

# Grammatical Analysis of Pretrained Sentence Encoders with Acceptability Judgments

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## Abstract

Recent pretrained sentence encoders achieve state of the art results on language understanding tasks, but does this mean they have implicit knowledge of syntactic structures? We introduce a grammatically annotated development set for the Corpus of Linguistic Acceptability (CoLA; Warstadt et al., 2018), which we use to investigate the grammatical knowledge of three pretrained encoders, including the popular OpenAI Transformer (Radford et al., 2018) and BERT (Devlin et al., 2018). We fine-tune these encoders to do acceptability classification over CoLA and compare the models' performance on the annotated analysis set. Some phenomena, e.g. modification by adjuncts, are easy to learn for all models, while others, e.g. long-distance movement, are learned effectively only by models with strong overall performance, and others still, e.g. morphological agreement, are hardly learned by any model.

## 1 Introduction

The effectiveness and ubiquity of pretrained sentence embeddings for natural language understanding has grown dramatically in recent years. Recent sentence encoders like OpenAI's Generative Pretrained Transformer (GPT; Radford et al., 2018) and BERT (Devlin et al., 2018) achieve the state of the art on the GLUE benchmark (Wang et al., 2018). Among the GLUE tasks, these state-of-the-art systems make their greatest gains on the *acceptability task* with the Corpus of Linguistic Acceptability (CoLA; Warstadt et al., 2018). CoLA contains example sentences from linguistics publications labeled by experts for grammatical acceptability, and written to show subtle grammatical features. Because minimal syntactic differences can separate acceptable sentences from unacceptable ones (*What did Bo write a book about? / \*What was a book about written by*

*Bo?*), and acceptability classifiers are more reliable when trained on GPT and BERT than on recurrent models, it stands to reason that GPT and BERT have better implicit knowledge of syntactic features relevant to acceptability.

Our goal in this paper is to develop an evaluation dataset that can locate which syntactic features that a model successfully learns by identifying the syntactic domains of CoLA in which it performs the best. Using this evaluation set, we compare the syntactic knowledge of GPT and BERT in detail, and investigate the strengths of these models over the baseline BiLSTM model published by Warstadt et al. (2018). The analysis set includes expert annotations labeling the entire CoLA development set for the presence of 63 fine-grained syntactic features.

We identify many specific syntactic features that make sentences harder to classify, and many that have little effect. For instance, sentences involving unusual or marked argument structures are no harder than the average sentence, while sentences with long distance dependencies are hard to learn. We also find features of sentences that accentuate or minimize the differences between models. Specifically, the transformer models seem to learn long-distance dependencies much better than the recurrent model, yet have no advantage on sentences with morphological violations.

## 2 Related Work

**Sentence Embeddings** Robust pretrained word embeddings like word2vec (Mikolov et al., 2013) and GloVe (Pennington et al., 2014) have been extremely successful and widely adopted in machine learning applications for language understanding. Recent research tries to reproduce this success at the sentence level, in the form of reusable sentence embeddings with pretrained weights. These rep-

Acceptability Sentence	Simple	Locative	PP Arg-VP	High Arity	Passive	Binding:Other	Emb Q	Complex QP	Modal	Raising	Trans-Adj	Coord	Ellipsis/Anaphor	Comparative	Infl/Agr Violation	Extra/Missing Expr
✓ The magazines were sent by Mary to herself.			X	X	X											
✓ John can kick the ball.									X							
* I know that Meg's attracted to Harry, but they don't know who.			X				X					X	X			
✓ They kicked them	X					X										
✓ Which topic did you choose without getting his approval?								X								
* It was believed to be illegal by them to do that.				X	X					X	X					
* Us love they.	X														X	
* The more does Bill smoke, the more Susan hates him.						X								X	X	X
✓ I ate a salad that was filled with lima beans.		X	X	X												
✓ That surprised me.	X															

Table 1: A random sample of sentences from the CoLA development set, shown with their original acceptability labels (✓= acceptable, \*=unacceptable) and with a subset of our new phenomenon-level annotations.

resentations are useful for language understanding tasks that require a model to classify a single sentence, as in sentiment analysis and acceptability classification; or a pair of sentences, as in paraphrase detection and natural language inference (NLI); or that require a model to generate text based on an input text, as in question-answering.

Early work in this area primarily uses recurrent models like Long Short-Term Memory (Hochreiter and Schmidhuber, 1997, LSTM) networks to reduce variable length sequences into fixed-length sentence embeddings. Current state of the art sentence encoders are pretrained on language modeling or related tasks with unlabeled-data. Among these, ELMo (Peters et al., 2018) uses a BiLSTM architecture, while GPT (Radford et al., 2018) and BERT (Devlin et al., 2018) use the Transformer architecture (Vaswani et al., 2017). Unlike most earlier approaches where the weights of the encoder are frozen after pretraining, the last two fine-tune the encoder on the downstream task. With additional fine-tuning on secondary tasks like NLI, these are the top performing models on the GLUE benchmark (Phang et al., 2018).

**Sentence Embedding Analysis** The evaluation and analysis of sentence embeddings is an active area of research. One branch of this work uses probing tasks which can reveal how much syntactic information a sentence embedding encodes about, for instance, tense and voice (Shi et al., 2016), sentence length and word content (Adi et al., 2017), or syntactic depth and morphological number (Conneau et al., 2018).

Related work indirectly probes features of sentence embeddings using language understanding tasks with custom datasets manipulating specific grammatical features. Linzen et al. (2016) uses several tasks including acceptability classification of sentences with manipulated verbal inflection to investigate whether LSTMs can identify violations in subject-verb agreement, and therefore a (potentially long distance) syntactic dependency. Ettinger et al. (2018) test whether sentence embeddings encode the scope of negation and semantic roles using semi-automatically generated sentences exhibiting carefully controlled syntactic variation. Kann et al. (2019) also semi-automatically generate data and use acceptability classification to test whether word and sentence embeddings encode information about verbs and their argument structures.

**CoLA & Acceptability Classification** The Corpus of Linguistic Acceptability (Warstadt et al., 2018) is a dataset of 10k example sentences including expert annotations for grammatical acceptability. The sentences are example sentences taken from 23 theoretical linguistics publications, mostly about syntax, including undergraduate textbooks, research articles, and dissertations. Such example sentences are usually labeled for acceptability by their authors or a small group of native English speakers. A small random sample of the CoLA development set (with our added annotations) can be seen in Table 1.

Within computational linguistics, the acceptability classification task has been explored in var-

ious settings. Lawrence et al. (2000) train RNNs to do acceptability classification over sequences of POS tags corresponding to example sentences from a syntax textbook. Wagner et al. (2009) also train RNNs, but using naturally occurring sentences that have been automatically manipulated to be unacceptable. Lau et al. (2016) predict acceptability from language model probabilities, applying this technique to sentences from a syntax textbook, and sentences which were translated round-trip through various languages.

Lau et al. attempt to model gradient crowd-sourced acceptability judgments, rather than binary expert judgments. This reflects an ongoing debate about whether binary expert judgments like those in CoLA are reliable (Gibson and Fedorenko, 2010; Sprouse and Almeida, 2012). We remain agnostic as to the role of binary judgments in linguistic theory, taking the expert judgments in CoLA at face value. However, Warstadt et al. (2018) measure human performance on a subset of CoLA (see Table 4), finding that new human annotators, while not in perfect agreement with the judgments in CoLA, still outperform the best neural network models by a wide margin.

### 3 Analysis Set

We introduce a grammatically annotated version of the entire CoLA development set to facilitate detailed error analysis of acceptability classifiers. These 1043 sentences are expert-labeled for the presence of 63 minor grammatical features organized into 15 major features. Each minor feature belongs to a single major feature. A sentence belongs to a major feature if it belongs to one or more of the relevant minor features. The Appendix includes descriptions of each feature along with examples and the criteria used for annotation.

The 63 minor features and 15 major features are illustrated in Table 2. Considering minor features, an average of 4.31 features is present per sentence (SD=2.59). The average feature is present in 71.3 sentences (SD=54.7). Turning to major features, the average sentence belongs to 3.22 major features (SD=1.66), and the average major feature is present in 224 sentences (SD=112). Every sentence is labeled with at least one feature.

#### 3.1 Annotation

The sentences were annotated manually by one of the authors, who is a PhD student with extensive

training in formal linguistics. The features were developed in a trial stage, in which the annotator performed a similar annotation with different annotation schema for several hundred sentences from CoLA not belonging to the development set.

#### 3.2 Feature Descriptions

Here we briefly summarize the feature set in order of the major features. Many of these constructions are well-studied in syntax, and further background can be found in textbooks such as Adger (2003) and Sportiche et al. (2013).

**Simple** This major feature contains only one minor feature, SIMPLE, including sentences with a syntactically simplex subject and predicate.

**Pred(icate)** These three features correspond to predicative phrases, including copular constructions, small clauses (*I saw Bo jump*), and resultatives/depictives (*Bo wiped the table clean*).

**Adjunct** These six features mark various kinds of optional modifiers. This includes modifiers of NPs (*The boy with blue eyes gasped*) or VPs (*The cat meowed all morning*), and temporal (*Bo swam yesterday*) or locative (*Bo jumped on the bed*).

**Argument types** These five features identify syntactically selected arguments, differentiating, for example, obliques (*I gave a book to Bo*), PP arguments of NPs and VPs (*Bo voted for Jones*), and expletives (*It seems that Bo left*).

**Argument Alternations** These four features mark VPs with unusual argument structures, including added arguments (*I baked Bo a cake*) or dropped arguments (*Bo knows*), and the passive (*I was applauded*).

**Imperative** This contains only one feature for imperative clauses (*Stop it!*).

**Bind** These are two minor features, one for bound reflexives (*Bo loves himself*), and one for other bound pronouns (*Bo thinks he won*).

**Question** These five features apply to sentences with question-like properties. They mark whether the interrogative is an embedded clause (*I know who you are*), a matrix clause (*Who are you?*), or a relative clause (*Bo saw the guy who left*); whether it contains an island out of which extraction is unacceptable (*\*What was a picture of hanging on the wall?*); or whether there is pied-piping or a multi-word *wh*-expressions (*With whom did you eat?*).

Major Feature ( <i>n</i> )	Minor Features ( <i>n</i> )
<b>Simple (87)</b>	Simple (87)
<b>Pred (256)</b>	Copula (187), Pred/SC (45), Result/Depictive (26)
<b>Adjunct (226)</b>	Particle (33), VP Adjunct (162), NP Adjunct (52), Temporal (49), Locative (69), Misc Adjunct (75)
<b>Arg Types (428)</b>	Oblique (141), PP Arg VP (242), PP Arg NP/AP (81), by-Phrase (58), Expletive (78)
<b>Arg Altern (421)</b>	High Arity (253), Drop Arg (112), Add Arg (91), Passive (114)
<b>Imperative (12)</b>	Imperatives (12)
<b>Bind (121)</b>	Binding:Refl (60), Binding:Other (62)
<b>Question (222)</b>	Matrix Q (56), Emb Q (99), Pied Piping (80), Rel Clause (76), Island (22)
<b>Comp Clause (190)</b>	CP Subj (15), CP Arg VP (110), CP Arg NP/AP (26), Non-finite CP (24), No C-izer (41), Deep Embed (30)
<b>Auxiliary (340)</b>	Neg (111), Modal (134), Aux (201), Psuedo-Aux (26)
<b>to-VP (170)</b>	Control (80), Raising (19), VP+Extract (26), VP Arg NP/AP (33), Non-finite VP Misc (38)
<b>N, Adj (278)</b>	Deverbal (53), Rel NP (65), Trans NP (21), Comp NP (106), NNCompd (35), Rel Adj (26), Trans Adj (39)
<b>S-Syntax (286)</b>	Dislocation (56), Info Struc (31), Frag/Paren (9), Coord (158), Subordinate/Cond (41), Ellipsis/Anaphor (118), S-Adjunct (30)
<b>Determiner (178)</b>	Quantifier (139), Partitive (18), NPI/FCI (29), Comparative (25)
<b>Violations (145)</b>	Sem Violation (31), Infl/Agr Violation (62), Extra/Missing Expr (65)

Table 2: Major features and their associated minor features (with number of occurrences *n*).

**Comp(lement) Clause** These six features apply to various complement clauses (CPs), including subject CPs (*That Bo won is odd*); CP arguments of VPs or NPs/APs (*The fact that Bo won*); CPs missing a complementizer (*I think Bo’s crazy*); or non-finite CPs (*This is ready for you to eat*).

**Aux(iliary)** These four minor features mark the presence of auxiliary or modal verbs (*I can win*), negation, or “pseudo-auxiliaries” (*I have to win*).

**to-VP** These five features mark various infinitival embedded VPs, including control VPs (*Bo wants to win*); raising VPs (*Bo seemed to fly*); VP arguments of NPs or APs (*Bo is eager to eat*); and VPs with extraction (e.g. *This is easy to read* \_).

**N(oun), Adj(ective)** These seven features mark complex NPs and APs, including ones with PP arguments (*Bo is fond of Mo*), or CP/VP arguments; noun-noun compounds (*Bo ate mud pie*); modified NPs, and NPs derived from verbs (*Baking is fun*).

**S-Syntax** These seven features mark various unrelated syntactic constructions, including dislocated phrases (*The boy left who was here earlier*); movement related to focus or information structure (*This I’ve gotta see* \_); coordination, subordinate clauses, and ellipsis (*I can’t*); or sentence-level adjuncts (*Apparently, it’s raining*).

**Determiner** These four features mark various determiners, including quantifiers, partitives (*two of the boys*), negative polarity items (*I \*do/don’t have any pie*), and comparative constructions.

**Violations** These three features apply only to unacceptable sentences, and only ones which are ungrammatical due to a semantic or morphological violation, or the presence or absence of a single salient word.

### 3.3 Correlations

We wish to emphasize that these features are overlapping and in many cases are correlated, thus not all results from using this analysis set will be independent. We analyzed the pairwise Matthews Correlation Coefficient (MCC; Matthews, 1975) of the 63 minor features (giving 1953 pairs), and of the 15 major features (giving 105 pairs). MCC is a special case of Pearson’s *r* for Boolean variables.<sup>1</sup> These results are summarized in Table 3. Regarding the minor features, 60 pairs had a correlation of 0.2 or greater, 17 had a correlation of 0.4 or greater, and 6 had a correlation of 0.6 or greater. None had an anti-correlation of greater magnitude than -0.17. Turning to the major features, 6 pairs had a correlation of 0.2 or greater, and 2 had an anti-correlation of greater magnitude than -0.2.

We can see at least three reasons for these observed correlations. First, some correlations can be attributed to overlapping feature definitions. For instance, EXPLETIVE arguments (e.g. *There are birds singing*) are, by definition, non-canonical arguments, and thus are a subset of ADD ARG.

<sup>1</sup>MCC measures correlation of two binary distributions, giving a value between -1 and 1. On average, any two unrelated distributions will have a score of 0, regardless of class imbalance. This is contrast to metrics like accuracy or F1, which favor classifiers with a majority-class bias.



Label 1	Label 2	MCC
<b>Minor Features</b>		
PP Arg NP/AP	Rel NP	0.755
by-Phrase	Passive	0.679
Coord	Ellipsis/Anaphor	0.634
VP Arg NP/AP	Trans Adj	0.628
NP Adjunct	Comp NP	0.623
Oblique	High Arity	0.620
RC	Comp NP	0.565
Expletive	Add Arg	0.558
CP Arg NP/AP	Trans NP	0.546
PP Arg NP/AP	Rel Adj	0.528
VP Adjunct	Temporal	0.518
Oblique	PP Arg VP	0.507
VP Adjunct	Misc Adjunct	0.485
Emb Q	Ellipsis/Anaphor	0.463
VP Adjunct	Locative	0.418
Drop Arg	Passive	0.414
Matrix Q	Pied Piping	0.411
<b>Major Features</b>		
Argument Types	Arg Altern	0.406
Question	Auxiliary	0.273
Question	S-Syntax	0.232
Predicate	N, Adj	0.231
Auxiliary	S-Syntax	0.224
Question	N, Adj	0.211
Simple	Arg Altern	-0.227
Simple	Argument Types	-0.238

Table 3: Correlation (MCC) of features in the annotated analysis set. We display only the correlations with the greatest magnitude.

However, some added arguments, such as benefactives (*Bo baked Mo a cake*), are not expletives. Second, some correlations can be attributed to grammatical properties of the relevant constructions. For instance, QUESTION and AUX are correlated because main-clause questions in English require subject-aux inversion and in many cases the insertion of auxiliary *do* (*Do lions meow?*). Third, some correlations may be a consequence of the sources sampled in CoLA and the phenomena they focus on. For instance, the unusually high correlation of EMB-Q and ELLIPSIS/ANAPHOR can be attributed to (Chung et al., 1995), which is an article about the sluicing construction involving ellipsis of an embedded interrogative (e.g. *I saw someone, but I don't know who*).

Finally, two strongest anti-correlations between major features are between SIMPLE and the two features related to argument structure, ARGUMENT TYPES and ARG ALTERN. This follows from the definition of SIMPLE, which excludes any sentence containing a large number or unusual configuration of arguments.

## 4 Models Evaluated

We train MLP acceptability classifiers for CoLA on top of three sentence encoders: (1) the CoLA baseline encoder with ELMo-style embeddings, (2) OpenAI GPT, and (3) BERT. We use publicly available sentence encoders with pretrained weights.<sup>2</sup>

**LSTM encoder: CoLA baseline** The CoLA baseline model is the sentence encoder with the highest performance on CoLA from Warstadt et al. The encoder uses a BiLSTM, which reads the sentence word-by-word in both directions, with max-pooling over the hidden states. Similar to ELMo (Peters et al., 2018), the inputs to the BiLSTM are the hidden states of a language model (only a forward language model is used in contrast with ELMo). The encoder is trained on a real/fake discrimination task which requires it to identify whether a sentence is naturally occurring or automatically generated. We train acceptability classifiers on CoLA using the CoLA baselines codebase with 20 random restarts, following the original authors' transfer-learning approach: The sentence encoder's weights are frozen, and the sentence embedding serves as input to an MLP with a single hidden layer. All hyperparameters are held constant across restarts.

**Transformer encoders: GPT and BERT** In contrast with recurrent models, GPT and BERT use a self attention mechanism which combines representations for each (possibly non-adjacent) pair of words to give a sentence embedding. GPT is trained using a standard language modeling task, while BERT is trained with masked language modeling and next sentence prediction tasks. For each encoder, we use the *jiant* toolkit<sup>3</sup> to train 20 random restarts on CoLA feeding the pretrained models published by these authors into a single output layer. Following the methods of the original authors, we fine-tune the encoders during training on CoLA. All hyperparameters are held constant across restarts.

<sup>2</sup>CoLA baseline: <https://github.com/nyu-mll/CoLA-baselines>  
 OpenAI GPT: <https://github.com/openai/finetune-transformer-lm>  
 BERT: <https://github.com/google-research/bert>

<sup>3</sup><https://github.com/jsalt18-sentence-repl/jiant>

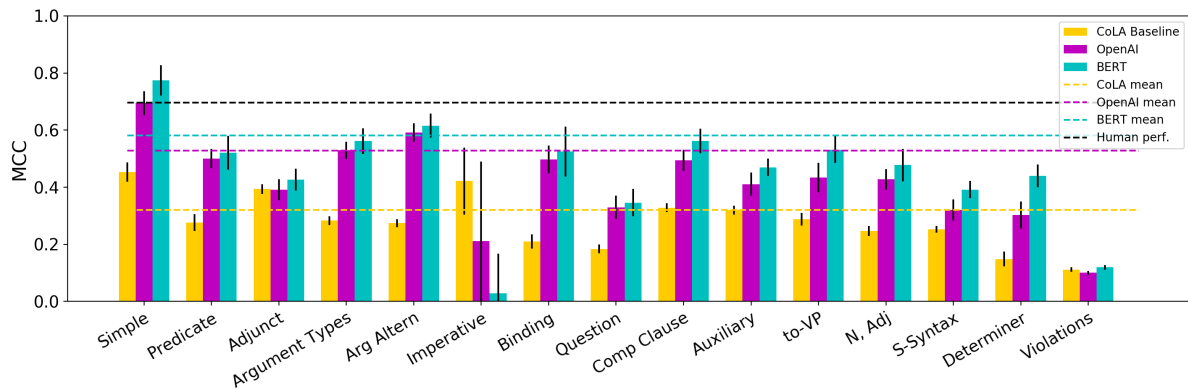


Figure 1: Performance (MCC) on CoLA analysis set by major feature. Dashed lines show mean performance on all of CoLA.

	Mean (STD)	Max	Ensemble
CoLA	0.320 (0.007)	0.330	0.320
GPT	0.528 (0.023)	0.575	0.567
BERT	<b>0.582</b> (0.032)	<b>0.622</b>	<b>0.601</b>
Human	0.697 (0.042)	0.726	0.761

Table 4: Performance (MCC) on the CoLA test set, including mean over restarts of a given model with standard deviation, max over restarts, and majority prediction over restarts. Human performance is measured by Warstadt et al.

## 5 Results

### 5.1 Overall CoLA Results

The overall performance of the three sentence encoders is shown in Table 4. Performance on CoLA is measured using MCC (Warstadt et al., 2018). We present the best single restart for each encoder, the mean over restarts for an encoder, and the result of ensembling the restarts for a given encoder, i.e. taking the majority classification for a given sentence, or the majority label of *acceptable* if tied.<sup>4</sup> For BERT results, we exclude 5 out of the 20 restarts because they were degenerate (MCC=0).

Across the board, BERT outperforms GPT, which outperforms the CoLA baseline. However, BERT and GPT are much closer in performance than they are to CoLA baseline. While ensemble performance exceeded the average for BERT and GPT, it did not outperform the best single model.

### 5.2 Analysis Set Results

The results for the major features and minor features are shown in Figures 1 and 2, respectively.

<sup>4</sup>Because we use the development set for analysis, we do not use it to weight models for weighted ensembling.

For each feature, we measure the MCC of the sentences including that feature. We plot the mean of these results across the different restarts for each model, and error bars mark the mean  $\pm 1$  standard deviation. For the VIOLATIONS features, MCC is technically undefined because these features only contain unacceptable sentences. We report MCC in these cases by including for each feature a single acceptable example that is correctly classified by all models.

Comparison across features reveals that the presence of certain features has a large effect on performance, and we comment on some overall patterns below. Within a given feature, the effect of model type is overwhelmingly stable, and resembles the overall difference in performance. However, we observe several interactions, i.e. specific features where the relative performance of models does not track their overall relative performance.

**Comparing Features** Among the major features (Figure 1), performance is universally highest on the SIMPLE sentences, and is higher than each model’s overall performance. Though these sentences are simple, we notice that the proportion of ungrammatical ones is on par with the entire dataset. Otherwise we find that a model’s performance on sentences of a given feature is on par with or lower than its overall performance, reflecting the fact that features mark the presence of unusual or complex syntactic structure.

Performance is also high (and close to overall performance) on sentences with marked argument structures (ARGUMENT TYPES and ARG(UMENT) ALT(ERNATION)). While these models are still worse than human (overall) per-

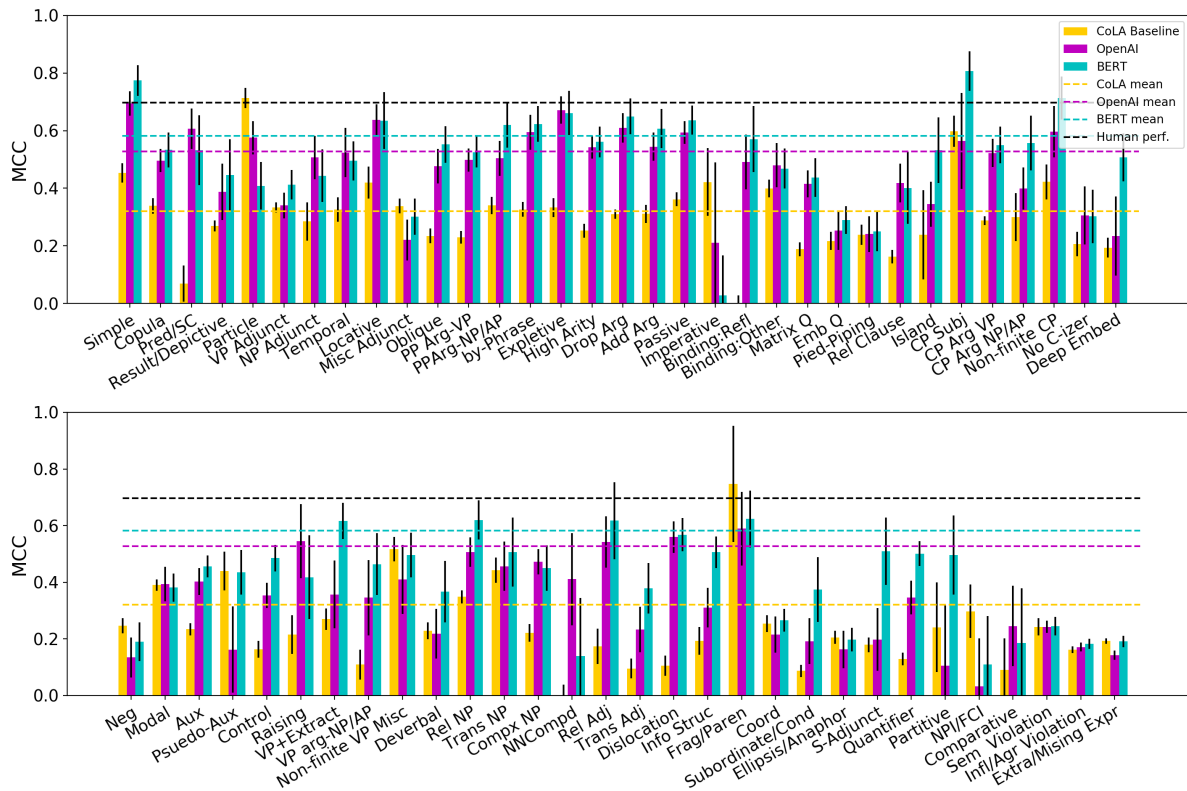


Figure 2: Performance (MCC) on CoLA analysis set by minor feature. Dashed lines show mean performance on all of CoLA.

formance on these sentences, this result indicates that argument structure is relatively easy to learn.

Comparing different kinds of embedded content, we observe higher performance on sentences with embedded clauses (major feature=COMP CLAUSE) embedded VPs (major feature=TO-VP) than on sentences with embedded interrogatives (minor features=EMB-Q, REL CLAUSE). An exception to this trend is the minor feature NO C-IZER, which labels complement clauses without a complementizer (e.g. *I think ~~that~~ you're crazy*). Low performance on these sentences compared to most other features in COMP CLAUSE might indicate that complementizers are an important syntactic cue for these models.

As the major feature QUESTION shows, the difficulty of sentences with question-like syntax applies beyond just embedded questions. Excluding polar questions, sentences with question-like syntax almost always involve extraction of a *wh*-word, creating a long-distance dependency between the *wh*-word and its extraction site, which may be difficult for models to recognize.

The most challenging features are all related to VIOLATIONS. Low performance on INFL/AGR

VIOLATIONS, which marks morphological violations (*He washed yourself, This is happy*), is especially striking because a relatively high proportion (29%) of these sentences are SIMPLE. These models are likely to be deficient in encoding morphological features is that they are word level models, and do not have direct access sub-word information like inflectional endings, which indicates that these features are difficult to learn effectively purely from lexical distributions.

Finally, unusual performance on some features is due to small samples, and have a high standard deviation, suggesting the result is unreliable. This includes CP SUBJ, FRAG/PAREN, IMPERATIVE, NPI/FCI, and COMPARATIVE.

**Comparing Models** Comparing within-feature performance of the three encoders to their overall performance, we find they have differing strengths and weaknesses. BERT stands out over other models in DEEP EMBED, which includes challenging sentences with doubly-embedded, as well as in several features involving extraction (i.e. long-distance dependencies) such as VP+EXTRACT and INFO-STRUC. The transformer models show evidence of learning long-distance dependencies

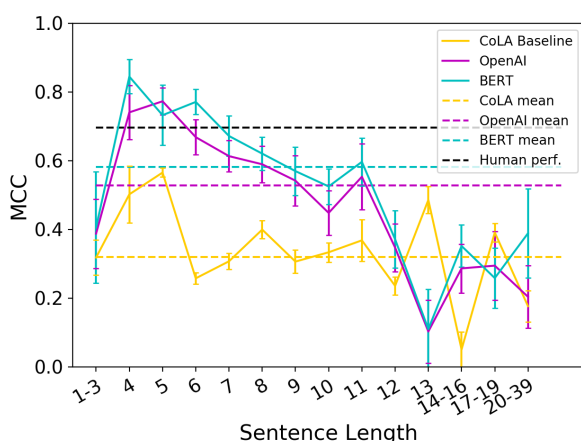


Figure 3: Performance (MCC) on the CoLA analysis set by sentence length.

better than the CoLA baseline. They outperform the CoLA baseline by an especially wide margin on BIND:REFL, which all involves establishing a dependency between a reflexive and its antecedent (*Bo tries to love himself*). They also have a large advantage in DISLOCATION, in which expressions are separated from their dependents (*Bo practiced on the train an important presentation*). The advantage of BERT and GPT may be due in part to their use of the transformer architecture. Unlike the BiLSTM used by the CoLA baseline, the transformer uses a self-attention mechanism that associates all pairs of words regardless of distance.

In some cases models showed surprisingly good or bad performance, revealing possible idiosyncrasies of the sentence embeddings they output. For instance, the CoLA baseline performs on par with the others on the major feature ADJUNCT, especially considering the minor feature PARTICLE (*Bo looked the word up*).

Furthermore, all models struggle equally with sentences in VIOLATION, indicating that the advantages of the transformer models over the CoLA baseline does not extend to the detection of morphological violations (INFL/AGR VIOLATION) or single word anomalies (EXTRA/MISSING EXPR).

### 5.3 Length Analysis

For comparison, we analyze the effect of sentence length on acceptability classifier performance. The results are shown in Figure 3. The results for the CoLA baseline are inconsistent, but do drop off as sentence length increases. For BERT and GPT, performance decreases very steadily with length. Exceptions are extremely short sentences

(length 1-3), which may be challenging due to insufficient information; and extremely long sentences, where we see a small (but somewhat unreliable) boost in BERT’s performance. BERT and GPT are generally quite close in performance, except on the longest sentences, where BERT’s performance is considerably better.

## 6 Conclusion

Using a new grammatically annotated analysis set, we identify several syntactic phenomena that are predictive of good or bad performance of current state of the art sentence encoders on CoLA. We also use these results to develop hypotheses about why BERT is successful, and why transformer models outperform sequence models.

Our findings can guide future work on sentence embeddings. A current weakness of all sentence encoders we investigate, including BERT, is the identification of morphological violations. Future engineering work should investigate whether switching to a character-level model can mitigate this problem. Additionally, transformer models appear to have an advantage over sequence models with long-distance dependencies, but still struggle with these constructions relative to more local phenomena. It stands to reason that this performance gap might be widened by training larger or deeper transformer models, or training on longer or more complex sentences. This analysis set can be used by engineers interested in evaluating the syntactic knowledge of their encoders.

Finally, these findings suggest possible controlled experiments that could confirm whether there is a causal relation between the presence of the syntactic features we single out as interesting and model performance. Our results are purely correlational, and do not mark whether a particular construction is crucial for the acceptability of the sentence. Future experiments following Ettinger et al. (2018) and Kann et al. (2019) can semi-automatically generate datasets manipulating, for example, length of long-distance dependencies, inflectional violations, or the presence of interrogatives, while controlling for factors like sentence length and word choice, in order determine the extent to which these features impact the quality of sentence embeddings.



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## A Feature Descriptions

### A.1 Simple

#### A.1.1 Simple

These are sentences with transitive or intransitive verbs appearing with their default syntax and argument structure. All arguments are noun phrases (DPs), and there are no modifiers or adjuncts on DPs or the VP.

#### (1) Included

- a. John owns the book. (37)
- b. Park Square has a festive air. (131)
- c. \*Herself likes Mary's mother. (456)

#### (2) Excluded

- a. Bill has eaten cake.
- b. I gave Joe a book.

### A.2 Pred (Predicates)

#### A.2.1 Copulas

These are sentences including the verb *be* used predicatively. Also, sentences where the object of the verb is itself a predicate, which applies to the subject. Not included are auxiliary uses of *be* or other predicate phrases that are not linked to a subject by a verb.

#### (3) Included

- a. John is eager. (27)
- b. He turned into a frog. (150)
- c. To please John is easy. (315)

#### (4) Excluded

- a. There is a bench to sit on. (309)
- b. John broke the geode open.
- c. The cake was eaten.

#### A.2.2 Pred/SC (Predicates and Small Clauses)

These sentences involve predication of a non-subject argument by another non-subject argument, without the presence of a copula. Some of these cases may be analyzed as small clauses. (see Sportiche et al., 2013, pp. 189-193)

#### (5) Included

- a. John called the president a fool. (234)
- b. John considers himself proud of Mary. (464)
- c. They want them arrested. (856)
- d. the election of John president surprised me. (1001)

### A.2.3 Result/Depictive (Resultatives and Depictives)

Modifiers that act as predicates of an argument. Resultatives express a resulting state of that argument, and depictives describe that argument during the matrix event. See (Goldberg and Jackendoff, 2004).

#### (6) Included

##### a. Resultative

- (i) \*The table was wiped by John clean. (625)
- (ii) The horse kicked me black and blue. (898)

##### b. Depictive

- (i) John left singing. (971)
- (ii) In which car was the man seen? (398)

#### (7) Excluded

- a. He turned into a frog. (150)

### A.3 Adjunct

#### A.3.1 Particle

Particles are lone prepositions associated with verbs. When they appear with transitive verbs they may immediately follow the verb or the object. Verb-particle pairs may have a non-compositional (idiomatic) meaning. See Carnie (2013, pp. 69-70) and Kim and Sells (2008, pp. 16-17).

#### (8) Included

- a. \*The argument was summed by the coach up. (615)
- b. Some sentences go on and on and on. (785)
- c. \*He let the cats which were whining out. (71)

#### A.3.2 VP-Adjunct

Adjuncts modifying verb phrases. Adjuncts are (usually) optional, and they do not change the category of the expression they modify. See (Sportiche et al., 2013, pp.102-106).

#### (9) Included

- a. PP-adjuncts, e.g. locative, temporal, instrumental, beneficiary
  - (i) Nobody who hates to eat anything should work in a delicatessen. (121)
  - (ii) Felicia kicked the ball off the bench. (127)
- b. Adverbs
  - (i) Mary beautifully plays the violin. (40)
  - (ii) John often meets Mary. (65)

1100	c. Purpose VPs	(i) Fiona might be here by 5 o'clock.	1150
1101	(i) We need another run to win. (769)	(426)	1151
1102	(10) Excluded	c. When	1152
1103	a. PP arguments	(i) I inquired when could we leave. (520)	1153
1104	(i) *Sue gave to Bill a book. (42)		1154
1105	(ii) Everything you like is on the table.	<b>A.3.5 Locative (Locative Adjuncts)</b>	1155
1106	(736)	These are adjuncts of VPs and NPs that specify a	1156
1107	b. S-adjuncts	location of an event or a part of an event, or of	1157
1108	(i) John lost the race, unfortunately.	an individual. Adjuncts are (usually) optional, and	1158
1109		they do not change the category of the expression	1159
1110	<b>A.3.3 NP-Adjunct</b>	they modify.	1160
1111	These are adjuncts modifying noun phrases. Ad-	(14) Included	1161
1112	juncts are (usually) optional, and they do not	a. Short adverbials	1162
1113	change the category of the expression they modify.	b. PPs	1163
1114	Single-word prenominal adjectives are excluded,	(i) The bed was slept in. (298)	1164
1115	as are relative clauses (this has another category).	(ii) *Anson demonized up the Khyber	1165
1116		(479)	1166
1117	(11) Included	(iii) Some people consider dogs in my	1167
1118	a. PP-adjuncts	neighborhood dangerous. (802)	1168
1119	(i) *Tom's dog with one eye attacked	(iv) Mary saw the boy walking toward the	1169
1120	Frank's with three legs. (676)	railroad station. (73)	1170
1121	(ii) They were going to meet sometime on	c. Where	1171
1122	Sunday, but the faculty didn't know	(i) I found the place where we can relax.	1172
1123	when. (565)	(307)	1173
1124	b. Phrasal adjectives	(15) Excluded	1174
1125	(i) As a statesman, scarcely could he do	a. Locative arguments	1175
1126	anything worth mentioning. (292)	(i) *Sam gave the ball out of the basket.	1176
1127	c. Verbal modifiers	(129)	1177
1128	(i) The horse raced past the barn fell.	(ii) Jessica loaded boxes on the wagon.	1178
1129	(900)	(164)	1179
1130	(12) Excluded	(iii) I went to Rome.	1180
1131	a. Prenominal Adjectives	<b>A.3.6 Misc Adjunct (Miscellaneous</b>	1181
1132	(i) It was the policeman met that several	<b>Adjuncts)</b>	1182
1133	young students in the park last night.	These are adjuncts of VPs and NPs not described	1183
1134	(227)	by some other category (with the exception of (6-	1184
1135	b. Relative Clauses	7)), i.e. not temporal, locative, or relative clauses.	1185
1136	c. NP arguments	Adjuncts are (usually) optional, and they do not	1186
1137	<b>A.3.4 Temporal</b>	change the category of the expression they modify.	1187
1138	These are adjuncts of VPs and NPs that specify a	(16) Included	1188
1139	time or modify tense or aspect or frequency of an	a. Beneficiary	1189
1140	event. Adjuncts are (usually) optional, and they	(i) *I know which book Jos didn't read for	1190
1141	do not change the category of the expression they	class, and which book Lilly did it for	1191
1142	modify.	him. (58)	1192
1143		b. Instrument	1193
1144	(13) Included	(i) Lee saw the student with a telescope.	1194
1145	a. Short adverbials (never, today, now, al-	(770)	1195
1146	ways)	c. Comitative	1196
1147	(i) *Which hat did Mike quip that she	(i) Joan ate dinner with someone but I	1197
1148	never wore? (95)	don't know who. (544)	1198
1149	b. PPs		1199



- d. VP adjuncts  
 (i) Which article did Terry file papers without reading? (431)  
 e. Purpose  
 (i) We need another run to win. (769)

#### A.4 Argument Types

##### A.4.1 Oblique

Oblique arguments of verbs are individual-denoting arguments (DPs or PPs) which act as the third argument of verb, i.e. not a subject or (direct) object. They may or may not be marked by a preposition. Obliques are only found in VPs that have three or more individual arguments. Arguments are selected for by the verb, and they are (generally) not optional, though in some cases they may be omitted where they are understood or implicitly existentially quantified over. See Kim and Sells (2008, p.40).

##### (17) Included

- a. Prepositional  
 (i) \*Sue gave to Bill a book. (42)  
 (ii) Mary has always preferred lemons to limes. (70)  
 (iii) Janet broke Bill on the finger. (141)  
 b. Benefactives  
 (i) Martha carved the baby a toy out of wood. (139)  
 c. Double object  
 (i) Susan told her a story. (875)  
 (ii) Locative arguments  
 Ann may spend her vacation in Italy. (289)  
 (iii) High-arity Passives  
 \*Mary was given by John the book. (626)

##### (18) Excluded

- a. Non-DP arguments  
 (i) We want John to win (28)  
 b. 3rd arguments where not all three arguments are DPs  
 (i) We want John to win (28)

##### A.4.2 PP Arg VP (PP Arguments of VPs)

Prepositional Phrase arguments of VPs are individual-denoting arguments of a verb which are marked by a preposition. They may or may not be obliques. Arguments are selected for by the verb, and they are (generally) not optional, though in some cases they may be omitted where they

are understood or implicitly existentially quantified over.

##### (19) Included

- a. Dative  
 (i) \*Sue gave to Bill a book. (42)  
 b. Conative (at)  
 (i) \*Carla slid at the book. (179)  
 c. Idiosyncratic prepositional verbs  
 (i) I wonder who to place my trust in. (711)  
 (ii) She voted for herself. (743)  
 d. Locative  
 (i) John was found in the office. (283)  
 e. PP predicates  
 (i) Everything you like is on the table. (736)

##### (20) Excluded

- a. PP adjuncts  
 b. Particles  
 c. Arguments of deverbal expressions  
 (i) \*the putter of books left. (892)  
 d. By-phrase  
 (i) Ted was bitten by the spider. (613)

##### A.4.3 PP Arg NP/AP (PP Arguments of NPs and APs)

Prepositional Phrase arguments of NPs or APs are individual-denoting arguments of a noun or adjective which are marked by a preposition. Arguments are selected for by the head, and they are (generally) not optional, though in some cases they may be omitted where they are understood or implicitly existentially quantified over.

##### (21) Included

- a. Relational adjectives  
 (i) Many people were fond of Pat. (936)  
 (ii) \*I was already aware of fact. (824)  
 b. Relational nouns  
 (i) We admired the pictures of us in the album. (759)  
 (ii) They found the book on the atom. (780)  
 c. Arguments of deverbal nouns  
 (i) \*the putter of books left. (892)

##### A.4.4 By-phrase

Prepositional arguments introduced with by. Usually, this is the (semantic) subject of a passive verb, but in rare cases it may be the subject of a nominalized verb. Arguments are usually selected for

by the head, and they are generally not optional. In this case, the argument introduced with *by* is semantically selected for by the verb, but it is syntactically optional. See [Adger \(2003, p.190\)](#) and [Collins \(2005\)](#).

(22) Included

- a. Passives
  - (i) Ted was bitten by the spider. (613)
- b. Subjects of deverbal nouns
  - (i) the attempt by John to leave surprised me. (1003)

**A.4.5 Expletive**

Expletives, or dummy arguments, are semantically inert arguments. The most common expletives in English are *it* and *there*, although not all occurrences of these items are expletives. Arguments are usually selected for by the head, and they are generally not optional. In this case, the expletive occupies a syntactic argument slot, but it is not semantically selected by the verb, and there is often a syntactic variation without the expletive. See [Adger \(2003, p.170-172\)](#) and [Kim and Sells \(2008, p.82-83\)](#).

(23) Included

- a. There—inserted, existential
  - (i) \*There loved Sandy. (939)
  - (ii) There is a nurse available. (466)
- b. It—cleft, inserted
  - (i) It was a brand new car that he bought. (347)
  - (ii) It bothers me that John coughs. (314)
  - (iii) It is nice to go abroad. (47)
- c. Environmental it
  - (i) Kerry remarked it was late. (821)
  - (ii) Poor Bill, it had started to rain and he had no umbrella. (116)
  - (iii) You’ve really lived it up. (160)

(24) Excluded

- a. John counted on Bill to get there on time. (996)
- b. I bought it to read. (1026)

**A.5 Arg Altern (Argument Alternations)**

**A.5.1 High Arity**

These are verbs with 3 or more arguments of any kind. Arity refers to the number of arguments that a head (or function) selects for. Arguments are usually selected for by the head, and they are generally not optional. They may be DPs, PPs, CPs,

VPs, APs or other categories.

(25) Included

- a. Ditransitive
  - (i) \*[Sue] gave [to Bill] [a book]. (42)
  - (ii) [Martha] carved [the baby] [a toy] out of wood. (139)
- b. VP arguments
  - (i) \*[We] believed [John] [to be a fountain in the park]. (274)
  - (ii) [We] made [them] [be rude]. (260)
- c. Particles
  - (i) [He] let [the cats which were whining] [out]. (71)
- d. Passives with *by*-phrase
  - (i) \*[A good friend] is remained [to me] [by him]. (237)
- e. Expletives
  - (i) \*[We] expect [there] [to will rain]. (282)
  - (ii) [There] is [a seat] [available]. (934)
  - (iii) [It] bothers [me] [that he is here]. (1009)
- f. Small clause
  - (i) [John] considers [Bill] [silly]. (1039)

(26) Excluded

- a. Results, depictives
  - (i) [John] broke [the geode] [open].

**A.5.2 Drop Arg (Dropped Arguments)**

These are VPs where a canonical argument of the verb is missing. This can be difficult to determine, but in many cases the missing argument is understood with existential quantification or generically, or contextually salient. See [Sportiche et al. \(2013, p.106-109\)](#).

(27) Included

- a. Middle voice/causative inchoative
  - (i) \*The problem perceives easily. (66)
- b. Passive
  - (i) The car was driven. (296)
- c. Null complement anaphora
  - (i) Jean persuaded Robert. (380)
  - (ii) Nobody told Susan. (883)
- d. Dropped argument
  - (i) \*Kim put in the box. (253)
  - (ii) The guests dined. (835)
  - (iii) I wrote to Bill. (1030)
- e. Transitive adjective
  - (i) John is eager. (27)
  - (ii) We pulled free. (144)

- 1400 f. Transitive noun  
 1401 (i) I sensed his eagerness. (155)  
 1402 g. Expletive insertion  
 1403 (i) \*It loved Sandy. (949)  
 1404 (28) Excluded  
 1405 a. Ted was bitten by the spider. (613)  
 1406

### 1407 A.5.3 Add Arg (Added Arguments)

1408 These are VPs in which a non-canonical argument  
 1409 of the verb has been added. These cases are clearer  
 1410 to identify where the additional argument is a DP.  
 1411 In general, PPs which mark locations, times, ben-  
 1412 eficiaries, or purposes should be analyzed as ad-  
 1413 juncts, while PPs marking causes can be consid-  
 1414 ered arguments. See [Pylkkänen \(2008\)](#).  
 1415

- 1417 (29) Included  
 1418 a. Extra argument  
 1419 (i) \*Linda winked her lip. (202)  
 1420 (ii) Sharon fainted from hunger. (204)  
 1421 (iii) I shaved myself. (526)  
 1422 b. Causative  
 1423 (i) \*I squeaked the door. (207)  
 1424 c. Expletive insertion  
 1425 (i) There is a monster in Loch Ness. (928)  
 1426 (ii) It annoys people that dogs bark. (943)  
 1427 d. Benefactive  
 1428 (i) Martha carved the baby a toy out of  
 1429 wood. (139)  
 1430

### 1431 A.5.4 Passive

1432 The passive voice is marked by the demotion of  
 1433 the subject (either complete omission or to a by-  
 1434 phrase) and the verb appearing as a past participle.  
 1435 In the stereotypical construction there is an auxil-  
 1436 iary *be* verb, though this may be absent. See [Kim](#)  
 1437 [and Sells \(2008, p.175-190\)](#), [Collins \(2005\)](#), and  
 1438 [Sag et al. \(2003, p.311-333\)](#).  
 1439

- 1440 (30) Included  
 1441 a. Verbs  
 1442 (i) The earth was believed to be round.  
 1443 (157)  
 1444 b. Psuedopassive  
 1445 (i) The bed was slept in. (298)  
 1446 c. Past participle adjuncts  
 1447 (i) The horse raced past the barn fell.  
 1448 (900)  
 1449

### 1450 A.6 Imperative

#### 1451 A.6.1 Imperative

1452 The imperative mood is marked by the absence of  
 1453 the a subject and the bare form of the verb, and  
 1454 expresses a command, request, or other directive  
 1455 speech act.  
 1456

1457 (31) Included

- 1458 a. \*Wash you! (224)  
 1459 b. Somebody just left - guess who. (528)  
 1460

### 1461 A.7 Binding

#### 1462 A.7.1 Binding:Refl (Binding of Reflexives)

1463 These are cases in which a reflexive (non-  
 1464 possessive) pronoun, usually bound by an an-  
 1465 tecedent. See [Sportiche et al. \(2013, p.163-186\)](#)  
 1466 and [Sag et al. \(2003, p.203-226\)](#).  
 1467

1468 (32) Included

- 1469 a. \*Ourselves like ourselves. (742)  
 1470 b. Which pictures of himself does John like?  
 1471 (386)  
 1472

#### 1473 A.7.2 Binding:Other (Binding of Other Pronouns)

1474 These are cases in which a non-reflexive pronoun  
 1475 appears along with its antecedent. This includes  
 1476 donkey anaphora, quantificational binding, and  
 1477 bound possessives, among other bound pronouns.  
 1478 See [Sportiche et al. \(2013, p.163-186\)](#) and [Sag](#)  
 1479 [et al. \(2003, p.203-226\)](#).  
 1480

1481 (33) Included

- 1482 a. Bound possessor  
 1483 (i) The children admire their mother.  
 1484 (382)  
 1485 b. Quantificational binding  
 1486 (i) Everybody gets on well with a certain  
 1487 relative, but often only his therapist  
 1488 knows which one. (562)  
 1489 c. Bound pronoun  
 1490 (i) \*We gave us to the cause. (747)  
 1491

### 1492 A.8 Question

#### 1493 A.8.1 Matrix Q (Matrix Questions)

1494 These are sentences in which the matrix clause is  
 1495 interrogative (either a wh- or polar question). See  
 1496 [Adger \(2003, pp.282-213\)](#), [Kim and Sells \(2008,](#)  
 1497 [pp.193-222\)](#), and [Carnie \(2013, p.315-350\)](#).  
 1498

1499 (34) Included

- 1500 a. Wh-question  
 1501 (i) Who always drinks milk? (684)  
 1502

- b. Polar question  
 (i) Did Athena help us? (486)

**A.8.2 Emb Q (Embedded Questions)**

These are embedded interrogative clauses appearing as arguments of verbs, nouns, and adjectives. Not including relative clauses and free relatives. See [Adger \(2003, p.297\)](#).

(35) Included

- a. Under VP  
 (i) I forgot how good beer tastes. (235)  
 (ii)\*What did you ask who saw? (508)  
 b. Under NP  
 (i) That is the reason why he resigned. (313)  
 c. Under AP  
 (i) They claimed they had settled on something, but it wasn't clear what they had settled on. (529)  
 d. Free relative  
 (i) What the water did to the bottle was fill it. (33)

(36) Excluded

(36) Relative clauses, free relatives

**A.8.3 Pied Piping**

These are phrasal Wh-phrases, in which the wh-word moves along with other expressions, including prepositions (pied-piping) or nouns in the case of determiner wh-words such as how many and which.

(37) Included

- a. Pied-piping  
 (i)\*The ship sank, but I don't know with what. (541)  
 b. Other phrasal wh-phrases  
 (i) I know which book Mag read, and which book Bob read my report that you hadn't. (61)  
 (ii) How sane is Peter? (88)

**A.8.4 Rel Clause (Relative Clause)**

Relative clauses are noun modifiers appearing with a relativizer (either that or a wh-word) and an associated gap. See [Kim and Sells \(2008, p.223-244\)](#).

(38) Included

- a. Though he may hate those that criticize Carter, it doesn't matter. (332)

- b.\*The book what inspired them was very long. (686)  
 c. Everything you like is on the table. (736)

(39) Excluded

- a.\*The more you would want, the less you would eat. (6)

**A.8.5 Island**

This is wh-movement out of an extraction island, or near-island. Islands include, for example, complex NPs, adjuncts, embedded questions, coordination. A near-island is an extraction that closely resembles an island violation, such as extraction out of an embedded clause, or across-the-board extraction. See [Adger \(2003, pp.323-333\)](#) and [Carnie \(2013, pp.332-334\)](#).

(40) Included

- a. Embedded question  
 b.\*What did you ask who Medea gave? (493)

(40) Adjunct

- a.\*What did you leave before they did? (598)

(40) Parasitic gaps

- a. Which topic did you choose without getting his approval? (311)

(40) Complex NP

- a. Who did you get an accurate description of? (483)

**A.9 Comp Clause (Complement Clauses)**

**A.9.1 CP Subj (CP Subjects)**

These are complement clauses acting as the (syntactic) subject of verbs. See [Kim and Sells \(2008, pp.90-91\)](#).

(41) Included

- a. That dogs bark annoys people. (942)  
 b. The socks are ready for for you to put on to be planned. (112)

(42) Excluded

- a. Expletive insertion  
 (i) It bothers me that John coughs. (314)

**A.9.2 CP Arg - VP (CP Arguments of VPs)**

These are complement clauses acting as (non-subject) arguments of verbs. See [Kim and Sells \(2008, pp.84-90\)](#).

(43) Included

- a. I can't believe Fred won't, either. (50)  
 b. I saw that gas can explode. (222)



1600	c. It bothers me that John coughs. (314)	<b>A.9.6 Deep Embed (Deep Embedding)</b>	1650
1601	d. Clefts	These are sentences with three or nested verbs,	1651
1602	(i) It was a brand new car that he bought.	where VP is not an aux or modal, i.e. with the	1652
1603	(347)	following syntax: [S ... [ VP ... [ VP ... [ VP ... ]	1653
1604		... ] ... ] ... ]	1654
1605	<b>A.9.3 CP Arg - NP/AP (CP Arguments of</b>	(47)Included	1655
1606	<b>NPs and APs)</b>	a. Embedded VPs	1656
1607	These are complement clauses acting as an argu-	(i) Max seemed to be trying to force Ted	1657
1608	ment of a noun or adjective. See <a href="#">Kim and Sells</a>	to leave the room, and Walt, Ira. (657)	1658
1609	(2008, pp.91-94).	b. Embedded clauses	1659
1610	(44)Included	(i) I threw away a book that Sandy	1660
1611	a. Under NP	thought we had read. (713)	1661
1612	(i) Do you believe the claim that some-		1662
1613	body was looking for something? (99)	<b>A.10 Aux (Auxiliaries)</b>	1663
1614	b. Under AP	<b>A.10.1 Neg (Negation)</b>	1664
1615	(i)*The children are fond that they have	Any occurrence of negation in a sentence, includ-	1665
1616	ice cream. (842)	ing sentential negation, negative quantifiers, and	1666
1617		negative adverbs.	1667
1618	<b>A.9.4 Non-Finite CP</b>	(48)Included	1668
1619	These are complement clauses with a non-finite	a. Sentential	1669
1620	matrix verb. Often, the complementizer is for,	(i) I can't remember the name of some-	1670
1621	or there is no complementizer. See <a href="#">Adger (2003,</a>	body who had misgivings. (123)	1671
1622	<a href="#">pp.252-253,256-260).</a>	b. Quantifier	1672
1623	(45)Included	(i) No writer, and no playwright, meets in	1673
1624	a. For complementizer	Vienna. (124)	1674
1625	(i) I would prefer for John to leave. (990)	c. Adverb	1675
1626	b. No Complementizer	(i) They realised that never had Sir	1676
1627	(i) Mary intended John to go abroad. (48)	Thomas been so offended. (409)	1677
1628	c. Ungrammatical		1678
1629	(i) Heidi thinks that Andy to eat salmon	<b>A.10.2 Modal</b>	1679
1630	flavored candy bars. (363)	Modal verbs ( <i>may, might, can, could, will, would,</i>	1680
1631	d. V-ing	<i>shall, should, must</i> ). See <a href="#">Kim and Sells (2008,</a>	1681
1632	(i) Only Churchill remembered Churchill	<a href="#">pp.152-155).</a>	1682
1633	giving the Blood, Sweat and Tears	(49)Included	1683
1634	speech. (469)	a. John can kick the ball. (280)	1684
1635		b. As a statesman, scarcely could he do any-	1685
1636	<b>A.9.5 No C-izer (No Complementizer)</b>	thing worth mentioning. (292)	1686
1637	These are complement clauses with no overt com-	(50)Excluded	1687
1638	plementizer.	a. Pseudo-modals	1688
1639	(46)Included	(i) Sandy was trying to work out which	1689
1640	a. Complement clause	students would be able to solve a cer-	1690
1641	(i) I'm sure we even got these tickets!	tain problem. (600)	1691
1642	(325)	<b>A.10.3 Aux (Auxiliaries)</b>	1692
1643	(ii) He announced he would marry the	Auxiliary verbs (e.g. <i>be, have, do</i> ). See <a href="#">Kim and</a>	1693
1644	woman he loved most, but none of his	<a href="#">Sells (2008, pp.149-174).</a>	1694
1645	relatives could figure out who. (572)	(51)Included	1695
1646	b. Relative clause	a. They love to play golf, but I do not. (290)	1696
1647	(i) The Peter we all like was at the party	b. The car was driven. (296)	1697
1648	(484)		1698
1649			1699

1700	c. he had spent five thousand dollars. (301)	(i) There is a bench to sit on. (309)	1750
1701	(52) Excluded	c. Subject VPs	1751
1702	a. Pseudo-auxiliaries	(i) To please John is easy. (315)	1752
1703	(i) *Sally asked if somebody was going to	d. Argument present participles	1753
1704	fail math class, but I can't remember	(i) Medea denied poisoning the phoenix.	1754
1705	who. (589)	(490)	1755
1706	(ii) The cat got bitten. (926)	e. Raising	1756
1707		(i) Anson believed himself to be hand-	1757
1708	<b>A.10.4 Psuedo-Aux (Pseudo Auxiliaries)</b>	some. (499)	1758
1709	These are predicates acting as near-auxiliary (e.g.		1759
1710	get-passive) or near-modals (e.g. willing)	<b>A.11.2 Raising</b>	1760
1711	(53) Included	These are VPs with raising predicates, where one	1761
1712	a. Near-auxiliaries	argument is a non-finite to-VP without a covert	1762
1713	(i) *Mary came to be introduced by the	subject co-indexed with an argument of the ma-	1763
1714	bartender and I also came to be. (55)	trix verb. Unlike control verbs, the coindexed ar-	1764
1715	(ii) *Sally asked if somebody was going to	gument is not a semantic argument of the rais-	1765
1716	fail math class, but I can't remember	ing predicate. See <a href="#">Adger (2003, pp.260-266)</a> ,	1766
1717	who. (589)	<a href="#">Sportiche et al. (2013, pp.203-222)</a> , and <a href="#">Kim and</a>	1767
1718	(iii) The cat got bitten. (926)	<a href="#">Sells (2008, pp.125-148)</a> .	1768
1719	b. Near-modals	(56) Included	1769
1720	(i) Clinton is anxious to find out which	a. Subject raising	1770
1721	budget dilemmas Panetta would be	(i) Under the bed seems to be a fun place	1771
1722	willing to tackle in a certain way, but	to hide. (277)	1772
1723	he won't say in which. (593)	b. Object raising	1773
1724	(ii) Sandy was trying to work out which	(i) Anson believed himself to be hand-	1774
1725	students would be able to solve a cer-	some. (499)	1775
1726	tain problem. (600)	c. Raising adjective	1776
1727		(i) John is likely to leave. (370)	1777
1728	<b>A.11 to-VP (Infinitival VPs)</b>		1778
1729	<b>A.11.1 Control</b>	<b>A.11.3 VP+Extraction (VPs with Extraction)</b>	1779
1730	These are VPs with control verbs, where one	These are embedded infinitival VPs containing a	1780
1731	argument is a non-finite to-VP without a covert	(non-subject) gap that is filled by an argument	1781
1732	subject co-indexed with an argument of the ma-	in the upper clause. Examples are purpose-VPs	1782
1733	trix verb. See <a href="#">Adger (2003, pp.252,266-291)</a> ,	and tough-movement. See <a href="#">Kim and Sells (2008,</a>	1783
1734	<a href="#">Sportiche et al. (2013, pp.203-222)</a> , and <a href="#">Kim and</a>	<a href="#">Sells (2008, pp.246-252)</a> .	1784
1735	<a href="#">Sells (2008, pp.125-148)</a> .	(57) Included	1785
1736	(54) Included	a. Tough-movement	1786
1737	a. Intransitive subject control	(i) *Drowning cats, which is against the	1787
1738	(i) *It tries to leave the country. (275)	law, are hard to rescue. (79)	1788
1739	b. Transitive subject control	b. Infinitival relatives	1789
1740	(i) John promised Bill to leave. (977)	(i) *Fed knows which politician her to vote	1790
1741	c. Transitive object control	for. (302)	1791
1742	(i) I want her to dance. (379)	c. Purpose	1792
1743	(ii) John considers Bill to be silly. (1040)	(i) the one with a red cover takes a very	1793
1744	(55) Excluded	long time to read. (352)	1794
1745	a. VP args of NP/AP	d. Other non-finite VPs with extraction	1795
1746	(i) This violin is difficult to play sonatas	(i) As a statesman, scarcely could he do	1796
1747	on. (114)	anything worth mentioning. (292)	1797
1748	b. Purpose		1798
1749			1799

### 1800 **A.11.4 VP arg - NP/AP (VP Arguments of** 1801 **NPs and APs)**

1802 These are non-finite VP arguments of nouns and  
1803 adjectives.

1804 (58) Included

- 1805 a. Raising adjectives
- 1806 (i) John is likely to leave. (370)
- 1807 b. Control adjectives
- 1808 (i) The administration has issued a state-  
1809 ment that it is willing to meet a stu-  
1810 dent group, but I'm not sure which  
1811 one. (604)
- 1812 c. Control nouns
- 1813 (i) As a teacher, you have to deal simul-  
1814 taneously with the administration's  
1815 pressure on you to succeed, and the  
1816 children's to be a nice guy. (673)
- 1817 d. Purpose VPs
- 1818 (i) there is nothing to do. (983)

### 1819 **A.11.5 Non-Finite VP Misc (Miscellaneous** 1820 **Infinitival VPs)**

1821 These are miscellaneous non-finite VPs.

1822 (59) Included

- 1823 a. I saw that gas can explode. (222)
- 1824 b. Gerunds/Present participles
- 1825 (i) \*Students studying English reads Con-  
1826 rad's Heart of Darkness while at uni-  
1827 versity. (262)
- 1828 (ii) Knowing the country well, he took a  
1829 short cut. (411)
- 1830 (iii) John became deadly afraid of flying.  
1831 (440)
- 1832 c. Subject VPs
- 1833 (i) To please John is easy. (315)
- 1834 d. Nominalized VPs
- 1835 (i) \*What Mary did Bill was give a book.  
1836 (473)

1837 (60) Excluded

- 1838 a. to-VPs acting as complements or modi-  
1839 fiers of verbs, nouns, or adjectives

## 1840 **A.12 N, Adj (Nouns and Adjectives)**

### 1841 **A.12.1 Deverbal (Deverbal Nouns and** 1842 **Adjectives)**

1843 These are nouns and adjectives derived from  
1844 verbs.

1845 (61) Included

- 1846 a. Deverbal nouns

1847 (i) \*the election of John president sur-  
1848 prised me. (1001)

1849 b. Light verbs

(i) The birds give the worm a tug. (815)

c. Gerunds

(i) If only Superman would stop flying  
1850 planes! (773)

d. Event-wh

(i) What the water did to the bottle was  
1851 fill it. (33)

e. Deverbal adjectives

(i) His or her least known work. (95)

### 1852 **A.12.2 Rel NP (Relational Nouns)**

1853 Relational nouns are NPs with an obligatory (or  
1854 existentially closed) argument. A particular rela-  
1855 tion holds between the members of the extension  
1856 of NP and the argument. The argument must be  
1857 a DP possessor or a PP. See [Kim and Sells \(2008,](#)  
1858 [pp.82-83\).](#)

1859 (62) Included

a. Nouns with of-arguments

(i) John has a fear of dogs. (353)

b. Nouns with other PP-arguments

(i) Henri wants to buy which books about  
1860 cooking? (442)

c. Measure nouns

(i) I bought three quarts of wine and two  
1861 of Clorox. (667)

d. Possessed relational nouns

(i) \*John's mother likes himself. (484)

1862 (63) Excluded

a. Nouns with PP modifiers

(i) Some people consider dogs in my  
1863 neighborhood dangerous. (802)

### 1864 **A.12.3 Trans-NP (Transitive NPs)**

1865 Transitive (non-relational) nouns take a VP or CP  
1866 argument. See [Kim and Sells \(2008,](#)  
1867 [pp.82-83\).](#)

1868 (64) Included

a. VP argument

(i) the attempt by John to leave surprised  
1869 me. (1003)

b. CP argument

(i) \*Which report that John was incompe-  
1870 tent did he submit? (69)

c. QP argument

(i) That is the reason why he resigned.  
1871 (313)

**A.12.4 Complex NP**

These are complex NPs, including coordinated nouns and nouns with modifiers (excluding prenominal adjectives).

(65) Included

- a. Modified NPs
  - (i) \*The madrigals which Henry plays the lute and sings sound lousy. (84)
  - (ii) John bought a book on the table. (233)
- b. NPs with coordination
  - (i) \*The soundly and furry cat slept. (871)
  - (ii) The love of my life and mother of my children would never do such a thing. (806)

**A.12.5 NN Compound (Noun-Noun Compounds)**

Noun-noun compounds are NPs consisting of two constituent nouns.

(66) Included

- a. It was the peasant girl who got it. (320)
- b. A felon was elected to the city council. (938)

**A.12.6 Rel Adj (Relational Adjectives)**

These are adjectives that take an obligatory (or existentially closed) argument. A particular relation holds between the members of the extension of the modified NP and the argument. The argument must be a DP or PP. See [Kim and Sells \(2008, pp.80-82\)](#).

(67) Included

- a. Of-arguments
  - (i) The chickens seem fond of the farmer. (254)
- b. Other PP arguments
  - (i) This week will be a difficult one for us. (241)
  - (ii) John made Bill mad at himself. (1035)

**A.12.7 Trans- AP (Transitive Adjectives)**

A transitive (non-relational) adjective. I.e. an adjectives that takes a VP or CP argument. See [Kim and Sells \(2008, pp.80-82\)](#).

(68) Included

- a. VP argument
  - (i) John is likely to leave. (370)
- b. CP argument
  - (i) John is aware of it that Bill is here. (1013)

c. QP argument

- (i) The administration has issued a statement that it is willing to meet a student group, but I'm not sure which one. (604)

**A.13 S-Syntax (Sentence-Level Syntax)**

**A.13.1 Dislocation**

These are expressions with non-canonical word order. See, for example, [Sportiche et al. \(2013, p.76\)](#).

(69) Includes

- a. Particle shift
  - (i) \*Mickey looked up it. (24)
- b. Preposed modifiers
  - (i) Out of the box jumped a little white rabbit. (215)
  - (ii) \*Because she's so pleasant, as for Mary I really like her. (331)
- c. Quantifier float
  - (i) The men will all leave. (43)
- d. Preposed argument
  - (i) With no job would John be happy. (333)
- e. Relative clause extraposition
  - (i) Which book's, author did you meet who you liked? (731)
- f. Misplaced phrases
  - (i) Mary was given by John the book. (626)

**A.13.2 Info Struc (Information Structural Movement)**

This includes topicalization and focus constructions. See [Kim and Sells \(2008, pp.258-269\)](#) and [Sportiche et al. \(2013, pp.68-75\)](#).

(70) Included

- a. Topicalization
  - (i) Most elections are quickly forgotten, but the election of 2000, everyone will remember for a long time. (807)
- b. Clefts
  - (i) It was a brand new car that he bought. (347)
- c. Pseudo-clefts
  - (i) What John promised is to be gentle. (441)

(71) Excluded

- a. There-insertion
- b. Passive



### A.13.3 Frag/Paren (Fragments and Parentheticals)

These are parentheticals or fragmentary expressions.

(72) Included

- a. Parenthetical
  - (i) Mary asked me if, in St. Louis, John could rent a house cheap. (704)
- b. Fragments
  - (i) The soup cooks, thickens. (448)
- c. Tag question
  - (i) George has spent a lot of money, hasn't he? (291)

### A.13.4 Coord (Coordination)

Coordinations and disjunctions are expressions joined with and, but, or, etc. See [Sportiche et al. \(2013, pp.61-68\)](#).

(73) Included

- a. DP coordination
  - (i) Dave, Dan, Erin, Jaime, and Alina left. (341)
- b. Right Node Raising
  - (i) Kim gave a dollar to Bobbie and a dime to Jean. (435)
- c. Clausal coordination
  - (i) She talked to Harry, but I don't know who else. (575)
- d. Or, nor
  - (i) \*No writer, nor any playwright, meets in Vienna. (125)
- e. Pseudo-coordination
  - (i) I want to try and buy some whiskey. (432)
- f. Juxtaposed clauses
  - (i) Lights go out at ten. There will be no talking afterwards. (779)

### A.13.5 Subord/Cond (Subordinate Clauses and Conditionals)

This includes subordinate clauses, especially with subordinating conjunctions, and conditionals.

(74) Included

- a. Conditional
  - (i) If I can, I will work on it. (56)
- b. Subordinate clause
  - (i) \*What did you leave before they did? (598)
  - (ii) \*Because Steve's of a spider's eye had been stolen, I borrowed Fred's dia-

gram of a snake's fang. (677)

- c. Correlative
  - (i) \*As you eat the most, you want the least. (5)

### A.13.6 Ellipsis/Anaphora

This includes VP or NP ellipsis, or anaphora standing for VPs or NPs (not DPs). See [Sportiche et al. \(2013, pp.55-61\)](#).

(75) Included

- a. VP Ellipsis
  - (i) If I can, I will work on it. (56)
  - (ii) Mary likes to tour art galleries, but Bill hates to. (287)
- b. VP Anaphor
  - (i) I saw Bill while you did so Mary. (472)
- c. NP Ellipsis
  - (i) Tom's dog with one eye attacked Fred's. (679)
- d. NP anaphor
  - (i) the one with a red cover takes a very long time to read. (352)
- e. Sluicing
  - (i) Most columnists claim that a senior White House official has been briefing them, and the newspaper today reveals which one. (557)
- f. Gapping
  - (i) Bill ate the peaches, but Harry the grapes. (646)

### A.13.7 S-adjunct (Sentence-Level Adjuncts)

These are adjuncts modifying sentences, sentence-level adverbs, subordinate clauses.

(76) Included

- a. Sentence-level adverbs
  - (i) Suddenly, there arrived two inspectors from the INS. (447)
- b. Subordinate clauses
  - (i) The storm arrived while we ate lunch. (852)

## A.14 Determiner

### A.14.1 Quantifier

These are quantificational DPs, i.e. the determiner is a quantifier.

(77) Included

- a. Quantifiers

2100	(i) *Every student, and he wears socks, is	lectional restrictions, polarity violations, definite-	2150
2101	a swinger. (118)	ness violations.	2151
2102	(ii) We need another run to win. (769)		2152
2103	b. Partitive	(81)Included	2153
2104	(i) *Neither of students failed. (265)	a. Violation of selectional restrictions	2154
2105		(i) *many information was provided. (218)	2155
2106	<b>A.14.2 Partitive</b>	(ii)*It tries to leave the country. (275)	2156
2107	These are quantifiers that take PP arguments, and	b. Aspectual violations	2157
2108	measure nouns. See <a href="#">Kim and Sells (2008, pp.109-</a>	(i) *John is tall on several occasions. (540)	2158
2109	118).	c. Definiteness violations	2159
2110	(78)Included	(i) *It is the problem that he is here. (1018)	2160
2111	a. Quantifiers with PP arguments	d. Polarity violations	2161
2112	(i) *Neither of students failed. (265)	(i) Any man didn't eat dinner. (388)	2162
2113	b. Numerals	<b>A.15.2 Infl/Agr violation (Inflection and</b>	2163
2114	(i) One of Korea's most famous poets	<b>Agreement Violations)</b>	2164
2115	wrote these lines. (294)	These are sentences that include a violation in	2165
2116	c. Measure nouns	inflectional morphology, including tense-aspect	2166
2117	(i) I bought three quarts of wine and two	marking, or agreement.	2167
2118	of Clorox. (667)	(82)Included	2168
2119	<b>A.14.3 NPI/FCI (Negative Polarity and Free</b>	a. Case	2169
2120	<b>Choice Items)</b>	(i) *Us love they. (46)	2170
2121	These are negative polarity items (any, ever, etc.)	b. Agreement	2171
2122	and free choice items (any). See <a href="#">Kadmon and</a>	(i) *Students studying English reads Con-	2172
2123	<a href="#">Landman (1993)</a> .	rad's Heart of Darkness while at uni-	2173
2124	(79)Included	versity. (262)	2174
2125	a. NPI	c. Gender	2175
2126	(i) Everybody around here who ever buys	(i) *Sally kissed himself. (339)	2176
2127	anything on credit talks in his sleep.	d. Tense/Aspect	2177
2128	(122)	(i) *Kim alienated cats and beating his	2178
2129	(ii) I didn't have a red cent. (350)	dog. (429)	2179
2130	b. FCI	<b>A.15.3 Extra/Missing Word</b>	2180
2131	(i) Any owl hunts mice. (387)	These are sentences with a violation that can be	2181
2132		identified with the presence or absence of a single	2182
2133	<b>A.14.4 Comparative</b>	word.	2183
2134	These are comparative constructions. See ( <a href="#">Culi-</a>	(83)Included	2184
2135	<a href="#">cover and Jackendoff, 1999</a> ).	a. Missing word	2185
2136	(80)Included	(i) *John put under the bathtub. (247)	2186
2137	a. Correlative	(ii)*I noticed the. (788)	2188
2138	(i) The angrier Mary got, the more she	b. Extra word	2189
2139	looked at pictures. (9)	(i) *Everyone hopes everyone to sleep.	2190
2140	(ii) They may grow as high as bamboo.	(467)	2191
2141	(337)	(ii)*He can will go (510)	2192
2142	(iii)I know you like the back of my hand.		2193
2143	(775)		2194
2144			2195
2145	<b>A.15 Violations</b>		2196
2146			2197
2147	<b>A.15.1 Sem Violation (Semantic Violations)</b>		2198
2148	These are sentences that include a semantic viola-		2199
2149	tion, including type mismatches, violations of se-		