



Syntax encodes information structure: Evidence from on-line reading comprehension

Meredith Brown^{a,*}, Virginia Savova^b, Edward Gibson^{b,c}

^a Department of Brain and Cognitive Sciences, University of Rochester, Rochester, NY 14627, USA

^b Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

^c Department of Linguistics and Philosophy, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

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ABSTRACT

Although sentences are thought to be generally easier to process when given information precedes new information, closer examination reveals that these preferences only manifest within some syntactic structures. Here, we examine the consequences of the relative ordering of given and new information (*information structure*) for the on-line comprehension of prepositional-object (PO) and double-object (DO) dative sentences. Experiment 1 demonstrated using self-paced reading that the on-line comprehension of DO structures, but not PO structures, is more difficult with new-before-given information structure. Experiment 2 assessed the comprehension of dative sentences with animate themes to evaluate two potential sources of this interaction: information-structural constraints encoded within syntactic representations (*argument structure hypothesis*) vs. word-to-word contingency statistics (*linear position hypothesis*). Despite experiment-wise differences in word-to-word contingency statistics, the interaction between syntactic structure and information structure persisted in Experiment 2. Taken together, these results suggest that syntactic representations can include information-structural constraints on their arguments.

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Introduction

Contextually given information tends to precede new information when syntactic optionality provides word order alternatives (e.g., Clark & Haviland, 1977; Givon, 1984; Halliday, 1967; Lambrecht, 1994; Prince, 1999). Although this given-before-new preference is widely documented, a closer examination reveals that it does not always apply uniformly across syntactic alternatives. An example of this interaction between word order and syntactic alternatives is provided by the English dative alternation, which allows two orders of its two post-verbal objects, the *theme* and the *goal*, as in (1):

- (1) a. Prepositional object (PO): The queen brought [a sword]_{theme} to [the knight]_{goal}.
 b. Double object (DO): The queen brought [the knight]_{goal} [a sword]_{theme}.

The dative alternation gives speakers a mechanism to control the relative order of the theme and goal, allowing the realization of word order preferences. Evidence from production indicates that given-before-new effects tend to manifest much more strongly in the DO structure than in the PO structure. In a large corpus of spoken English, for example, DO sentences are over eight times more likely than PO sentences to have given-before-new word order (Bresnan, Cueni, Nikitina, & Baayen, 2007; see also Collins, 1995). The goal of this paper is to examine the consequences of the relative ordering of given and new

* Corresponding author. Address: University of Rochester, Meliora Hall, Box 270268, Rochester, NY 14627-0268, USA. Fax: +1 585 442 9216.

E-mail address: mbrown@alum.mit.edu (M. Brown).

information (hereafter referred to as *information structure*¹) for the on-line comprehension of the dative alternation.

Previous work on the comprehension of the dative alternation suggests an interaction between syntactic structure and information structure that parallels the asymmetrical distribution of given-before-new preferences observed in production. Clifton and Frazier (2004) conducted a speeded whole-sentence reading study using pairs of sentences. These pairs included a context sentence that introduced either the goal or theme of a target DO or PO sentence, such that half of the target sentences had given-before-new information structure and half had new-before-given information structure. They found that the relative order of the contextually given and new constituents had no consistent effect on acceptability judgments or response times for PO sentences. In DO sentences, however, new-before-given information structure resulted in significantly lower acceptability judgments and slower responses.

Because given-before-new effects in comprehension do not consistently interact with syntactic alternations cross-linguistically (e.g., Birner & Ward, 1998; Fedorenko & Levy, 2007; Vallduví & Vilkkuna, 1998), it is reasonable to assume that the convergence of the comprehension effects found by Clifton and Frazier (2004) with production patterns results from learned associations between syntactic structures and information-structural variables. The structural associations that comprehenders learn, however, can potentially take multiple forms, ranging from structure-level associations between syntactic forms and information structures to local transitional probabilities. The sections that follow describe how each of these possibilities could give rise to the convergence between comprehension preferences and patterns in the production of the dative alternation.

The argument structure hypothesis

The argument structure hypothesis assumes that discourse-level information can be included in syntactic representations. In the case of the dative alternation, a strong tendency for given entities to precede new entities in DO structures may become incorporated into comprehenders' representation of the DO construction, constraining the discourse status of the arguments licensed within this construction. These representational constraints are hypothesized to cause comprehenders to disprefer DO structures with new-before-given information structure.

This hypothesis derives support from linguistic investigations of the syntax-discourse interface, which observe that linguistic structures are fundamentally shaped by their functions in language use. In particular, the less frequent or less basic of two alternating syntactic structures

seems to be more likely to serve specific discourse functions, particularly with respect to information status. Birner and Ward (1998, 2009) propose a set of cross-structural regularities in the distribution of given and new expressions in these so-called *non-canonical* English structures: "Whereas the basic, or 'canonical', word order can be used felicitously in a wide range of discourse contexts, the alternative, or 'noncanonical', word orders require a specific type of discourse context for their felicity, [...] while given/new ordering is preferred for canonical word order, it is not required" (Birner & Ward, 2009). The specific type of discourse context that they propose for argument-reversing syntactic alternations involves a relative givenness constraint, whereby the first of the two arguments in question must be at least as given as the second.

Evidence from a number of sources suggests that the PO structure is the more canonical form within the dative alternation. Although the DO structure has higher token frequency than the PO structure, its overall prevalence likely arises in part from the tendency for goals to be animate and for themes to be inanimate: In the Bresnan et al. (2007) corpus, 93% of goals are animate, compared to 2% of themes. Because animate entities generally come more readily to mind than inanimate entities, goals tend to be mentioned before themes, resulting in a relatively high prevalence of DO sentences. In contrast, the PO structure has higher type frequency than the DO structure: Whereas almost all dative verbs can be used with the PO structure, only a subset permit the felicitous use of the DO structure. This type frequency discrepancy is observed in most of the world's languages that exhibit a dative alternation (Van Valin, 2005). Further, in languages that lack the dative alternation, the PO construction is much more frequently observed than the DO construction (Haspelmath, 2008; Van Valin, 2005). Finally, the PO structure is more congruent with the basic English SVOX word order than the DO structure (Bresnan, personal communication), which may account in part for the increased constraints on the forms of DO structures relative to PO structures (e.g., restrictions on pronominal arguments and on nominalizations; Van Valin, 2005).

Assuming the DO structure to be non-canonical relative to the PO structure, the tendency for given expressions to precede new expressions more frequently in the production of DO structures is consistent with Birner and Ward's description of information-structural constraints in argument-reversing alternations. Likewise, their claim that the relation between information structure and syntax is best described at the level of structural relations is compatible with the argument structure hypothesis regarding the comprehension of the DO structure, which also assumes that structure-level generalizations are the basis of the interaction between information structure and syntactic structure in the comprehension of the dative alternation.

Discourse-level or lexical constraints other than relative givenness constraints could in principle become incorporated into syntactic representations as well. For example, one or both types of dative structures could be subject to an animacy constraint favoring animate goals and

¹ Information structure has been characterized in terms of distinctions between various constructs other than givenness, such as topic vs. comment (e.g., Gundel, 1974), background vs. focus (e.g., Halliday, 1967), and theme vs. rheme (e.g., Firbas, 1966). For the purposes of this paper, however, we will focus on the given-new dimension of information structure, without a theoretical commitment to this dimension as being more fundamental to information structure than other dimensions that have been proposed.

inanimate themes. Although this paper focuses primarily on information-structural constraints on DO structures, the possibility that dative structures also encode animacy constraints is considered as well.

The linear position hypothesis

An alternative explanation for the interaction between syntactic structure and information structure in the comprehension of the dative alternation is that comprehenders are sensitive to linear statistical patterns in the production of the dative alternation, rather than structure-level patterns. Numerous statistical learning studies have demonstrated that comprehenders are sensitive to the sequential structure of language (e.g., Newport & Aslin, 2000). Across language tasks, simple models of local context, such as n-gram models, capture a significant proportion of the variance in the estimates of more sophisticated language models with hierarchical organization. For example, lexical co-occurrence statistics have been demonstrated to provide sufficient information to establish thematic relations between nouns and verbs (Willits, Sussman, & Amato, 2008). Effects of surface statistical patterns in on-line language comprehension have also been demonstrated experimentally. For example, transitional probability statistics correlate inversely with fixation times during the reading of newspaper text (McDonald & Shillcock, 2003) and cause garden-path effects during the reading of sentences containing locally coherent word sequences that are inconsistent with the global syntactic structure of the sentence (e.g., “The coach smiled at the player tossed the frisbee”; Tabor, Galantucci, & Richardson, 2004). These demonstrations have contributed to an emerging view that language comprehension processes may rely primarily on low-level statistical cues and may be relatively insensitive to hierarchical phrase structure information. Simple recurrent network models, which capture local sequential statistics, better predict reading times in eye-tracking data than hierarchical phrase structure grammars (Frank, 2009; Frank & Bod, 2011). Even though phrase structure grammars more accurately model the structure of language, these findings suggest that local statistics may be more relevant to on-line language comprehension, lending credence to the idea that the processes involved in language comprehension may not in all cases reflect “what have been described as purely formal aspects of the language” (Marks, 1967), but instead may capitalize on other sources of information in the linguistic input.

These observations, taken together, suggest that apparent effects of higher-level structure in comprehension can emerge from linear statistical patterns, including comprehenders’ knowledge about the probability of a particular word or word class given the immediately preceding context. This idea can be extended to explain apparent effects of information structure in the dative alternation by considering differences in the distribution of DO and PO sentences in terms of the transitional probabilities of words with certain features, rather than in terms of structure-level associations. Several lexical and context-derived features of dative goals and themes, such as animacy, pronominality, and givenness, are known to contribute un-

iquely to the selection of DO and PO structures in production (Bresnan et al., 2007) and to correlate with explicit judgments of the naturalness of DO and PO sentences in context (Bresnan, 2007). It is possible that comprehenders are sensitive to sequential statistical patterns based on these features in PO and DO structures, and develop expectations about the probable features of upcoming referential expressions given the immediately preceding context during on-line sentence processing.

This account provides several potential explanations for the apparent interaction between syntactic structure and information structure in the dative alternation obtained by Clifton and Frazier (2004), because PO and DO structures with different information structures contain referential expressions that typically differ with respect to a number of lexical or context-derived features. One simple such explanation is based on the observation that indefinite expressions following a dative verb are over five times more likely to be inanimate than animate (Bresnan et al., 2007). It is therefore possible that comprehenders reading dative sentences are generally slower to process an animate noun following an indefinite article (e.g., *a knight*) because this situation is relatively infrequent and therefore unexpected. Further, the processing cost incurred by an animate expression following an indefinite article may depend on the *overall predictability* of the animate expression in the sentential context. In the PO structure, the animate goal occurs after a strong cue to its syntactic role – the preposition *to* or *for* – increasing the predictability of the goal noun. This increased predictability may mitigate the processing cost incurred by indefinite articles preceding animate goals in PO sentences. In contrast, in the DO structure, the animate goal occurs following only the verb, where it may be either the goal or the patient, so that it is less predictable, and hence potentially more costly.

These predictions are compatible with the results of Clifton and Frazier’s (2004) experiments, in which they found not only consistent and robust evidence of processing difficulty for DO sentences with indefinite goals, but also inconsistent evidence of a weaker dispreference for PO sentences with indefinite goals. It is possible, therefore, that their findings resulted from the violation of an expectation for indefinite articles to be followed by inanimate expressions that was attenuated by strong syntactic cues in PO sentences, rather than from a general information-structural constraint on the use of the DO structure.

The present study

Our goal is to determine whether the interaction between syntactic and information structures in comprehension arises from a general information-structural constraint on DO sentences or from the use of transitional statistical cues in on-line comprehension. Because both argument structure regularities and sequential statistical regularities describe the same phenomena using different types of statistics, effects of NP feature co-occurrence frequencies are likely to be consistent with structure-level generalizations in the comprehension of the majority of dative sentences. However, the argument

structure and linear position hypotheses do make distinct predictions for the comprehension of certain dative sentences. The argument structure hypothesis predicts that DO-specific information-structural constraints should hold regardless of other properties of DO sentences, such as the definiteness or animacy of the goal and theme. In contrast, the linear position hypothesis claims that the definiteness and animacy of referential expressions in dative sentences form the basis of observed interactions between syntax and information structure. Thus, the linear position hypothesis, unlike the argument structure hypothesis, predicts that comprehension preferences should differ for dative sentences when indefinite articles are followed by animate vs. inanimate nouns. On the other hand, if DO sentences are subject to a general given-before-new constraint, as claimed by the argument structure hypothesis, then this constraint should manifest in sentence comprehension even when the features of referential expressions within dative sentences are manipulated.

Experiment 1 used an on-line comprehension task to demonstrate that syntactic and information structures interact in the comprehension of dative sentences with prototypical themes and goals. Experiment 2 then distinguished between the argument structure and linear position hypotheses by manipulating information structure in dative sentences with animate themes. The results from these experiments show that sensitivity to linear position statistics alone cannot account for comprehension preferences in the dative alternation, suggesting that structure-level discourse constraints on the use of certain syntactic structures play a role in sentence comprehension.

Experiment 1

The goal of Experiment 1 was to characterize the interaction between information structure and the dative alternation in on-line comprehension. This interaction was previously found by Clifton and Frazier (2004) using a speeded acceptability judgment paradigm. In Experiment 1, we extended these findings using a self-paced reading task, enabling us to capture comprehension effects in the on-line processing of DO and PO sentences in which information structure (Given-First, New-First) was manipulated.

Methods

Participants

We recruited 123 participants from MIT and the surrounding community for the self-paced reading task. All participants were native English speakers between the ages of 18 and 40.

Materials

The 24 stimuli used in Experiment 1 were constructed by manipulating information structure (Given-First, New-First) in pairs of sentences, as in (2).

(2) **Theme context:** An understudy for a new Broadway show kept a notebook to document the show's progress.

- a. PO/Given-First: The understudy showed the notebook to a violinist as he explained his ideas.
- b. DO/New-First: The understudy showed a violinist the notebook as he explained his ideas.

Goal context: An understudy for a new Broadway show began conversing with a violinist who played in the orchestra.

- a. PO/New-First: The understudy showed a notebook to the violinist as he explained his ideas.
 - b. DO/Given-First: The understudy showed the violinist a notebook as he explained his ideas.
-

Givenness was signaled both through the appearance of the given referent in a preceding context sentence and through definiteness (i.e., given referents had definite articles, and new referents had indefinite articles). At least one constituent separated the given referent from the end of the context sentence to minimize the expectation for the given referent to be pronominalized in the target sentence (i.e., to minimize processing effects caused by violations of repeated name penalty constraints for the goal or theme, such as those described by Gordon, Grosz, and Gilliom (1993) for repeated subject NPs). Similarly, the second object in each target sentence was separated from the end of the sentence by 3–7 words, to enable the detection of spill-over effects persisting beyond the objects of each verb. This region was identical across conditions.

Procedure

The primary task was self-paced, word-by-word reading using a moving window display (Just, Carpenter, & Woolley, 1982). The stimuli were presented using Linger 2.88 software by Doug Rohde (available at <http://www.tedlab.mit.edu/~dr/Linger/>). At the start of each trial, participants viewed a series of dashes that marked the length and position of the words in the context and target sentences. The context sentence was always presented above the target sentence. Context sentences were presented in regions of 2–6 words to minimize button-pressing fatigue, whereas each word of the target sentences was presented individually. Participants pressed the spacebar to reveal each word or region of the sentence and conceal the word or region before it. The response time (RT) between each pair of button-presses was recorded.

Each testing session began with six practice items designed to familiarize participants with the task paradigm. Each participant viewed one condition per stimulus, with all conditions equally represented. Stimuli were pseudo-randomly intermixed with 72 filler context-target sentence pairs containing a variety of syntactic structures. All items were followed by a two-alternative comprehension question. Participants received feedback after incorrect responses, and their accuracy was recorded. Each session lasted approximately 30 min.

Stimulus norming

A written plausibility ratings task assessed the plausibility of target sentences with respect to both the theme and goal context sentences. Thirty participants who did not complete the self-paced reading experiment read half of the PO target sentences with the Goal-Context sentence, and half with the Theme-Context sentence. They then rated the plausibility of each context-target pair on a seven-point scale. The context with which each stimulus was presented was counterbalanced across two lists. The stimuli were pseudorandomly intermixed with 106 filler items of varied syntax and plausibility. A two-tailed paired *t* test revealed no differences in plausibility ratings between context types ($t(23) = 0.50$, $p > .6$).

In addition, two sentence completion tasks were conducted to estimate the relative frequency with which the verbs used in our stimuli appear in PO sentences, DO sentences, or sentences with other structures, because verb subcategorization frequencies are likely to affect RTs across different structures (e.g., Trueswell, Tanenhaus, & Kello, 1993). These tasks were conducted using Amazon.com's Mechanical Turk, an Internet-based marketplace service that can be used to obtain behavioral data (e.g., Gibson & Fedorenko, in press).

In the first task, 200 self-reported native speakers of American English read the subject and verb of each target sentence and then typed a completion for each item into a web form. In the second task, 100 additional participants were also given the theme and goal of each target sentence (e.g., *The understudy showed... VIOLINIST NOTEBOOK*) and were asked to include the two nouns in their completions. To minimize ordering effects, the two nouns were presented on two lines beneath the subject and verb, with the noun in the top line right-aligned and the noun in the bottom line left-aligned, and the order of the nouns was counterbalanced across participants. Filler materials for both tasks included 24 additional dative items and 48 non-dative items, and the order of presentation of items was randomized.

From each of these studies, we obtained two measures: the frequency with which each verb was used in either type of dative sentence relative to all sentence types (*dative bias*) and the frequency with which each verb was used in a PO sentence relative to all dative sentences (*PO bias*). The dative bias measures ranged from 23% to 59% in the first task, and from 50% to 99% in the second task (which provided additional information suggesting a dative completion). Alternative sentence completions consisted primarily of simple transitive and intransitive sentences. Likewise, the PO bias measures ranged from 36% to 68% in the first task, and from 45% to 94% in the second task (in which the use of pronominal arguments was greatly reduced).

Analysis

Effects of syntactic structure and information structure on participants' performance on the comprehension questions were assessed using multi-level logistic regression, with random intercepts and slopes for participants and items included to account for variability in accuracy across

individual participants and items.² In addition to the fixed effects of syntactic structure and information structure, model factors included semantic plausibility ratings, the position of the item in the sequence seen by the subject, and the dative bias and PO bias measures from each sentence completion task. Including these predictors allowed us to assess the effects of syntactic structure and information structure above and beyond these secondary factors. Final models were chosen by removing factors stepwise and comparing each simplified model to the more complex model using the likelihood ratio test, following Baayen, Davidson, and Bates (2008).

Likewise, the effects of syntactic structure and information structure on RTs were analyzed using multi-level linear regression with random intercepts and slopes for participants and items. For the purpose of these analyses, target sentences were divided into five regions. The first region included the subject and verb, which were the same across all conditions. The second region consisted of the first object (the theme in PO sentences and the goal in DO sentences), and the third region consisted of the second object. These regions included articles but not the preposition introducing the goal in PO sentences. The post-NP2 region was split into two spillover regions. The first spillover region included the first two words following NP2, and the second spillover region included the remaining 3–7 words in the sentence. Both spillover regions were the same across all conditions.

As in the analysis of comprehension question performance, semantic plausibility, sequential item position, and dative bias and PO bias measures from each sentence completion task were included as predictors in the RT models, allowing us to control for these factors in our analysis of syntactic structure and information structure. Additional factors included in the RT models included accuracy of responses to comprehension questions, orthographic word length, and a measure of lexical frequency estimated using the CELEX Lexical Database (Baayen, Piepenbrock, & Gulikers, 1995). The latter two factors have been shown in previous experiments to influence reading time (e.g., Just & Carpenter, 1980; Rayner & Duffy, 1986). Across all models, continuous variables were standardized by subtracting the mean value and dividing by the standard deviation.

All regression modeling was conducted in R (R Development Core Team, 2009), using the *lmer* function within the *lme4* package (Bates, Maechler, & Dai, 2008). The logistic accuracy model was fit by the Laplace approximation and the linear RT models were fit using restricted maximum likelihood estimation. The number of degrees of freedom in linear multi-level models is debatable (Baayen et al., 2008), and standard methods for obtaining *p* values for each predictor are not yet compatible with multi-level models including random slopes. The large number of observations in this experiment, however, enabled us to estimate significance for each predictor by assuming

² For both experiments, 2×2 ANOVAs crossing syntactic structure with information structure yielded the same general pattern of results, so the main findings reported here are not dependent on the use of particular analysis techniques.

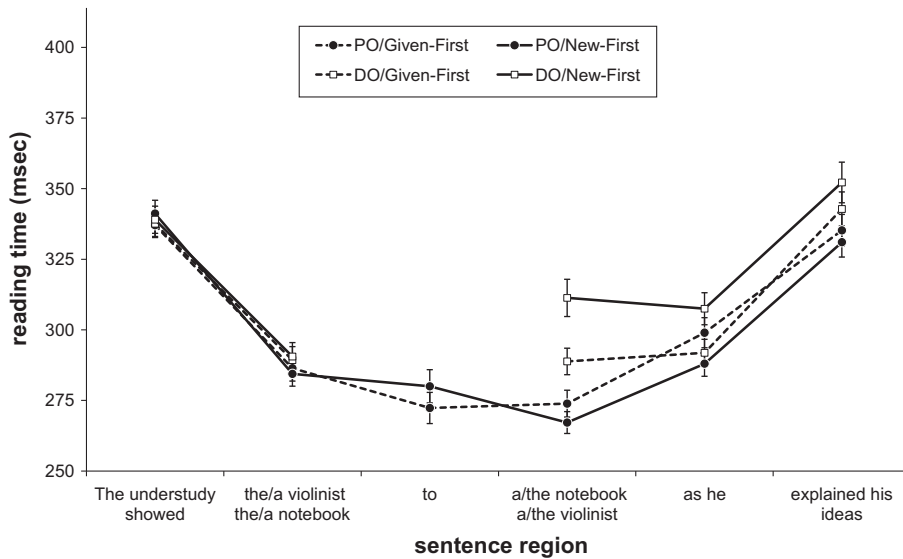


Fig. 1. Reading times by sentence region for the four conditions in Experiment 1. Error bars denote 95% confidence intervals.

convergence of the t distribution with the z distribution (Baayen et al., 2008).

Results

Data from three participants in the self-paced reading study were excluded from analysis because of poor performance on the comprehension task (overall accuracy <75%). Mean accuracy across all remaining participants was 95.18%. A logistic mixed-effects model with random effects for participants and items found no significant effects of syntactic structure, information structure, or their interaction on accuracy. For RT analyses, all data points more than three standard deviations from the mean (1.67% of the data) were excluded.

Fig. 1 shows mean RTs for each condition as a function of sentence region. For each of these regions, a linear mixed-effects model was fitted to the raw RT data, with random effects and slopes for participants and items. In addition to syntactic structure and information structure, each of these models contained log frequency, log length, semantic plausibility, sequential stimulus position, accuracy of responses to comprehension questions, and dative bias and PO bias measures for each verb from both sentence completion tasks as fixed effects. The main effects and interactions of syntactic structure and information structure reported here therefore represent the effects of the primary variables of interest after accounting for effects of secondary factors.

The first region analyzed consisted of the subject and verb (Table 1). Within each item, this region was identical across conditions, so no significant effects of syntactic structure or information structure were predicted. As expected, a linear mixed-effects model with random effects for participants and items showed no significant main effects or interactions between syntactic structure and information structure in the first region. Likewise, analysis of the second region (NP1) also found no significant effects

of syntactic structure, information structure, or interactions between the two factors, after controlling for secondary factors.

In the third region (NP2), a linear mixed-effects model revealed a highly significant interaction between syntactic structure and information structure. Model coefficients and statistics are displayed in Table 2. Post-hoc paired t tests revealed differences in the effect of information structure on PO and DO sentences: Whereas PO structures were read marginally faster when they contained new-before-given information structure ($t_1(119) = 1.81, p = .07; t_2(23) = 2.07, p = .05$), DO structures were read more slowly when they contained new-before-given information structure ($t_1(119) = -5.51, p < .0001; t_2(23) = -3.83, p < .001$).

The interaction between syntactic structure and information structure persisted into the first spillover region (Table 3). In this region, RTs for PO/New-First sentences were again faster than for PO/Given-First sentences ($t_1(119) = 3.00, p < .005; t_2(23) = 2.87, p < .01$), and RTs for DO/New-First sentences were slower than for DO/Given-First sentences ($t_1(119) = -4.44, p < .0001; t_2(23) = -3.09, p < .01$). The interaction was also associated with significant main effects of syntactic structure and information structure, whereby RTs were slower for DO sentences and for sentences with new-before-given information structure.

In the final region, the main effects of syntactic structure and information structure were no longer significant ($p > .1$) and the interaction between syntactic structure and information structure continued to be significant ($\beta = 18.62, SE = 5.43, t = 3.43, p < .001$). However, unlike in the previous two regions, the RT difference between the DO/Given-First and DO/New-First conditions was not reliably significant ($t_1(119) = 2.29, p < .05; t_2(23) = 1.38, p > .10$), and neither was the RT difference between the PO/Given-First and PO/New-First conditions ($t_1(119) = 1.59, p > .10; t_2(23) = 1.91, p = .07$). Rather, the interaction in this region was driven by differences in the

Table 1

Mean RTs and 95% confidence intervals for each sentence region as a function of condition in Experiment 1.

Condition	Region					
	Subject and verb	NP1	Preposition	NP2	First spillover	Second spillover
PO/Given-First	337.04 (2.23)	286.41 (2.32)	272.32 (2.82)	273.87 (2.42)	298.98 (2.72)	335.23 (2.88)
PO/New-First	341.15 (2.41)	284.40 (2.22)	279.99 (3.00)	267.15 (1.98)	287.99 (2.27)	331.03 (2.68)
DO/Given-First	337.60 (2.31)	289.28 (2.43)		288.80 (2.39)	291.84 (2.44)	342.81 (3.07)
DO/New-First	338.98 (2.46)	290.52 (2.53)		311.30 (3.37)	307.46 (2.89)	352.19 (3.67)

Table 2

Parameters of the final linear regression model of RTs across the NP2 region in Experiment 1. In addition to the fixed effects listed below, the final models included by-subject and by-item random intercepts as well as by-subject random slopes for the interaction between syntactic structure and information structure and by-item random slopes for structure.

	β	SE	<i>t</i>	<i>p</i>
Intercept	316.84	8.62	36.76	<.0001
Structure = DO	-15.15	7.80	-1.94	<.10
Word order = new-first	-5.62	3.29	-1.71	<.10
Structure \times word order	29.46	4.25	6.93	<.0001
Semantic plausibility	-3.63	1.22	-2.99	<.005
Log word frequency	-0.97	0.86	-1.13	n.s.
PO bias (subject and verb only)	5.16	1.40	3.70	<.0005
Comprehension accuracy	-14.94	5.18	-2.89	<.005
Position of stimulus in list	-0.42	0.04	-10.81	<.0001

Table 3

Parameters of the final linear regression model of RTs across the first spillover region in Experiment 1. In addition to the fixed effects listed below, the final models included by-subject and by-item random intercepts as well as by-subject and by-item random slopes for the interaction between syntactic structure and information structure.

	β	SE	<i>t</i>	<i>p</i>
Intercept	338.15	10.76	31.41	<.0001
Structure = DO	-35.90	12.73	-2.72	<.01
Word order = new-first	-11.43	4.62	-2.48	<.05
Structure \times word order	28.10	7.98	3.52	<.001
Semantic plausibility	-4.68	2.01	-2.33	<.05
Log word frequency	-6.82	2.56	-2.66	<.01
PO bias (subject and verb only)	5.38	2.45	2.20	<.05
Position of stimulus in list	-0.47	0.04	-12.00	<.0001

effect of syntactic structure on sentences with different information structures. In sentences with given-before-new information structure, RTs in the final region did not differ significantly between PO and DO structures ($t_1(119) = -1.02, p > .30$; $t_2(23) = -1.28, p > .20$), whereas in sentences with new-before-given information structure, RTs were slower for DO sentences than for PO sentences ($t_1(119) = 4.62, p < .0001$; $t_2(23) = 3.51, p < .005$).

To summarize, the primary result found in Experiment 1 was a significant tendency for comprehenders to respond disproportionately slowly to DO sentences with new-before-given information structure, above and beyond main effects of syntactic structure and information structure, and for PO sentences with new-before-given information structure to be processed slightly faster than PO sentences

with given-before-new information structure. This interaction was present in the NP2 and initial spillover regions.

Discussion

In this experiment, we manipulated information structure within the dative alternation to characterize how discourse constraints interact with syntactic constraints in on-line comprehension. Our results show that the DO/New-First condition incurs a cost in on-line processing relative to the other three conditions. These effects, which were also found by Clifton and Frazier (2004) in speeded acceptability judgments, are unlikely to have resulted from semantic or pragmatic differences between Goal-Context and Theme-Context items, since plausibility ratings did not differ between conditions. Likewise, although factors including stimulus plausibility, position within the stimulus list, and verb bias toward PO structures significantly predicted RTs in the critical sentence regions, the inclusion of these factors in the regression models demonstrates that the interaction between syntactic structure and information structure affects RTs above and beyond the effects of each of these factors. Our results therefore indicate that syntactic and discourse information interact in the comprehension of the dative alternation.

This finding is predicted by the argument structure hypothesis. This hypothesis assumes that discourse information can be incorporated into syntactic representations, and that the representation of the DO structure, but not the PO structure, includes constraints on the relative order of given and new expressions. The key prediction of this hypothesis is that DO structures that violate these information-structural constraints incur a cost in processing. The argument structure hypothesis therefore predicts the relatively slow RTs in the DO/New-First condition, because the sentences in this condition violate the given-before-new constraint.

The argument structure hypothesis does not directly predict the small but significant difference in RTs between the PO/Given-First and PO/New-First conditions, an effect also found by Clifton and Frazier (2004) in one of their three experiments. However, this RT difference could result from differences in the cognitive accessibility of the target expression introduced by each of the two context sentences. In the Goal-Context conditions (PO/New-First, DO/Given-First), the target expression refers to an animate entity, whereas in the Theme-Context conditions (PO/Given-First, DO/New-First), it refers to an inanimate entity. Expressions referring to animate entities come more readily to mind and are more likely to be referred to multiple

times within a discourse (Branigan, Pickering, & Tanaka, 2008) and hence tend to be analyzed as being more accessible than those referring to inanimate entities. This difference in probability of repeated mention could facilitate the processing of stimuli in which the animate goal, rather than the inanimate theme, is mentioned in both context and target sentences. It is important to note, however, that the magnitude of the processing cost in the DO/New-First condition cannot be explained solely on the basis of differences between contexts.

The results of Experiment 1 are also consistent with the predictions of the linear position hypothesis. According to this hypothesis, the apparent structure-level relation between syntactic and information-structural representations in the dative alternation arises epiphenomenally from the statistical infrequency of an animate expression following an indefinite article. This hypothesis can therefore account for the observations that RTs in the DO/New-First and PO/Given-First conditions are slower than RTs in the DO/Given-First and PO/Given-First conditions, respectively. Further, because frequency effects manifest most strongly in relatively early sentence positions, the linear position hypothesis also accounts for the greater magnitude of the processing cost in the DO/New-First condition. In terms of the time course of these effects, the linear position hypothesis predicts RT differences between conditions as early as the NP1 position. Although no RT differences were observed in Experiment 1 until the NP2 position, self-paced reading effects sometimes do not manifest until the word or region following the point at which the reader first encounters difficulty. Thus, the timing of the effects observed in Experiment 1 is consistent with the predictions of the linear position hypothesis.

Experiment 2

Because both the argument structure and linear position hypotheses can account for the pattern of results from Experiment 1, we conducted an experiment in which both themes and goals were animate in order to distinguish between the two hypotheses. Under these conditions, the argument structure hypothesis predicts the same pattern of results as in Experiment 1: an interaction between syntactic structure and information structure starting at NP2, such that the RT difference between sentences with new-before-given information structure and sentences with given-before-new information structure is greater for DO structures than for PO structures. If the results of Experiment 1 arose from the co-occurrence of indefinite articles and animate nouns, however, then there should be a main effect of information structure in Experiment 2, but no interaction between information structure and syntactic structure. Specifically, conditions in which context-new (indefinite) NPs precede contextually given (definite) NPs should be processed more slowly than conditions in which given entities precede new entities, because the linear position hypothesis predicts slower RTs when animate entities follow indefinite articles in the NP1 position. Importantly, no RT differences should arise within each information-structure type.

Methods

Participants

We recruited 48 participants for the self-paced reading task. All were native English speakers between the ages of 18 and 40.

Materials

The stimuli used in Experiment 2 were constructed by manipulating information structure in DO and PO sentences in which both the goal and the theme were animate, as in (3).

-
- (3) **Theme-Context:** A manager met with an engineer who was concerned about the availability of building materials.
 (a) PO/Given-First: The manager brought the engineer to an architect so they could discuss the plans.
 (b) DO/New-First: The manager brought an architect the engineer so they could discuss the plans.
- Goal-Context:** A manager met with an engineer who was concerned about the availability of building materials.
 (c) PO/New-First: The manager brought an architect to the engineer so they could discuss the plans.
 (d) DO/Given-First: The manager brought the engineer an architect so they could discuss the plans.
-

For all stimuli, the context sentence was identical across all conditions. As in Experiment 1, at least one constituent separated the given referent from the end of the context sentence to minimize the expectation for the given referent to be pronominalized in the target sentence. To increase variation in event types featured in the stimuli, half of the 24 stimuli had goals and themes that referred to human entities, and the remaining half had goals and themes that referred to animals.

Procedure

The self-paced reading procedures were the same as in Experiment 1.

Stimulus norming

A written plausibility ratings task was conducted to evaluate the plausibility of each stimulus, following the same design and administration procedures as in Experiment 1. Analysis of ratings revealed no differences in ratings between Goal-Context and Theme-Context stimuli ($t(23) = 0.250, p > .8$). In addition, two sentence completion tasks were conducted to estimate the verb subcategorization frequencies of each item, following the design and administration procedures used in Experiment 1. For the task in which participants were not provided with the theme and goal nouns from our stimuli, dative bias scores ranged from 17% to 50%, and PO bias scores ranged from

29% to 72%. For the task in which completions included the theme and goal nouns, dative bias scores ranged from 3% to 65%, and PO bias scores ranged from 33% to 99%.

Analysis

The methods for analyzing accuracy and RT data in Experiment 2 were the same as in Experiment 1, with one exception. In Experiment 2, the type of goal and theme (i.e., humans or animals) was included as an additional fixed effect in the analyses. To determine whether the type of goal and theme influenced the effects of syntactic structure and/or information structure in comprehension, we further included the three-way interaction between NP type (human, animal), syntactic structure (PO, DO), and information structure (Given-First, New-First) as a factor in our analyses. The other fixed and random effects were the same as in Experiment 1.

Results

Data from six participants in the self-paced reading study were excluded from analysis due to poor comprehension task performance (overall accuracy <70%). Mean accuracy across all remaining participants was 86.21%. Multi-level logistic regression with random effects and slopes for participants and items revealed no significant effect of syntactic structure or information structure, nor an interaction between these two factors. A main effect of NP type was detected ($\beta = 0.78$, $SE = .35$, $z = 2.21$, $p < .05$): Participants were significantly less accurate in their responses to stimuli containing human goals and themes than to stimuli containing animal goals and themes (81.80% vs. 90.62%). However, NP type did not interact significantly with syntactic structure or information structure.

For RT analyses, data points that fell more than three standard deviations from the mean (1.47% of the data) were excluded from analysis. Target sentences were divided into regions as in Experiment 1. Fig. 2 shows mean

RTs by region and condition. For each region, a linear mixed-effects model was fitted to the raw RT data, with random effects and slopes for participants and items. In addition to syntactic structure, information structure, NP type, and their interactions, each of these models contained log word frequency, log word length, semantic plausibility, measures of dative bias and PO bias for each verb, comprehension accuracy, and sequential stimulus position as secondary fixed effects.

In the first region (subject and verb), a linear mixed-effects model with random effects and slopes for participants and items revealed that PO sentences were read more quickly than DO sentences ($\beta = 15.33$, $SE = 6.08$, $t = 2.52$, $p < .01$). Because the difference between syntactic structures was numerically small (Table 4), and because each stimulus was identical up to this point across conditions, we consider it likely that this main effect arose by chance. The main effect of syntactic structure persisted into the NP1 region ($\beta = 9.58$, $SE = 3.47$, $t = 2.76$, $p < .005$), but no other significant main effects or interactions of syntactic structure, information structure, and NP type were found.

In the NP2 region, a linear mixed-effects model with random effects for participants and items revealed a main effect of syntactic structure, with slower RTs for DO sentences than for PO sentences (Table 5). In addition, a significant interaction between syntactic structure and information structure was detected, after accounting for other factors. Post-hoc paired *t* tests revealed differences in the effect of information structure on PO and DO sentences: Whereas no significant effect of information structure was found for PO sentences ($t_1(41) = 0.84$, $p > .4$; $t_2(23) = 0.32$, $p > .7$), RTs were slower for DO structures with given-before-new information structure ($t_1(41) = 3.40$, $p < .005$; $t_2(23) = 2.31$, $p < .05$), as in Experiment 1.

In the first spillover region, the interaction between syntactic structure and information structure, but not the main effect of syntactic structure, continued to be signifi-

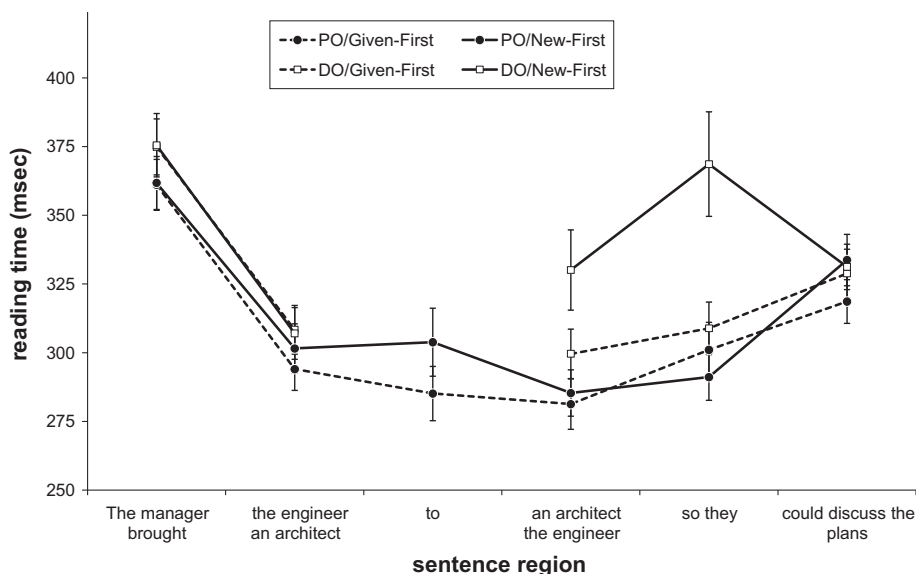


Fig. 2. Reading times by sentence region for the four conditions in Experiment 2. Error bars denote 95% confidence intervals.

Table 4

Mean RTs and 95% confidence intervals for each sentence region as a function of condition in Experiment 2.

Condition	Region					
	Subject and verb	NP1	Preposition	NP2	First spillover	Second spillover
All NP types						
PO/Given-First	361.08 (4.73)	294.00 (3.95)	285.11 (5.04)	281.28 (4.68)	301.01 (5.11)	318.61 (4.06)
PO/New-First	361.77 (4.92)	301.53 (4.56)	303.81 (6.32)	285.31 (4.30)	291.10 (4.31)	333.71 (4.77)
DO/Given-First	374.88 (5.20)	308.33 (4.52)		299.57 (4.59)	308.86 (4.88)	328.80 (4.52)
DO/New-First	375.51 (5.89)	306.99 (4.80)		330.08 (7.45)	368.64 (9.70)	331.22 (4.22)
Human NPs						
PO/Given-First	362.39 (6.48)	298.35 (6.06)	290.82 (7.36)	286.74 (6.93)	309.51 (7.99)	321.99 (6.28)
PO/New-First	357.25 (6.55)	306.25 (6.67)	318.27 (10.48)	290.63 (6.79)	286.61 (5.36)	326.21 (6.12)
DO/Given-First	369.67 (6.43)	309.58 (6.73)		304.44 (7.15)	324.33 (7.70)	325.16 (5.64)
DO/New-First	381.18 (8.05)	317.12 (7.36)		356.98 (12.61)	379.11 (13.78)	323.96 (5.33)
Animal NPs						
PO/Given-First	359.78 (6.89)	289.67 (5.06)	279.37 (6.87)	275.88 (6.29)	292.40 (6.33)	315.28 (5.15)
PO/New-First	366.24 (7.34)	296.83 (6.24)	289.45 (6.91)	280.02 (5.29)	295.55 (6.73)	341.05 (7.30)
DO/Given-First	380.09 (8.18)	307.10 (6.05)		294.68 (5.75)	293.64 (5.90)	332.36 (7.03)
DO/New-First	369.87 (8.59)	297.16 (6.16)		303.08 (7.55)	358.16 (13.61)	338.24 (6.48)

Table 5

Parameters of the final linear regression model of RTs across the NP2 region in Experiment 2. In addition to the fixed effects listed below, the final models included by-subject and by-item random intercepts as well as by-subject random slopes for the interaction between syntactic structure and information structure.

	β	SE	t	p
Intercept	304.24	11.90	25.56	<.0001
Structure = DO	17.94	6.54	2.74	<.005
Word order = new-first	5.61	6.11	0.92	n.s.
Structure \times word order	27.25	11.33	2.41	<.01
Log word frequency	-5.78	1.65	-3.50	<.0005
Position of stimulus in list	-0.43	0.08	-5.47	<.0001

cant (Table 6). In this region, as in NP2, information structure had no reliable effect on RTs for PO sentences ($t_1(41) = 1.78$, $p < .10$; $t_2(23) = 1.00$, $p > .3$), whereas RTs for DO/New-First sentences were slower than for DO/Given-First sentences ($t_1(41) = 4.75$, $p < .0001$; $t_2(23) = 4.45$, $p < .0005$).

No interactions reached significance in the second spillover region. However, new-before-given information structure was processed significantly more slowly than given-before-new information structure across syntactic structures ($\beta = 8.87$, $SE = 3.94$, $t = 2.25$, $p < .05$).

To summarize, the main result of this experiment was a strong interaction found in the NP2 and first spillover regions of the target sentence. This interaction was driven

Table 6

Parameters of the final linear regression model of RTs across the NP2 region in Experiment 2. In addition to the fixed effects listed below, the final model included by-subject random intercepts and random slopes for the interaction between syntactic structure and information structure.

	β	SE	t	p
Intercept	346.03	12.85	26.93	<.0001
Structure = DO	7.03	7.66	0.92	n.s.
Word order = new-first	-9.80	7.72	-1.27	n.s.
Structure \times word order	72.35	15.50	4.67	<.0001
Log word length	-29.96	13.01	-2.30	<.05
Position of stimulus in list	-0.70	0.10	-7.01	<.0001

by disproportionately slow RTs in the DO/New-First condition, relative to the other three conditions. The relationships between factors and time-course of the interaction found in Experiment 2 parallel the main result of Experiment 1.

Discussion

In Experiment 2, we manipulated information structure in dative sentences with animate themes and goals to distinguish between the predictions of two hypotheses about the representations underlying the interaction between discourse and syntactic constraints in on-line comprehension. Our results again showed evidence for a processing cost in the DO/New-First relative to the other three conditions, as in Experiment 1. This interaction between syntactic structure and information structure was observed in the NP2 and first spillover regions, and this effect did not differ significantly between human and animal stimulus types. Further, the inclusion of factors such as stimulus plausibility and verb bias in the regression models demonstrates that the obtained interaction effects are unlikely to be epiphenomena of these secondary factors. Thus, we conclude that the timing and nature of the interaction between information structure and syntactic structure is similar across experiments.

The goal of Experiment 2 was to distinguish between the predictions of two hypotheses concerning the basis for interaction between syntactic and information-structural constraints. Our results are not consistent with the predictions of the linear position hypothesis. This hypothesis predicts that the processing difficulty incurred by animate nouns following indefinite articles should be greater when these expressions occur relatively early in a sentence, as in the PO/New-First and DO/New-First conditions of Experiment 2. Importantly, the linear position hypothesis predicts no RT difference between the PO/New-First and DO/New-First conditions. The only condition in which RTs are relatively slow in Experiment 2, however, is the DO/New-First condition. The data are therefore inconsistent with the linear position hypothesis.

On the other hand, the patterns of data obtained in Experiment 2 are consistent with the argument structure hypothesis, which predicts that the DO structure should only be appropriate in comprehension when it satisfies constraints on the information structure of its arguments. This hypothesis licenses DO/Given-First structures, but not DO/New-First structures. This prediction is supported by the results of Experiment 2, which show slowed RTs in only the DO/New-First condition. These data are therefore consistent with a structure-level interaction between syntactic and information structures.

General discussion

The goals of this study were (1) to determine whether information structure and syntactic structure interact in the on-line comprehension of the dative alternation; and (2) to determine a plausible source of this interaction. To this end, we conducted two self-paced reading experiments in which information structure was manipulated within dative sentences. Our results from Experiment 1 confirm previous reports that syntactic and information-structural constraints interact in comprehension (Clifton & Frazier, 2004), and extend these findings to on-line processing. Critically, Experiment 2 contained dative sentences with animate themes and goals, which allowed us to test two plausible sources of the interaction: (1) the inclusion of discourse constraints within structure-level representations; or (2) comprehenders' sensitivity to linear statistical patterns. Our results from Experiment 2 support the interaction of syntactic and discourse constraints at the level of structural representations.

According to the linear position hypothesis, the apparent interaction between syntactic structure and information structure emerges from comprehenders' expectation for indefinite articles to be followed by animate nouns within dative sentences, especially in relatively early sentence positions. The results from Experiment 1 were consistent with this hypothesis: Only sentences that violated this expectation were associated with a processing cost, so the results from this experiment were consistent with the predictions of the linear position hypothesis. In Experiment 2, however, only the DO/New-First condition was associated with a processing cost, even though both the DO/New-First and PO/New-First conditions had indefinite animate expressions in the same sentence position. This difference between conditions is inconsistent with the predictions of the linear position hypothesis.

The argument structure hypothesis, on the other hand, is consistent with results from both experiments. This hypothesis holds that discourse constraints on the relative givenness of the theme and goal are included in comprehenders' representation of DO structures. The main prediction of the argument structure hypothesis, therefore, is that DO structures in which these discourse constraints are violated should be dispreferred in comprehension. These constraints are only violated in the DO/New-First conditions of both Experiments 1 and 2, so this hypothesis correctly predicts the processing cost observed in the DO/

New-First condition in both experiments. These data are consistent with the hypothesis that discourse constraints can be included within syntactic representations.

It remains an open question whether other types of discourse or lexical constraints are encoded in syntactic representations as well. Although we did not observe a main effect of the animate theme between structures in Experiment 2, our experiments were not designed to directly address the possibility that dative structures are subject to constraints on the animacy of their arguments as well as their relative givenness. Further work would be necessary to directly test this possibility.

Likewise, it remains a possibility that linear statistical cues other than the likelihood of animate nouns following indefinite articles result in the observed interaction between information structure and syntactic alternations. Although any version of the linear position hypothesis involving features of a single referential expression in a particular position would be inconsistent with our results, more complex linear statistics might be able to account for the comprehension effects that we found, e.g., by extending the statistics in consideration to include features of additional expressions. By the principle of parsimony, however, we maintain that representational associations between information structure and syntactic structure constitute the best available explanation of discourse effects in the comprehension of the dative alternation.

This perspective is consistent with previous research by Kaiser and Trueswell (2004) investigating the role of discourse context in the processing of Finnish sentences with canonical SVO and non-canonical OVS syntactic structures. In one self-paced reading experiment, they manipulated the relative word order of contextually given and new entities in SVO and OVS sentences. Participants read OVS sentences more slowly in the new-before-given information structure condition than in the given-before-new condition, but no differences were found between SVO conditions. This interaction indicates that the non-canonical OVS structure is licensed only in supportive discourse contexts, paralleling the RT effects we obtained for the dative alternation.

However, not all syntactic alternations interact with information structure. Fedorenko and Levy (2007) conducted a self-paced reading study of Russian sentences in which the word order of given and new entities within SVO (canonical) and OVS (scrambled) sentences was manipulated, as in the experiment conducted by Kaiser and Trueswell (2004). Unlike in Finnish, however, the comprehension of the Russian sentences was characterized by main effects of both syntactic structure and information structure, such that SVO sentences were processed more easily than OVS sentences, and sentences with given-before-new information structure were processed more easily than sentences with new-before-given information structure. Critically, however, these two factors did not interact, suggesting that syntax and information structure exert independent effects on sentence processing in Russian.

Together, these differences in the comprehension of Finnish and Russian syntactic alternations suggest that

discourse constraints on non-canonical syntactic structures are language- and structure-specific, and are therefore not a universal property of non-canonical structures. It is possible that the presence or absence of interactions between information structure and syntactic alternations in comprehension is related to the distribution of information-structural regularities among syntactic structures in production, and this would be an interesting question for future research.

It is also worth noting that the interaction between information structure and syntactic structure in Finnish could result from the use of linear position statistics involving case features. In Finnish, the subject of a sentence is usually marked with nominative case and the object is often marked with partitive case. Partitive case, however, can also denote the subject of an experienter verb. A subject-initial noun with partitive case marking therefore generates a temporary ambiguity between an OVS interpretation and an SVO interpretation. Supportive discourse contexts could alleviate the processing cost associated with the resolution of this temporary ambiguity, for example, if listeners are sensitive to a statistical tendency for previously mentioned sentence-initial partitive NPs to correspond to objects, rather than subjects. The apparent interaction between syntax and information structure in Kaiser and Trueswell's self-paced reading data could therefore emerge from the use of statistical information at particular linear positions, as opposed to a learned association between information structure and non-canonical syntactic forms. Because the case-marking system of Russian does not give rise to the local ambiguities seen in Finnish, an account of the Finnish data based on these linear position statistics might also be consistent with the absence of the information structure interaction in the Russian data. Further work would be necessary to distinguish between accounts based on structure-level associations and local statistics in the comprehension of these syntactic alternations.

In conclusion, our results demonstrate that statistical patterns involving the features of individual referential expressions are insufficient to account for the selective dispreference for new-before-given word order in the comprehension of DO structures. Instead, our results favor the hypothesis that information-structural constraints form part of the DO representation. More generally, they are consistent with the idea that non-canonical syntactic structures like the DO structure may be more likely to serve specific functions in discourse than their canonical counterparts, and that these non-canonical structures are only licensed when constraints on their use in discourse are satisfied.

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Appendix A. Materials used in Experiment 1

The context and target sentences for each of the stimuli used in Experiment 1 are shown below. Each of the four experimental conditions is illustrated for the first item only; the remaining items present only the target sentence for the PO/Given-First condition.

-
1. (a) Context sentence: A professor was exhausted because he had been working on the first draft of a grant all day long. / A professor was exhausted because he was writing long emails to an administrator all day long about personality conflicts.
(b) Target sentence:
PO/Given-First: The professor sent the grant to an administrator after he was finally finished.
DO/New-First: The professor sent an administrator the grant after he was finally finished.
DO/Given-First: The professor sent the administrator a grant after he was finally finished.
PO/New-First: The professor sent a grant to the administrator after he was finally finished.
 2. (a) Context: A socialite was planning a dinner party for her closest friends, and she decided to make a casserole as the main dish. / A socialite was planning a dinner party for her closest friends, and she decided to invite an attorney that she had known for several years.
(b) Target: The socialite baked the casserole for an attorney because it was his favorite dish.
 3. (a) Context: A retailer was browsing through a popular website of merchandise and bought a laptop that was on sale. / A retailer often did business with a local university, and one week he was approached by a physicist with a special request.
(b) Target: The retailer sold the laptop to a physicist because hers was broken.
 4. (a) Context: An executive at a local company had purchased a new lamp for her office, and she was trying to get rid of her old lamp quickly. / An executive at a local company walked around her employees' cubicles and stopped at the cubicle of an engineer who had just been hired.
(b) Target: The executive offered the lamp to an engineer because his cubicle was dark.
 5. (a) Context: The manager of a restaurant that was under construction did not normally cook, but on Saturday he made a sandwich. / The manager of a restaurant that was under

(continued on next page)

- construction arrived at work Monday to find a carpenter who was replacing the windows.
 (b) Target: The manager fixed the sandwich for a carpenter because the carpenter had been working since 8 am.
6. (a) Context: A retiring flight attendant was about to depart for her last flight with United Airlines, and she was saying goodbye to a pilot in the airport. / A flight attendant was browsing through the gift shops in the airport, and she eventually purchased a gift from a gourmet food store.
 (b) Target: The flight attendant gave the gift to a pilot before she left.
7. (a) Context: A webmaster was designing a website for a software company in Boston, and he was collaborating with an executive in the public relations department. / A webmaster was designing a website for a software company in Boston, and he had just drafted a preliminary schedule for the completion of the project.
 (b) Target: The webmaster emailed the schedule to an executive after work on Tuesday.
8. (a) Context: An attorney had just finished preparing some files for an important lawsuit, and she put her crumpled notes in a trashcan next to her desk. / An attorney was preparing some files for an important lawsuit, and at the end of the day she called an intern into her office to clean up.
 (b) Target: The attorney handed the trashcan to an intern as she left the office.
9. (a) Context: A CEO recently fired his secretary, and therefore the secretary's office needed to be reassigned. / A CEO was having some trouble running his business, so he hired an analyst to make recommendations on securities.
 (b) Target: The CEO assigned the office to an analyst after consulting his partner.
10. (a) Context: An understudy for a new Broadway show planned to write a book about his experiences, and he had kept a notebook to document the progress of the show. / An understudy for a new Broadway show was waiting to rehearse a scene, and he began conversing with a violinist from the orchestra.
 (b) Target: The understudy showed the notebook to a violinist as he explained his latest project.
11. (a) Context: An assistant at the Four Seasons hotel made me angry because he could not give me the suite on the top floor when I arrived in New York. / An assistant was helping to run a conference, and he was approached by a historian who had not registered before the conference.
 (b) Target: The assistant reserved the suite for a historian early Tuesday morning.
12. (a) Context: A musician in the marching band learned how to knit last month, and this week he finished a blue wool scarf. / A musician in the marching band wanted to give a Christmas present to a teacher who had given him extra tutoring.
 (b) Target: The musician made the scarf for a teacher because of her help with music theory.
13. (a) Context: A student was taking several art classes, and in her photography course she had taken an exceptional photograph of a flower as part of a project. / A student was completing a research project involving qualitative study of a particular plant species with a well-known botanist from Brandeis.
 (b) Target: The student sent the photograph to a botanist after the completion of her project.
14. (a) Context: A surgeon who had worked in a bakery to pay his medical school tuition baked a delicious pie from scratch last Tuesday. / A surgeon who had worked in an airport to pay his medical school tuition invited a stewardess to his apartment last Tuesday.
 (b) Target: The surgeon served the pie to a stewardess after a romantic dinner.
15. (a) Context: An editor was enjoying a catered brunch, but he did not want his muffin, because he was dieting. / An editor had to leave a catered brunch early to meet with a typist, because he broke his wrist yesterday.
 (b) Target: The editor saved the muffin for a typist because she had not eaten.
16. (a) Context: A bartender was closing up at the end of the night, and he had only one remaining beer behind the bar. / A bartender was closing up at the end of the night, and he struck up a conversation with a dancer at the bar.
 (b) Target: The bartender offered the beer to a dancer because she looked lonely.
17. (a) Context: A waiter was the only person working in the restaurant on Tuesday night, so he had to make a salad for the first time in his career. / A waiter was the only person working in the restaurant on Tuesday night when a student came to the restaurant for dinner.
 (b) Target: The waiter prepared the salad for a student after clearing the tables.
18. (a) Context: A librarian received a novel for her birthday, but she already owned a copy of it. / A librarian was recataloguing her fiction collection with the help of a student who worked in the campus library every weekend.
 (b) Target: The librarian gave the novel to a student because she had two copies of it.
19. (a) Context: A skier was purchasing new equipment for the upcoming winter season, and he found a coupon in a catalog. / A skier wanted to purchase some new equipment for the upcoming winter season, so he wrote to a retailer in Wisconsin.

- (b) Target: The skier mailed the coupon to a retailer to get a 15% discount.
20. (a) Context: A secretary at a local church was putting together evangelical brochures and she was using a stapler to bind them. / A secretary at a local church was working extra hours to put together evangelical brochures with a priest on Thursday.
(b) Target: The secretary handed the stapler to a priest because he asked to use it.
21. (a) Context: A psychologist needed some extra help with a number of her experiments, so she hired an intern over the weekend. / A psychologist was running lots of experiments, and stacks of data were piling up on the desk of the statistician in charge of data analysis.
(b) Target: The psychologist assigned the intern to a statistician on Monday morning.
22. (a) Context: A little boy was at work with his mother, and he was very excited because she had just bought him a new toy with flashing lights. / A little boy was at work with his mother, and he was very excited because he was spending all day with a secretary in her office.
(b) Target: The boy showed the toy to a secretary because she asked to see it.
23. (a) Context: A security guard who worked at a local mall had witnessed the theft of a computer, and he was responsible for the videotape documenting the crime. / A security guard who worked at a local mall was investigating the theft of a computer, and he was collaborating with a technician at the police department.
(b) Target: The security guard mailed the videotape to a technician for digital analysis.
24. (a) Context: A cheerleader at UMass prepared for the biggest athletic event of the year by designing a banner on her computer. / A cheerleader at UMass was preparing for an athletic event because a popular swimmer was competing in his last meet.
(b) Target: The cheerleader made the banner for a swimmer because he was a national champion.
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- PO/Given-First: The chair offered the programmer to a statistician to help with data analysis.
DO/New-First: The chair offered a statistician the programmer to help with data analysis.
DO/Given-First: The chair offered the programmer a statistician to help with data analysis.
PO/New-First: The chair offered a statistician to the programmer to help with data analysis.
2. (a) Context: A salesman greeted a customer who had arrived at the store just before closing time.
(b) Target: The salesman showed the customer to a janitor because they had the same hat.
3. (a) Context: The director of an advertising agency met with a marketer who was working on an ad campaign.
(b) Target: The director assigned the marketer to a designer in order to help with another project.
4. (a) Context: A nurse witnessed a child throwing a violent fit in the inpatient ward.
(b) Target: The nurse sent the child to a counselor after consulting a doctor.
5. (a) Context: An assistant received a call from an accountant who had just arrived for an appointment.
(b) Target: The assistant brought the accountant to a lawyer in order to go over some files.
6. (a) Context: A laboratory supervisor was approached by a technician who needed help processing some samples.
(b) Target: The supervisor assigned the technician to a student so they could work together.
7. (a) Context: A manager met with an engineer who was concerned about the availability of building materials.
(b) Target: The manager brought the engineer to an architect so they could discuss the plans.
8. (a) Context: A recruiter asked an electrician if he was available to do contract work in September.
(b) Target: The recruiter sent the electrician to a carpenter in order to work on a small project.
9. (a) Context: An artist interviewed with a critic for a featured story in the local newspaper.
(b) Target: The artist showed the critic to a client because they resembled each other.
10. (a) Context: A government official was monitoring an agent who was working undercover in another country.
(b) Target: The official offered the agent to a contact so they could compare information.
11. (a) Context: An anthropologist arranged a meeting with the chief of a local indigenous tribe that she was studying.
(b) Target: The anthropologist brought the chief to an explorer so they could exchange information.

Appendix B. Materials used in Experiment 2

The context and target sentences for each of the stimuli used in Experiment 2 are shown below. Each of the four experimental conditions is illustrated for the first item only; the remaining items present only the target sentence for the PO/Given-First condition.

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1. (a) Context sentence: The chair of a physics department met with a programmer to discuss his role in a research project.
(b) Target sentence:

(continued on next page)

12. (a) Context: A prisoner stole a radio from the warden of the jail as part of his plan to obtain a uniform and escape in disguise.
(b) Target: The prisoner sent the warden to a guard so they would both be distracted.
13. (a) Context: A scientist was monitoring a cow to study how domesticated animals gather in herds.
(b) Target: The scientist brought the cow to a goat in order to see how they interacted.
14. (a) Context: A child owned a pet weasel that lived in a tiny cage and was poorly cared for.
(b) Target: The child fed the weasel to a snake so he could watch them fight.
15. (a) Context: A farmer was studying a goose that had been abandoned by its flock.
(b) Target: The farmer showed the goose to a turkey in order to see if they would cooperate.
16. (a) Context: A park ranger trapped a hyena as part of an annual cull of diseased animals.
(b) Target: The ranger threw the hyena to a lion in the park's feeding pen.
17. (a) Context: A show breeder owned a beagle that would howl if left alone, especially at night.
(b) Target: The breeder offered the beagle to a poodle so they could keep each other company.
18. (a) Context: A farmer was training a raven to control the pest population in his corn fields.
(b) Target: The farmer fed the raven to a ferret because the training was not working.
19. (a) Context: An emperor bought a pet tiger to compete in his gladiatorial arena.
(b) Target: The emperor threw the tiger to a bear as his evening entertainment.
20. (a) Context: A diver captured an eel in a bucket while he was searching a small bay for fossils.
(b) Target: The diver brought the eel to a tuna to see what they would do.
21. (a) Context: A biologist discovered an owl that seemed to belong to a new species.
(b) Target: The biologist showed the owl to a rat to gauge their reactions.
22. (a) Context: A rancher bought a horse because he wanted to diversify his herd.
(b) Target: The rancher gave the horse to a donkey to see if they would mate.
23. (a) Context: A hippie bought a sheep so he could gather his own wool.
(b) Target: The hippie offered the sheep to a pig because he thought they could be friends.
24. (a) Context: A tourist trapped a beaver when his annual fishing expedition started to get boring.
(b) Target: The tourist threw the beaver to a snake in violation of park regulations.

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