Expectation Adaptation to High-Level Word Order Preferences

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Psycholinguistic research suggests that humans have implicit probabilistic knowledge of their language which guides expectations during online processing. Recent work takes this further, suggesting that such probabilistic knowledge is not only stored but is also flexibly adaptable based on recent experience [1]. However, these questions have largely been explored for knowledge of marginal frequencies of syntactic structures. But there are more fine-grained statistics as well; for example, there exist probabilistic constraints on word order involving relations between semantic or discourse features of the constituents. It is unclear whether comprehenders track these more fine-grained statistics, or whether they make simplifying independence assumptions between probabilistic constraints on word order and syntactic structure. In this study, we ask (1) whether comprehenders track fine-grained statistics that require knowledge of contingencies between arguments, and (2) whether even such fine-grained knowledge is malleable to recent experience. We use the definiteness ordering preference in the ditransitive alternation ([2]; see Table 1 for examples). We first conduct a corpus study to make predictions about relative processing difficulty of definiteness orders in the ditransitive alternation. We then conduct a self-paced reading experiment to assess whether there is indeed a processing difference, and whether these expectations are malleable given recent experience. **Corpus Study.** We use the corpus from [2] to assess the relative processing difficulty of ditransitive argument orders based on the definitness of the arguments. We estimate the surprisal of each order in the double object (DO) and prepositional object (PO) structures. Higher values of surprisal correlate with longer reading times and more processing difficulty [3]. We find that within the DO structure, the definite-indefinite order has lower surprisal than the indefinite-definite order at the point of structural disambiguation, i.e., the second argument ($\hat{\beta} = -1.7, p < 0.01$), while in POs there is a smaller preference in the opposite direction ($\hat{\beta} = 1.1, p < 0.01$) (Fig 1). Thus, we predict processing differences in spillover regions after the second argument. We conducted a self-paced reading experiment manipulating structure and order within-subjects which confirmed these predictions. Since previous studies have found that structures with higher surprisal show larger adaptation effects [4], we decided to use only DOs in the adaptation experiment. **Experiment.** Subjects (N=178) read 90 sentences (54 fillers) in a self-paced reading experiment. In the first phase of the experiment, *exposure*, one group of participants read 24 sentences in the definite-indefinite order; the other group read the same sentences in the indefinite-definite order. Afterwards, in the *test* phase, they read 12 sentences, half in each definiteness order (see Table 2). In the exposure phase, as predicted, subjects read the definite-indefinite order faster than the indefinite-definite order at several regions: the determiner of Argument 1, the noun of Argument 2, and the first two spillover regions (ps < 0.05; Fig 2a). In the test phase, we found that this reading time advantage for the definite-indefinite order was reduced in subjects who were exposed to the indefinite-definite order as compared to the definite-indefinite exposure group. This was significant at the second spillover region ($p < 0.01$), and marginal at the determiners of Argument 1 and Argument 2 ($p < 0.1$; Fig 2b). **Conclusions.** Our results suggest that comprehension seems to draw on fine-grained expectations about the order of different types of arguments conditioned on syntactic structure. Furthermore, these expectations are affected based on recent experience, suggesting that even very fine-grained probabilistic knowledge is flexibly adaptable.

References [1] Fine, A. et al. (2013) PLOS One. [2] Bresnan, J. et al. (2007). [3] Levy, R. (2008) Cognition. [4] Jaeger, T. F. & Snider, N. (2013) Cognition.

Syntactic Structure	Definiteness Order	Example Sentence
Double Object	Definite-Indefinite	The woman wrote the author a letter ...
Double Object	Indefinite-Definite	The woman wrote an author the letter ...
Prepositional Object	Definite-Indefinite	The woman wrote the letter to an author ...
Prepositional Object	Indefinite-Definite	The woman wrote a letter to the author ...

Table 1: Examples of definiteness orderings in the ditransitive alternation.

Exposure Order	Test Order	Exposure Phase	Test Phase
Definite-Indefinite	Definite-Indefinite	... the ... a ... [x 24]	... the ... a ... [x 6]
	Indefinite-Definite		... a ... the ... [x 6]
Indefinite-Definite	Definite-Indefinite	... a ... the ... [x 24]	... the ... a ... [x 6]
	Indefinite-Definite		... a ... the ... [x 6]

Table 2: Structure of the experiment. All critical sentences are in the DO structure.

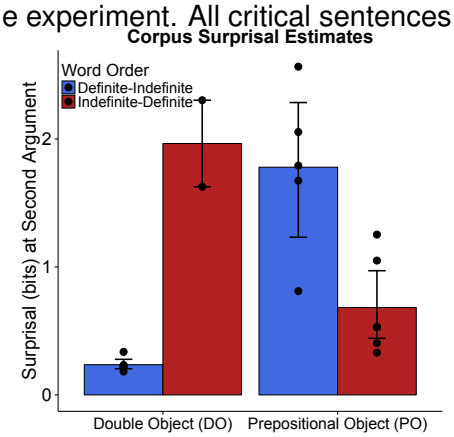
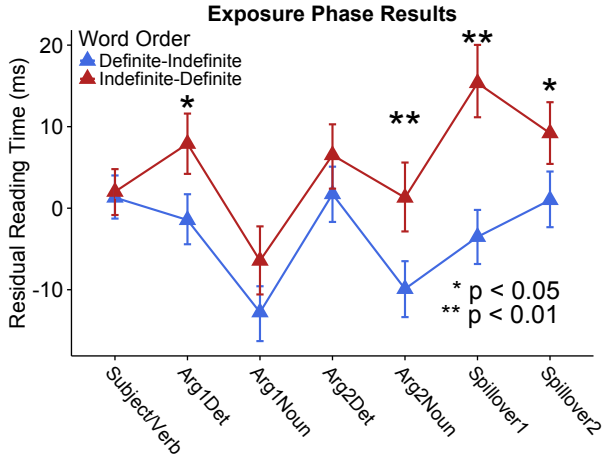
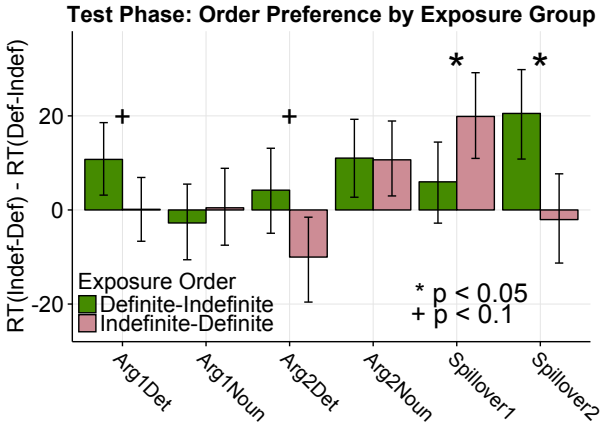


Figure 1: Corpus surprisal estimates for each word order and syntactic structure for the verbs used in our experiment at point of structural disambiguation (i.e., Argument 2). Error bars are 95% confidence intervals. Black dots represent individual verbs.



(a) Reading times during the exposure phase by by sentence region. Error bars are 95% confidence intervals.



(b) Effect of exposure on reading times by sentence region. Higher values on the Y axis indicate a reading time advantage for the definite-indefinite word order. Error bars are 95% confidence intervals.

Figure 2: Results of self-paced reading experiment.