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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 30(30)

ISSN
1069-7977

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Publication Date
2008

Peer reviewed

Syntax and Discourse Constraints Interact at the Level of Structural Representation: Evidence from On-line Sentence Comprehension

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Abstract

The claim that contextually given information is preferred early in a sentence relative to new information has been discussed extensively in previous work. Syntactic alternations like the English dative alternation provide a mechanism for the realization of these information-structural word order preferences. We conducted two self-paced reading experiments to determine whether syntactic and information structures exert independent effects or interact in the on-line processing of the dative alternation. Experiment 1, which manipulated information structure (Given-First, New-First) in dative structures, revealed that information structure interacts with syntactic structure, such that the non-canonical double-object form is licensed only when it expresses the preferred given-before-new information structure. These results are consistent with two theories based on the granularity of the probabilistic use of available information in sentence processing: one based on structural dependency and one based on the tracking of surface statistics. Experiment 2, which manipulated information structure in dative structures with animate goals and themes, is consistent only with the predictions of the structure-level account. Taken together, these experiments provide a cognitive framework for the interaction between syntactic and discourse constraints at the level of structural representation.

Keywords: Sentence comprehension; information structure; word order; discourse; syntax

Introduction

Across languages, speakers encounter situations requiring them to choose rapidly and unconsciously among multiple syntactic structures that express the same meaning. Cases of syntactic optionality emerge even in rigid word order languages like English, in which word order is key to structural and semantic interpretation. For example, the dative alternation allows a proposition to be expressed in either the prepositional-object (PO) or the double-object (DO) form:

(1) PO: The queen offered a prize to the knight.
DO: The queen offered the knight a prize.

Optional structures like these incur learning and processing costs by enlarging the space of possible strings in a language and complicating the mapping between meaning and form. In most cases of syntactic optionality, one structure is less complex than the others. Given this asymmetry, why do languages provide non-canonical alternatives to canonical structures?

One explanation is that non-canonical structures exist to control the flow of information in discourse, such that contextually given information precedes new information. This claim has been discussed extensively in previous work (e.g., Clark & Clark, 1977; Givon, 1984; Lambrecht, 1994; Prince, 1999). Syntactic optionality provides a mechanism for the realization of given-before-new preferences. As an example, the alternation between the canonical PO and the non-canonical[1] DO forms in (1) provides flexibility in the ordering of the *theme* ("prize") and *goal* ("knight"), allowing the accommodation of given-before-new word order preferences determined by information structure.

How syntactic and information structures are represented is an open question in theories of linguistic representation. One plausible theory is that these two kinds of information are represented independently (e.g., implicit in Chomsky, 1981, 1986). If so, then processing should be easier in general within canonical syntactic forms and preferred discourse structures, but the two types of structures should not interact. Alternatively, if syntactic and information structures are represented together within the same structure (e.g., as in construction theory; Goldberg, 1995, 2006), then the two factors might interact in production and comprehension, such that information structure effects occur only within some syntactic structures and not others.

Evidence from production supports the proposal that syntactic and information structures are represented within the same structure. Corpus analyses show that given-before-new preferences are not symmetrically distributed across dative structures: Instead, they manifest much more strongly in the DO structure than in the PO structure (Collins, 1995; Bresnan et al., 2007), suggesting an interaction between syntactic and information-structural constraints in production. Whether these constraints interact in comprehension, however, is an open question. Fedorenko and Levy (2007) demonstrated independent effects of information structure (given-first, new-first) and syntactic structure (canonical word order, scrambled word order) in the self-paced reading of Russian main-clause sentences, with no evidence of constraint interaction for this construction. On the other hand, Finnish, a language that is similar to Russian in terms of word order flexibility, shows evidence for interaction between word order and given-before-new preferences, such that processing is only slowed when non-canonical syntactic structures express context-new information earlier than given information (Kaiser & Trueswell, 2004). Similarly, within the English dative alternation, new-before-old word order incurs a processing cost only within the non-canonical DO structure (Clifton

[1] Although the DO structure is more frequent than the PO structure (Collins, 1995; Bresnan, Cueni, Nikitina, & Baayen, 2007; Wasow, 1997), the DO structure incurs a processing cost relative to the PO structure (Arnold, Wasow, Losongco, & Ginstrom, 2000; Paterson, Filik, & Liversedge, in press). The higher frequency of DO structures results largely from the relatively high accessibility of goals (which are usually animate and pronominalized) compared to themes.

& Frazier, 2004). These two studies suggest that syntactic and information-structural constraints interact in on-line language processing, such that syntactic and information structures are represented together.

The experiments described below use the self-paced reading paradigm to investigate whether syntactic and information-structural constraints exert independent effects or interact in on-line comprehension. Experiment 1 confirms that syntax and information structure interact in the comprehension of the dative alternation. Experiment 2 then distinguishes between two hypotheses concerning the cognitive operations underlying this interaction by manipulating information structure in dative sentences with animate themes and goals. Taken together, these experiments show that syntactic and discourse constraints interact at the level of structural representation: The non-canonical DO structure is licensed in comprehension only when it expresses the given-before-new preferences determined by information structure.

Experiment 1

In Experiment 1, we manipulated information structure (Given-First, New-First) in DO and PO sentences containing an animate goal and an inanimate theme. If syntactic and information-structural constraints exert independent effects in on-line comprehension, we would expect main effects of syntactic form and information structure in on-line processing, such that New-First structures are processed more slowly than Old-First structures and DO structures are processed more slowly than PO structures. If syntactic and information structures are represented together, however, we would expect to see a dependent relation between these variables, such that DO/New-First sentences are processed more slowly than DO/Old-First or PO sentences.

Methods

Participants We recruited 123 participants from MIT and the surrounding community for the self-paced reading task, and 30 for a plausibility ratings 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 DO and PO 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.

(c) PO/New-First: The understudy showed a notebook to the violinist as he explained his ideas.

(d) 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 the manipulation of the objects' 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 avoid processing costs of the type repeated-name-penalty). 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 spillover effects persisting beyond the objects of each verb. This spillover 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), presented using Linger 2.88 software by Doug Rohde. 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-choice comprehension question. Participants received feedback after incorrect responses, and their accuracy was recorded. Each session lasted approximately 30 min.

In a separate task, 30 participants rated the plausibility of one version of each stimulus on a seven-point scale, to ensure that Context-Goal and Context-Theme stimuli were similarly plausible. The stimuli were intermixed with 106 filler items of varied syntax and plausibility.

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 participants was 94.9%, and mean performance did not vary by condition.

For RT analyses, we excluded all data points that were more than three standard deviations from the mean or corresponded to inaccurate responses to comprehension questions. Target sentences were divided into four regions for RT analysis. 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, including articles but not the preposition "to"), and the third region consisted of the second object. Finally, the spillover region included the 3-7 words following the second object, which were the same in all conditions. Figure 1 shows mean RTs for each region by condition.

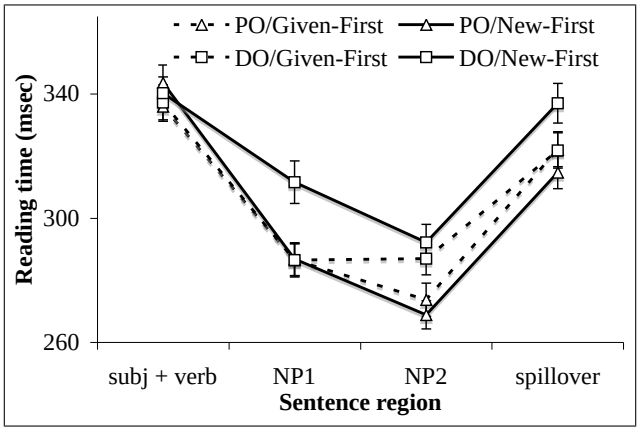

Figure 1: Mean reading times across target sentences in Experiment 1 ($\pm$ standard error).

We conducted 2x2 ANOVAs crossing syntactic structure (PO, DO) with word order (Given-First, New-First) across each of the four regions, generalizing across participants ($F1$) and items ($F2$). No reliable differences were found in the first region, which was identical across conditions. Analysis of the second region (NP1) revealed main effects of structure ($F1(1,119) = 22.815$, $p < .0005$; $F2(1,23) = 5.921$, $p < .05$) and word order ($F1(1,119) = 20.455$, $p < .0005$; $F2(1,23) = 18.111$, $p < .0005$), as well as an interaction between structure and word order ($F1(1,119) = 20.266$, $p < .0005$; $F2(1,23) = 7.897$, $p < .01$). Simple effects tests showed that the interaction in the NP1 region was driven by the DO/New-First condition, which was read more slowly than the other three conditions ($t1(119) = 5.674$, $p < .0005$; $t2(23) = 3.910$, $p < .001$). In the third region (NP2), we found only a main effect of structure ($F1(1,119) = 56.826$, $p < .0005$; $F2(1,23) = 20.617$, $p < .0005$), with DO structures being read more slowly than the PO structures. In the spillover region, the main effect of structure persisted ($F1(1,119) = 17.150$, $p < .0005$; $F2(1,23) = 8.290$, $p < .01$), and the interaction between structure and word order reemerged ($F1(1,119) = 21.378$, $p < .0005$; $F2(1,23) = 9.313$, $p < .01$). Post-hoc comparisons revealed a crossover interaction in this region: DO/New-First sentences were read more slowly than DO/Given-First sentences ($t1(119) = 3.868$, $p < .0005$; $t2(23) = 2.382$, $p < .05$), and PO/Given-First sentences were read more slowly than PO/New-First sentences ($t1(119) = 2.261$, $p < .05$; $t2(23) = 2.415$, $p < .05$).

For plausibility analyses, a two-tailed paired t test revealed no differences in plausibility ratings between Goal-Context and Theme-Context stimuli ($t(23) = 0.503$, $p > .6$).

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 replicate previous findings that DO structures are harder to process overall than PO structures, and also 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), are unlikely to have resulted from semantic or pragmatic differences between Goal-Context and Theme-Context items, because plausibility ratings did not differ between conditions. Our results therefore indicate that syntactic and discourse information interact in the comprehension of the dative alternation.

This interaction suggests that syntactic and information structures are represented together in one structure. It is possible, however, that comprehenders are using information from surface-level statistics to generate probabilistic structural inferences in a way that disfavors the statistically infrequent DO/New-First condition. By this account, the observed interaction between syntactic and information structures may be an emergent property of the use of frequency-based heuristics to ease the processing of common combinations of animate and given words. This hypothesis is mechanistically plausible, given that comprehenders have been shown to use similar sources of local coherence information in on-line comprehension (e.g., Tabor et al., 2004). Further, the theoretical importance of this surface-level account should not be underestimated. It falls into the class of emergentist accounts that have gained popularity in cognitive science in recent years (Bates, Elman, Johnson, & Karmiloff-Smith, 1998). According to emergentists, large-scale grammatical patterns are merely epiphenomenal consequences of complex statistical patterns. Thus, the surface-level hypothesis may be argued to be more parsimonious, since it avoids postulating structure-level generalizations and instead seeks to explain patterns at the surface, feature-cooccurrence level.

Below, we describe these structure-based and surface-based accounts of how information from the discourse may be used in the on-line processing of the dative alternation. These accounts are based on the granularity of the probabilistic use of available information in on-line sentence processing.

The structure-level hypothesis The structure-level hypothesis assumes that syntactic and information structures are represented within the same structure, yielding the prediction that non-canonical syntactic structures that violate information-structural constraints incur a cost in processing. The structure-level model therefore predicts the processing cost associated with DO/New-First items in Experiment 1, because these items violate the given-before-new constraint within the non-canonical DO structure.

The surface-level hypothesis The data from Experiment 1 are also consistent with a second account, whereby the interaction between syntactic and information-structural constraints is an emergent property of the tracking of combinations of animacy and information structure within alternating syntactic forms. Three patterns of note appear in the statistical distribution of dative structures: (a) Goals are almost always animate; (b) Themes are usually inanimate; and (c) DO-goals are usually contextually given (cf. Bresnan et al., 2007). The comprehender can use these sources of information to predict the syntactic structure of a sentence prior to its full syntactic disambiguation by means of two heuristics. First, when a dative verb is followed by an inanimate entity, the structure is likely to be PO. Using this heuristic, the comprehender can correctly predict the PO structure in the PO/Given-First and PO/New-First conditions of Experiment 1, when "The understudy showed" is immediately followed by "the notebook" or " a notebook." Second, when a dative verb is followed by a contextually given animate entity, the structure is likely to be DO. The use of this heuristic results in a correct structural prediction in the DO/Old-First condition ("The understudy showed the violinist..."). Notably, neither of these two heuristics offers a structural prediction for sentences in which a dative verb is followed by a context-new animate entity, as in the DO/New-First condition ("The understudy showed a violinist..."). Because the comprehender is thought to be sensitive to the statistical infrequency of this verb-NP combination, processing costs are correctly predicted in the NP1 region of the DO/New-First condition.

Experiment 2

Because both the structure-level and surface-level accounts accurately predict the pattern of results obtained in Experiment 1, we conducted a similar experiment in which both themes and goals were animate in order to distinguish between the two hypotheses. Under these conditions, the structure-level model predicts slowed RTs in the DO/New-First condition alone. The surface-level model, on the other hand, predicts two sources of processing costs. First, both New-First conditions should generate a processing cost following the verb, because of the statistical infrequency of context-new animate entities immediately following a dative verb. Second, slowed RTs are predicted in the PO/Old-First condition: Upon hearing a contextually given animate entity immediately after a dative verb, the comprehender should inaccurately expect an upcoming DO structure, and the subsequent structural disambiguation should result in a reanalysis-based processing cost relatively late in the sentence.

Methods

Participants We recruited 48 participants for the self-paced reading task and 30 for a plausibility ratings 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. In half of the 24 stimuli, the goals and themes referred to human entities, and in the other half, they referred to animals.

Procedure The procedures for the self-paced reading and plausibility ratings tasks were the same as Experiment 1.

Results

Data from 6 participants in the self-paced reading study were excluded from analysis due to poor comprehension task performance (overall accuracy $< 70\%$). Mean accuracy across all participants was 86.3%, and mean performance did not differ across conditions. For RT analyses, data points corresponding to incorrect responses were excluded, as were data points that fell more than three standard deviations from the mean. The sentences were divided into four regions as in Experiment 1. Figure 2 shows mean RTs by region and condition.

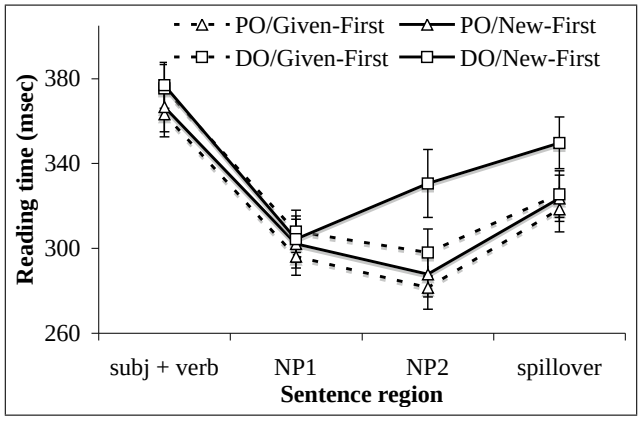

Figure 2: Mean reading times across target sentences in Experiment 2 ($\pm$ standard error).

We conducted 2x2 ANOVAs crossing structure (PO, DO) with word order (Given-First, New-First) across each of the four regions. No significant differences were found in the first or second regions. In the third region (NP2), we found a statistically significant interaction between structure and word order ($F1(1,41) = 4.432$, $p < .05$; $F2(1,23) = 5.505$, $p < .05$), driven by higher RTs in the DO/New-First condition than in the other conditions ($t1(32) = 3.475$, $p < .005$; $t2(23) = 3.315$, $p < .005$). This interaction contributed to main effects of structure ($F1(1,41) = 26.788$, $p < .0005$; $F2(1,23) = 19.329$, $p < .0005$) and word order ($F1(1,41) = 11.8$, $p < .001$; $F2(1,23) = 4.415$, $p < .05$) in this region. In the spillover region, only a main effect of structure was reliable ($F1(1,41) = 14.441$, $p < .0005$; $F2(1,23) = 6.552$, $p < .05$), but a main effect of word order was detected in the participants-based analysis ($F1(1,41) = 10.590$, $p < .005$; $F2(1,23) = 2.338$, $p > .1$).

Plausibility analyses again revealed no differences in ratings between Goal-Context and Theme-Context stimuli ($t(23) = 0.250$, $p > .8$).

Discussion

In Experiment 2, we manipulated information structure in dative sentences with animate themes and recipients to distinguish between the predictions of two hypotheses about the cognitive processes underlying the interaction between discourse and syntactic constraints in on-line comprehension. Our results again showed a main effect of structure: DO structures are reliably harder to process than PO structures. More interestingly, we found evidence for a processing cost in the DO/New-First relative to the other three conditions, as in Experiment 1. For comparison, Experiments 1 and 2 both revealed a processing cost in the DO/New-First condition, with the resulting slowdown in RTs occurring slightly later in Experiment 2 (NP2) than in Experiment 1 (NP1).

The goal of Experiment 2 was to distinguish between the predictions of two theories of the cognitive operations underlying the interaction between syntactic and information-structural constraints. Below, we discuss the results of Experiment 2 in terms of each of these theories.

The structure-based hypothesis The patterns of data obtained in Experiment 2 are consistent with the structure-based proposal, which predicts that non-canonical structures should only be appropriate in comprehension when they expresses discourse constraints better than canonical structures. This hypothesis licenses DO/Old-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.

Critically, the structure-based hypothesis does not rule out the use of any surface-based statistics in on-line processing. In fact, statistical expectations can explain why the slowdown in the DO/New-First condition appears at the NP1 position in Experiment 1, before the syntactic structure is fully disambiguated. After encountering the dative verb in the DO/New-First condition, the comprehender expects the inanimate entity introduced in the Theme-Context to reappear as the theme of the verb to maintain discourse continuity. After then encountering a new animate entity in the NP1 position, the comprehender has enough information to infer the syntactic and information structures of the sentence, based on the knowledge that inanimate entities are statistically unlikely to be goals. Because all given entities are animate in Experiment 2, this disambiguation cannot occur before the second NP is revealed.

The surface-based hypothesis Our results do not, however, match the predictions of the surface-based model. This theory predicts two sources of processing difficulty in Experiment 2. First, in conditions in which a context-new animate referent immediately follows a dative verb (PO/New-First, DO/New-First), the surface-based model predicts a slowdown in processing speed, given the assumption that the comprehender is sensitive to the statistical infrequency of context-new animate referents immediately following dative verbs. Second, in the PO/Old-First condition, the comprehender incorrectly predicts a DO structure upon encountering a contextually given animate referent immediately following the verb, due to the statistical association between given animate entities and DO-goals. In the PO/Old-First condition, therefore, the structural reanalysis necessary to recover from this incorrect prediction should result in relatively slow RTs in the NP2 sentence region or later, compared to the PO/New-First condition. The only condition in which RTs are relatively slow in Experiment 2, however, is the DO/New-First condition. The data are therefore not consistent with either prediction of the surface-based model.

Conclusions

The goal of this study was to determine whether syntax and discourse constraints interact in sentence processing, and if so, whether this interaction occurs at the level of structure- or surface-based representations. To this end, we conducted two self-paced reading experiments in which information structure was manipulated within dative structures. The stimuli in Experiment 1 comprised typical dative sentences, with inanimate themes and animate goals, and our results from this experiment confirm previous reports that syntactic and information-structural constraints interact in on-line comprehension (Clifton & Frazier, 2004; Kaiser & Trueswell, 2004). Critically, Experiment 2 contained dative sentences with animate themes and goals, which allowed us to test the differing predictions of the structure-level and surface-level hypotheses. Our results from Experiment 2 support the interaction of syntactic and discourse constraints at the level of structural representation.

According to the surface-level hypothesis, the interaction between syntax and information structure is an epiphenomenal consequence of the tracking of animacy and givenness statistics within alternating syntactic structures. Statistically

frequent combinations lead to heuristics that the comprehender can use to predict the syntactic structure of a sentence prior to the full syntactic disambiguation of that sentence. Two predictions of the surface-level hypothesis were tested in Experiment 2. First, because comprehenders should be sensitive to the statistically infrequent combination of a dative verb and a context-new entity, the surface-level hypothesis predicts that this sensitivity should manifest in slowed RTs following the verb in the DO/New-First and PO/New-First conditions. This prediction is not consistent with our data, which show slowed RTs in only the DO/New-First condition. Second, the surface-level hypothesis holds that the combination of a dative verb and a contextually given animate entity should generate an expectation for a DO structure, resulting in a reanalysis-based processing cost at the NP2 position or later in the PO/Given-First condition. The processing cost predicted to result from this reanalysis does not appear in our data.

The structure-level hypothesis, on the other hand, is consistent with results from both experiments. The main prediction of this theory is that a processing cost should arise when non-canonical syntactic structures, like the DO form, express dispreferred discourse structures, like new-before-given word order. This situation only occurs in the DO/New-First conditions of Experiments 1 and 2, so this hypothesis correctly predicts the processing slowdown observed in the DO/New-First condition in both experiments. These data are consistent with the theory that syntactic and information-structural constraints are represented together within one structure.

Taken together, these experiments provide a cognitive framework for the interaction between syntactic and discourse constraints at the level of structural representation. Non-canonical structures like the DO structure exist to realize information-structural constraints, and they are only licensed when these constraints are satisfied.

Acknowledgments

We gratefully acknowledge Mara Breen, Charles Clifton, Timothy Desmet, Evelina Fedorenko, Vic Ferreira, Michael Frank, Florian Jaeger, Laura Kertz, Jeff Runner, Michael Tanenhaus, three anonymous reviewers, and the audiences at CUNY 2007 and 2008 for helpful discussions of this work.

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