

Understanding center embedding sentences: Can agreement and resumption help?

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Introduction. Center Embedding (CE) sentences, which consist of two nested object-relative filler-gap dependencies (e.g. 'The reporter who the senator who the professor met attacked resigned') are notoriously difficult to process (Chomsky & Miller, 1963; Baltin & Collins, 2008). Two main explanations have been offered for this difficulty. Gibson (1998) argues for prohibitively high integration costs at the second verb, exceeding the working memory capacity of most comprehenders. Lewis, Vasishth, & Van Dyke (2006) claim that the difficulty arises at retrieval: in the absence of sufficient cues, retrieval of the filler at the verb site fails due to the similarity between the different NPs, leading to interference.

The present study focuses on Hebrew CE sentences and examines whether their comprehension can benefit from the presence of (i) agreement features differentially marking the different NPs and identifying every verb's subject, and (ii) Resumptive pronouns (RPs, grammatical in Hebrew), which can aid retrieval by allowing more processing time and/or exhibiting the filler's agreement features, thus unambiguously identifying the verb's object.

Experiment 1 (160 participants; 8 sets + 24 grammatical filler sentences) used a comprehensibility rating task. It included four conditions crossing the factors DISTINCT AGREEMENT (agreement features on the three subject NPs and verbs are all identical vs. all different) and RESUMPTION (embedded verbs are followed by an RP or not). See Table 1 for sample materials. Sentences were presented in full. Participants read the sentences at their own pace and rated their comprehensibility on a 1-7 scale.

Results revealed that neither DISTINCT AGREEMENT nor RESUMPTION significantly affected comprehensibility. The interaction between the factors was significant ($p = .03$), signaling an advantage of distinct agreement only in the absence of resumption (Figure 1).

Experiment 2 (192 participants; 8 sets + 24 grammatical filler sentences) used end-of-sentence comprehension questions. Experimental sentences were of the same four conditions as in Experiment 1. The comprehension questions manipulated VERB POSITION, targeting either the first or second verbs' objects (see Table 1). Sentences were presented word by word at a rate of 400ms per word + 200ms inter-stimulus interval.

Results showed that DISTINCT AGREEMENT significantly improved comprehension ($p = .004$), while RESUMPTION did not. The interaction between the two factors was non-significant, i.e. in contrast to Experiment 1, here RPs did not reliably cancel out the advantage of distinct agreement. The results also revealed an effect of VERB POSITION ($p = .001$), such that the resolution of the dependency at the first, most embedded verb presented the most difficulty. The interaction between VERB POSITION and DISTINCT AGREEMENT was significant ($p = .001$), showing that while resolution of the dependency at the most embedded verb was not aided by distinct agreement, distinct agreement did aid the comprehension of the second verb (Figure 2).

Discussion. The results of Experiment 2 suggest that CE sentences are comprehensible to some extent, especially given aid by distinct agreement. It could be that by aiding to identify each verb's subject, distinct agreement also indirectly helps to identify the verbs' correct objects (targeted by the comprehension questions in Experiment 2). In contrast, resumption, though potentially identifying each verb's object unambiguously, did not help comprehension. These results suggest either that RPs are not used by comprehenders for retrieval, or that interference had arisen already during the encoding of the three similar NPs (Gordon, Hendrick, & Johnson, 2004; Villata, Tabor, & Franck, 2018), rendering the fillers not sufficiently distinct for successful retrieval at the verb.

Not only was resumption unhelpful, but it cancelled out the advantage offered by distinct agreement in Experiment 1. This finding can be explained similarly to the 'missing V2' illusion, the observation that center embedding is better accepted when only two of the verbs appear (Frazier, 1985; Gibson & Thomas, 1999). Gibson & Thomas suggest that in such cases one of the dependencies is compromised, thus concealing the processing difficulty. Adopting this idea, it can be assumed that resumption blocks the option to neglect one of the dependencies, leading to decreased ratings.

Different agreement features	<i>The child.SG-M that the neighbors.PL-M that the guest.SG-F frightened.SG-F {Ø/them} liked.PL-M {Ø/him} fell.SG-M</i>
Same agreement features	<i>The child.SG-M that the neighbor.SG-M that the guest.SG-M frightened.SG-M {Ø/him} liked.SG-M {Ø/him} fell.SG-M</i>
Comprehension questions:	
First verb's object:	
Who did the guest(SG-F/SG-M) frighten?	The child / The neighbor (PL-M/SG-M)
Second verb's object:	
Who did the neighbor(PL-M/SG-M) like?	The child / The guest (SG-F/SG-M)

Table 1. Sample sentences (Experiments 1 and 2) and comprehension questions and answer options (correct in bold) (Experiment 2), translated from Hebrew

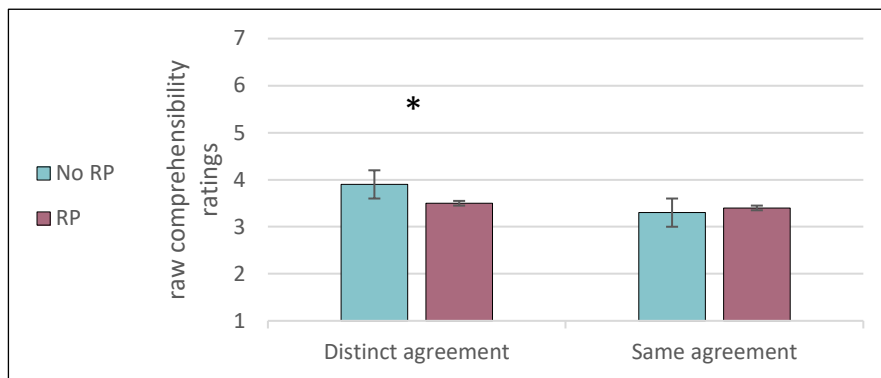


Figure 1. Results of Experiment 1. Error bars mark +/- 1 SE; * represents $p < .05$; Analysis was conducted with a linear mixed-model regression.

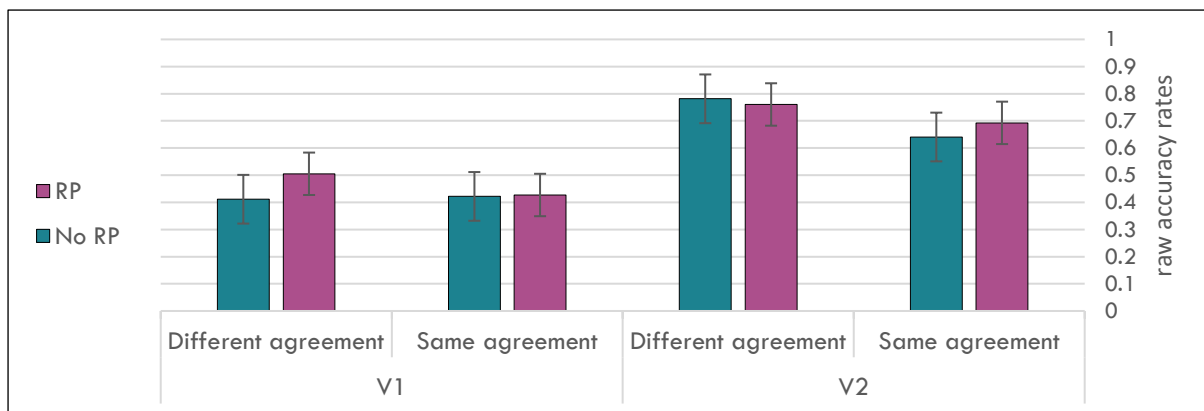


Figure 2. Results of Experiment 2. Error bars mark +/- 1 SE; Chance level is 50%; Analysis was conducted with a linear mixed-model regression.

References

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