw on associated world knowledge not directly encapsulated in linguistic expressions. In this new work, we consider the effect of working memory on negation processing. Given the idea that inferring the actual scenario of negative sentences is more resource intensive, especially in comparison to the affirmative sentences, we contend that for simple negative sentences in [1], individuals with more working memory (WM) resources are more likely to integrate background inferences about the positive context and activate the true soa at an earlier stage. We present the results of two fully-normed, probe task experiments based on [1-2], where the participants' WM capacity is manipulated in a dual-task (Exp.1) and measured in a WSPAN task (Exp.2). The results bring convergent evidence that inferring aspects of the content for simple negative sentences requires more cognitive resources than computing the expected context.

The Norming Task: Participants (N=46) completed an object-name probe task which used the same nouns (N=28) and images as in Experiment 1 and 2. Their task was to decide if the object had been mentioned in the preceding screen. Filler nouns (N=28) counterbalanced for response.

Results: A LME model predicting the Log (RT) from match showed no significant ME of match (p=.284).

Experiment 1: Participants (N=40) in the no-memory load group only did the probe recognition task, which asked to first read a sentence and then to decide whether the item in the image had been mentioned in the sentence. The other group (N=41) additionally completed a memory load task, which consisted of remembering a simple grid pattern at the beginning of each trial and recreating it after the probe task response. The probe task has a 2 (polarity) * 2 (match) within-group design. See Table 1.

Results: A LME model was constructed to predict the Log(RT) from polarity, match and WM load. Results showed highly significant MEs of polarity and match (ps<.001), interactions between WM load and match (p=.007), and between polarity and match (p=.005). Crucially, the three-way interaction was significant (p=.05). We further broke down the interaction by the load group which revealed that no-load group showed only main effects of match and polarity (ps<.001), whereas the memory-load group showed an interaction between polarity and match (*p*=.001). See Figure 1 (left).

Experiment 2: Participants (N=72) undertook two tasks in the following order: (a) Word span task (WSPAN) ([5-6]); (b) probe recognition task. The design of (b) is the same as the probe task of Exp. 1.

Results: Analysis of just the probe task showed significant main effects of polarity (*p*=.03), match (*p*=.01) and an interaction between polarity and match (*p*=.002). Then we constructed a LME model predicting Log(RT) from polarity, match and WSPAN score. There was a significant interaction between polarity and match (p=.001), and an interaction between match and WM score (*p*=.04). Additionally, there was a marginal three-way interaction (*p*=.08). To follow up, we separately looked into the data of High (top 25%) and Low (bottom 25%) WSPAN score participants. The post hoc analyses revealed that High WM group showed a main effect of match (*p*<.001) and also an interaction between polarity and match (*p*=.03) whereas the Low WM group showed no main effect of match only a significant interaction between polarity and match (*p*=.02). See Figure 1 (right).

Discussion: The results of norming task show that given only the nouns there was no preference for one state over the other. In low load/negative trials of Exp.1, the response delay for negative compared to positive soa indicates that WM load has a greater impact on processes that arrive at the expectations for the actual content. For Exp.2, regardless of polarity, HWM individuals' responses were most influenced by inferences about the true soas while LWM individuals do not consistently show this. Two experiments jointly attest the costs involving in getting to the truth of simple negative sentences.

Polarity	Match	Example Sentence	Display
Affirmative	Match	The banana is peeled.	
	Mismatch	The banana is peeled.	
Negative	Match	The banana isn't peeled.	
	Mismatch	The banana isn't peeled.	

Table 1. Example items for the probe task. 2 (Polarity) * 2 (Match) design.

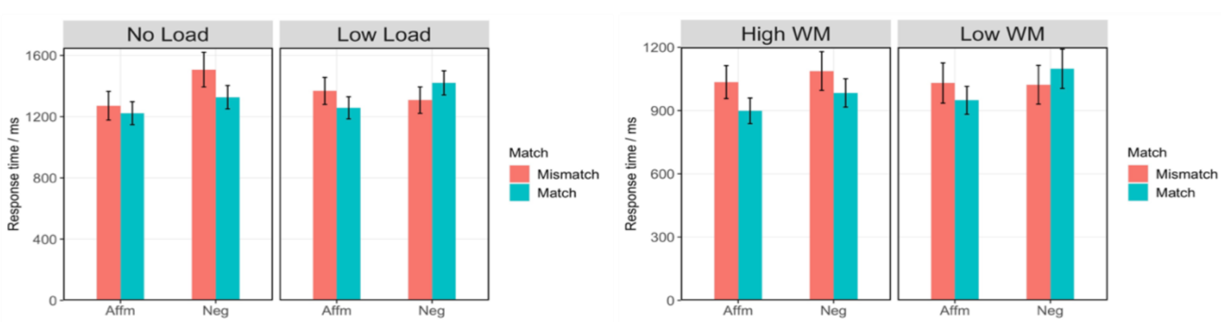

Figure 1. Exp. 1 (Left). Mean RT for each condition of No/Low Load groups. Error bars represent 95% confidence intervals.
Exp. 2 (Right). Mean RT for each condition of High and Low WM groups. Error bars represent 95% confidence intervals.

References: [1] Kaup, Yaxley, Madden, Zwaan, & Lüdtke (2007). QJEP, 60, 976-990. [2] Tian, Breheny, & Ferguson. (2010). QJEP, 63(12), 2305-2312. [3] Tian, Ferguson, & Breheny, (2016). LCN. 31, 683-698. [4] Wang, Sun, Tian, & Breheny. (2021). J.of Psycholinguistic Research. 50, 1511-1534. [5] Engle, Tuholski, Laughlin, & Conway (1999). J. of Experimental Psychology: General. 128(3), 309-331. [6] La Pointe, & Engle (1990). J. of Experimental Psychology: Learning, Memory, and Cognition. 16, 1118-1133.