Processing ambiguities in NP attachment: Evidence from Hebrew

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Background. Examining one of the central issues in sentence processing, i.e. parsing choices for structurally ambiguous input, some theories argued that these are made primarily based on locality considerations [1-3], while others have highlighted the role of lexical biases [4-6]. An alternative theory, which has received very little empirical attention, is presented in Pritchett (1992) [7]. Pritchett's theory can be viewed as a hybrid between modular theories and fully interactive ones. Unlike structural theories, it argues that processing is driven by thematic requirements: specifically, at every point during comprehension, the parser attempts to satisfy the Theta Criterion, given the maximal thematic grid of the available verbs. Unlike fully interactive approaches, however, Pritchett proposes that thematic biases do not guide processing: a weakly transitive verb should attempt to discharge its thematic role just as actively as a strongly transitive verb. We report two rapid serial visual presentation with forced-choice completion experiments in Hebrew, testing Pritchett's predictions.

Experiment 1 (58 participants, 24 sets). Optionally transitive (OT) verbs varying in their transitivity bias were incorporated into sentences of two types: Adjunct sentences; and Subject relative (SR) sentences, where the verb was preceded by an obligatorily ditransitive verb. Two possible completions were provided, one indicating local attachment, and the other – nonlocal attachment. Similar sentences with intransitive (IN) verbs, where only one completion option was grammatical, served as baseline (see Table 1). In the OT conditions, theories which highlight locality predict that completions indicating local attachment will be preferred, and interactive theories predict that completion preferences will be correlated with the verb's transitivity bias, in both Adjunct and SR conditions. According to Pritchett, performance will differ between Adjunct and SR conditions. In the Adjunct condition, the need to satisfy the theta criterion given the maximal grid of the verb will invariably lead to local attachment of the ambiguous NP, and transitivity bias will not play a role. In contrast, in the SR condition, the local and high attachment options both satisfy the theta criterion to the same degree. Frequency biases can thus play a role in the decision. **Results.** Rates of completions are presented in Figure 1. We found a main effect for condition, with significant differences between OT and IN verbs in each sentence type, as well between OT,SR and OT,Adjunct, with increased choice of local attachment preferences in the latter (all p's < .001). The effect of transitivity bias is presented in Figure 2. A GLM model showed that transitivity bias was positively correlated with the choice of local attachment in the SR ($p=.001$), but not in the Adjunct condition ($p=.279$).

Experiment 2 (48 participants, 24 sets). We added an SR condition with an obligatorily transitive verb (Table 1) and examined only the 3 SR conditions. Completion rates are presented in Figure 3. We observed a main effect for verb type, with significant differences between all three conditions (all p's < .001). Transitivity bias was positively correlated with choice of local attachment ($p=.022$).

Discussion. The study provides evidence for the precedence of the Theta Criterion during parsing. When there is only one theta assigner for an ambiguous NP, the NP will invariably attach to that verb, regardless of its transitivity bias (see also [8]). However, when the sentence fragment includes two verbs, and the Theta Criterion can be satisfied in two different ways, other factors – i.e., transitivity bias and proximity – can affect processing choices. In the transitive SR conditions, transitivity bias was correlated with rates of selecting a local attachment. While this confirms the role of probabilistic information in sentence processing, the absence of a similar effect in the Adjunct conditions suggests that this information does not always guide processing. The results from the Obligatory Transitive condition further show that only when the Theta Criterion can be equally satisfied in two different ways, proximity affects attachment decisions.

Table 1. Example set, translated from Hebrew

Condition	Sentence	Completion options (all two-word strings in Hebrew)
Adjunct, Intransitive	After the guests departed cold water	**Local attachment:** the catering arrived **Subject attachment:** was returned to the refrigerator
Adjunct, Transitive	After the guests drank cold water	**Object attachment:** the catering arrived **Subject attachment:** was returned to the refrigerator
Subject relative, Intransitive	The owner brought to the guests that showered with cold water	**Local attachment:** orange juice **High attachment:** last night at the farm
Subject relative, Transitive	The owner brought to the guests that drank cold water	**Local attachment:** orange juice **High attachment:** last night at the farm
Subject relative, Obligatorily Transitive (**Experiment 2 only**)	The owner brought to the guests that received cold water	**Local attachment:** orange juice **High attachment:** last night at the farm

Note: The pre-tests ensured the plausibility of the completion options in Adjunct condition and the plausibility and equality of the ambiguous NP 'water' attachment to the main and embedded verbs in the Transitive and Obligatorily Transitive SR

Figure1.

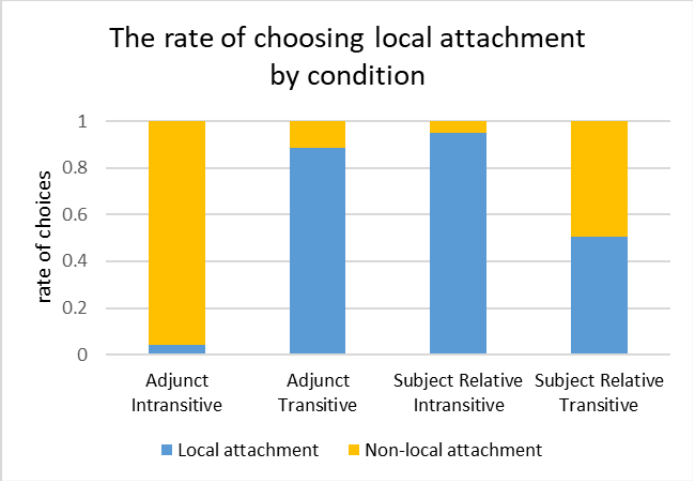
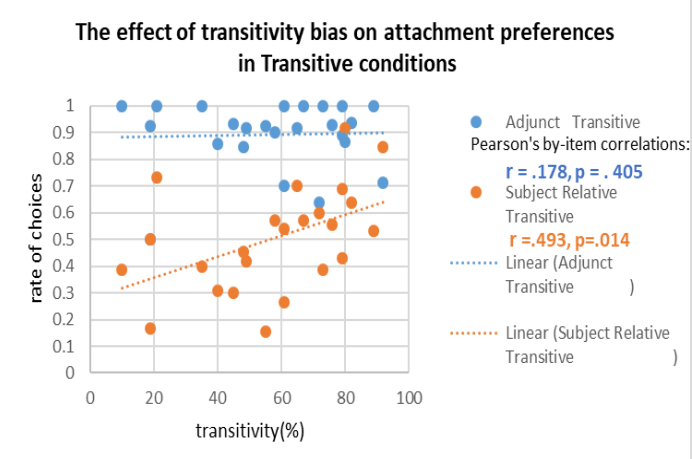
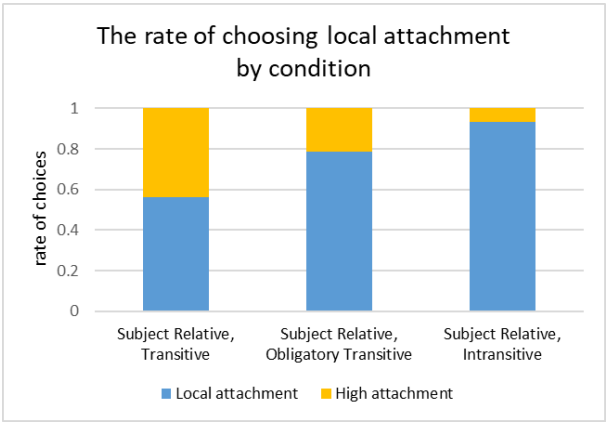


Figure 3.



Note. The coding is: local attachment=1, non-local attachment=0. The figure illustrates the correlation between verb's transitivity and the average by item completion choices in two sentence types, Adjunct and Subject Relative.

Figure 2



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[1] Gibson, E. (2000). The dependency locality theory: A distance-based theory of linguistic complexity. *Image, Language, Brain:* 95-126. MIT Press. [**2**] Frazier, L. (1987). Sentence Processing: A Tutorial Review. In M. Coltheart (Ed.), *Attention and Performance XII: The Psychology of Reading* (559-586). Hillsdale New Jersey: Lawrence Erlbaum Associates. [**3**] Vasishth, S., Nicenboim, B., Engelmann F., Burchert F. (2019). Computational Models of Retrieval Processes in Sentence Processing. *Trends in Cognitive Sciences,23*, 968-982. [**4**] Garnsey, S. M., Pearlmutter, N. J., Myers, E., & Lotocky, M. A. (1997). The contributions of verb bias and plausibility to the comprehension of temporarily ambiguous sentences. *Journal of Memory and Language*, 37, 58-93. **[5]** MacDonald, M.C. (1994). Probabilistic constraints and syntactic ambiguity resolution. *Language and Cognitive Processes*, 9, 157–201. **[6]** Trueswell, J. C., Tanenhaus, M. K., & Kello, C. (1993). Verb-specific constraints in sentence processing: Separating effects of lexical preference from Garden Paths. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 528-553. **[7]** Pritchett, B. L. (1992). Grammatical Competence and Parsing Performance. *University of Chicago Press*. **[8]** Staub, A. (2007). The parser doesn't ignore intransitivity, after all! *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33(3):* 550–569.