# Linguistic Analysis of Pretrained Sentence Encoders with Acceptability Judgments

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### **Abstract**

Recent work on evaluating grammatical knowledge in pretrained sentence encoders gives a fine-grained view of a small number of phenomena. We introduce a new analysis dataset that also has broad coverage of linguistic phenomena. We annotate the development set of the Corpus of Linguistic Acceptability (CoLA; Warstadt et al., 2018) for the presence of 13 classes of syntactic phenomena including various forms of argument alternations, movement, and modification. We use this analysis set to investigate the grammatical knowledge of three pretrained encoders: BERT (Devlin et al., 2018), GPT (Radford et al., 2018), and the BiLSTM baseline from Warstadt et al. We find that these models have a strong command of complex or noncanonical argument structures like ditransitives (Sue gave Dan a book) and passives (The book was read). Sentences with longdistance dependencies like questions (What do you think I ate?) challenge all models, but for these, BERT and GPT have a distinct advantage over the baseline. We conclude that recent sentence encoders, despite showing nearhuman performance on acceptability classification overall, still fail to make fine-grained grammaticality distinctions for many complex syntactic structures.

### 1 Introduction

Models for sentence understanding such as BERT (Devlin et al., 2018) and GPT (Radford et al., 2018) are becoming more effective and ubiquitous, leading to a rise in new fine-grained datasets for evaluating their knowledge of grammar. Such evaluations are important for both guiding the development of more robust models and answering theoretical questions about what grammatical concepts are can be acquired through data-driven learning. To date, most evaluation datasets consist

of constructed sentences illustrating a highly specific kind of grammatical contrast (Ettinger et al., 2016, 2018; Marvin and Linzen, 2018; Wilcox et al., 2018, 2019; Futrell and Levy, 2019), or naturalistic sentences labeled for a particular grammatical feature (Linzen et al., 2016; Shi et al., 2016; Conneau et al., 2017, 2018). These evaluation datasets are useful for studying a single phenomenon such as subject-verb agreement in depth (Linzen et al., 2016), but fail to test domain general grammatical knowledge.

By contrast, the Corpus of Linguistic Acceptability<sup>1</sup> (CoLA; Warstadt et al., 2018) tests these models' ability to judge the grammatical acceptability of sentences in a wide domain. CoLA is a dataset of over 10k example sentences labeled for acceptability and sampled from linguistics publications discussing numerous linguistic phenomena. However, in its original formulation, CoLA does not distinguish between phenomena, making it difficult to analyze a model's knowledge a particular phenomenon.

In this work, we augment CoLA with a new syntactically annotated evaluation set<sup>2</sup> that is both fine-grained and domain general. All 1043 examples in the CoLA development set are labeled with expert annotations that indicate the presence or absence of 13 classes of syntactic phenomena, each defined as a union of several more specific phenomena. This resource makes it uniquely easy to conduct analyses whose conclusions can be directly interpreted in terms of modern linguistic theory, since CoLA data is sampled from example sentences in mainstream linguistics publications and our annotations adapt concepts from that

<sup>&</sup>lt;sup>1</sup>The original CoLA can be downloaded here: https://nyu-mll.github.io/CoLA/#

<sup>&</sup>lt;sup>2</sup>The grammatically annotated CoLA can be downloaded here: https://nyu-mll.github.io/CoLA/#grammatical\_annotations

literature.

We use our analysis set to assess GPT and BERT, which achieve near-human performance (Nangia and Bowman, 2019) on many tasks in the GLUE benchmark (Wang et al., 2018), including CoLA. We treat acceptability classification as a probing task (Adi et al., 2017), in which a small classifier is trained on CoLA on top of pretrained encoders and tested on the analysis set. We compare these models to a baseline pretrained BiL-STM model released by Warstadt et al. (2018) with CoLA.

Our results identify specific syntactic features that make sentences harder to classify, such as long distance dependencies (What do you think I ate?), and others that have little effect on difficulty, such as non-canonical argument structures like passives (*The book was read*). Furthermore, some constructions highlight or minimize the differences between models. For example, GPT and BERT far out perform the BiLSTM on movement phenomena such as clefts (It is Bo that left), yet have no advantage on sentences with adjuncts (Sue exercises in the morning). We wish to exercise caution in interpreting these results since it is not clear to what extent an encoder's failure on a particular phenomenon is due to a weakness of the encoder rather than the training data or probing classifier. However, this caveat applies to varying degrees to all probing resources. In this context of other similar linguistically informed datasets, our analysis set addresses the critical need for a evaluation task with wide coverage of linguistic phenomena.

## 2 Related Work

Sentence Encoders Recent research tries to reproduce the success of robust pretrained word embeddings (Mikolov et al., 2013; Pennington et al., 2014) at the sentence level, in the form of reusable sentence encoders with pretrained weights. Current state-of-the-art sentence encoders are pretrained on language modeling or related self-supervised tasks. 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 newer attention-based 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. They are among the top performing<sup>3</sup> models on the GLUE benchmark, an evaluation suite for general-purpose sentence understanding models like these, which is built around a set of nine sentence-level classification tasks (Wang et al., 2018).

Probing Sentence Representations The evaluation and analysis of sentence representations is an active area of research. Most of this work to date focuses on in-depth investigation of a particular phenomenon. A popular evaluation technique uses probing tasks in which a small probing classifier is trained to identify particular syntactic and surface features of a sentence based on a sentence representation.

Some datasets for probing tasks label naturally occurring data with the relevant features. For instance, Shi et al. (2016) label sentences with features such as past/present tense and active/passive voice. Linzen et al. (2016) label present tense verbs for whether they have singular or plural agreement marking. Adi et al. (2017) label sentences for length and word content. Conneau et al. (2018) label sentences for syntactic depth and morphological number.

Another common method is to semiautomatically generate data manipulating a small set of grammatical features. For instance, Ettinger et al. (2016, 2018) build datasets of this kind to test whether sentence encoders represent the scope of negation and semantic roles, and Kann et al. (2019) do so to test whether word and sentence encoders representations information about verbal argument structure.

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 examples taken from 23 theoretical linguistics publications and represent a wide array of phenomena discussed in that literature. 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 pre-

<sup>&</sup>lt;sup>3</sup>The current top performing model (Liu et al., 2019) is based on BERT, but includes ensembling and extra fine-tuning.

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

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

viously: 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. also attempt to model gradient crowd-sourced acceptability judgments, reflecting 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, but note that Warstadt et al. (2018) and Nangia and Bowman (2019) measure expert and non-expert human performance, respectively, on subsets of CoLA (see Table 4 for the former's results), both finding that new human annotators, while not in perfect agreement with the judgments in CoLA, still agree well and outperform the best neural network models.

# 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 labeled with 13 major features, further divided into 59 minor features. Each feature marks the presence of a particular

phenomenon or class of phenomena in the sentence. 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 supplementary materials include descriptions of each feature along with examples and the criteria used for annotation.

The major and minor features are listed in Table 5, and are fully documented in the Appendix. The average sentence is positively labeled with 3.22 major features (SD=1.66) on average, and the average a major feature is present in 224 sentences (SD=112). The average sentence is positively labeled with 4.31 minor features (SD=2.59). The average minor feature is present in 71.3 sentences (SD=54.7). Every sentence is labeled with at least one feature. Sentences without any obvious phenomena of interest are labeled SIMPLE.

# 3.1 Annotation

The sentences were annotated manually by one of the authors, who is trained in formal linguistics and linguistic annotation. 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. These constructions are well-studied in syntax, and further background can be found in textbooks such as Adger (2003) and Sportiche et al. (2013).

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

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

**Simple** This major feature contains only one minor feature, SIMPLE, including sentences where the subject and predicate are unmodified (*Bo ate an apple.*)

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

Adjunct These six features mark various kinds of optional modifiers, including modifiers of NPs (*The boy with blue eyes gasped*) or VPs (*Bo sang with Jo*), and temporal (*Bo awoke at dawn*) or locative (*Bo jumped on the bed*) adjuncts.

**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*).

**Bind** These are two minor features, one for bound reflexives (*Bo loves <u>himself</u>*), and one for other bound pronouns (*Bo thinks <u>he</u> 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?)<sup>4</sup>; or whether there is pied-piping or a multiword wh-expressions (With whom did you eat?).

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, subor-

<sup>&</sup>lt;sup>4</sup>Following standard notation in linguistics, the '\*' precedes sentences that are not grammatically acceptable.

dinate 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.

#### 3.3 Correlations

These features are overlapping and in many cases are correlated, so not all results from using this analysis set will be independent. We analyzed the between-feature 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. These results are summarized in Table 3. Regarding the minor features, 60 pairs had a correlation of 0.2 or greater and 15 had a correlation of 0.5 or greater. 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 features have overlapping definitions; for example EXPLETIVE is a strict subset of ADD ARG because expletive arguments (e.g. There are birds singing) are by definition non-canonical. Similarly, the strong anticorrelation between SIMPLE and the two features related to argument structure, ARGUMENT TYPES and ARG ALTERN, follows from the definition of SIMPLE, which explicitly excludes sentences with unusual argument structure. Second, grammatical facts of English drive the correlation between, for instance, QUESTION and AUX, because mainclause questions in English require subject-aux inversion. Third, the unusually high correlation of, for example, EMB-Q and ELLIPSIS/ANAPHOR, can be attributed largely to a bias in a particular source in CoLA, 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). This third case highlights a limitation of this analysis set. The set of examples associated with a particular feature is not a controlled set designed to test knowledge

Label 1	MCC					
Major Features						
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				
Minor Features						
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	Compx NP	0.623				
Oblique	High Arity	0.620				
RC	Compx NP	0.565				
Expletive	Add Arg	0.558				
	TE AID	0.516				
CP Arg NP/AP	Trans NP	0.546				

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

of that particular construction, but rather a sample of sentences from the linguistics literature, and as such may not be full representative of the construction in question. However, this cost comes with the advantage that results on the analysis set can be directly connected to relevant linguistics literature.

### 4 Models Evaluated

We train MLP acceptability classifiers for CoLA on top of three sentence encoders: (1) CoLA's pretrained BiLSTM baseline encoder, (2) OpenAI GPT, and (3) BERT. We use publicly available pretrained sentence encoders.<sup>6</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 maxpooling 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

<sup>&</sup>lt;sup>5</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.

<sup>6</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

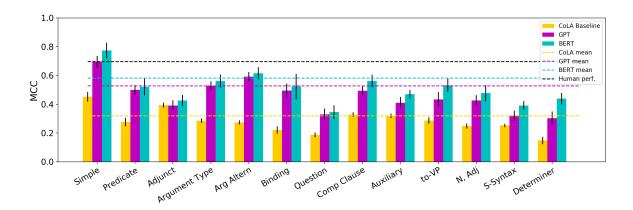


Figure 1: Performance (MCC) on our analysis set by major feature. Dashed lines show mean performance on the entire CoLA development set. Error bars mark the mean  $\pm 1$  standard deviation. From left to right, performance for each feature is given for the CoLA Baseline, OpenAI GPT, and BERT.

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 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. We use BERT<sub>LARGE</sub>. For each encoder, we train 20 random restarts on CoLA feeding the pretrained models published by these authors into a single output layer, using code which will be released upon publication. Following the methods of the original authors, we fine-tune the encoders during training on CoLA. All hyperparameters are held constant across restarts.

### 5 Results

## 5.1 Overall CoLA Results

The overall performance of the three sentence encoders is shown in Table 4. Following Warstadt et al., performance on CoLA is measured using MCC. We present the best single restart for each

	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)	0.622	0.601
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 agreement is measured by Warstadt et al..8

encoder, the mean over restarts for an encoder, and the result of ensembling the restarts for a given encoder, i.e. the majority classification for a given sentence, or *acceptable* if tied.<sup>7</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 and minor features are shown in Figures 1 and 2, respectively. 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.

Comparison across features reveals that the presence of certain features has a large effect on performance, and we comment on some patterns

<sup>&</sup>lt;sup>7</sup>Because we use the development set for analysis, we do not use it to weight models for weighted ensembling.

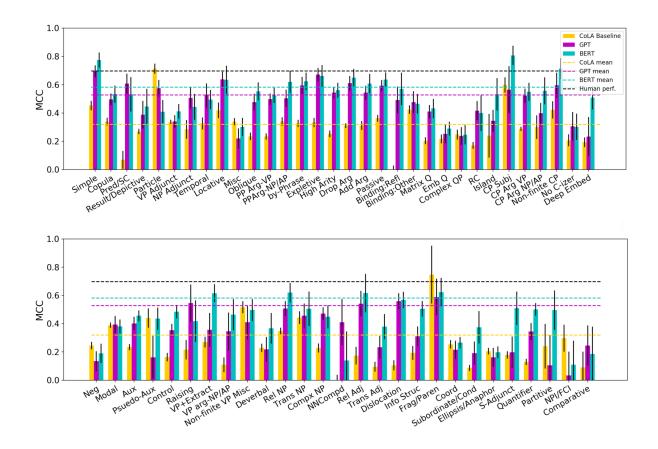


Figure 2: Performance (MCC) on our analysis set by minor feature. Dashed lines show mean performance on the entire CoLA development set. Error bars mark the mean  $\pm 1$  standard deviation. From left to right, performance for each feature is given for the CoLA Baseline, OpenAI GPT, and BERT.

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. In interpreting these results, we caution against drawing strong conclusions from rare minor features. For this reason, we do not discuss any results for features appearing in fewer than 50 sentences. Furthermore, we cannot conclude with certainty that any particular mode of success or failure reflects what the information in the pretrained encoder, rather than what sorts of contrasts are easy or hard to learn from the CoLA training data. However, we consider results for major features more likely to be reliable due to the large number and variety of sentences with each label.

**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. 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)), indicating 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). Interrogatives are quite challenging in general (major feature=QUESTION). Sentences with question-like syntax may be difficult because they usually 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.

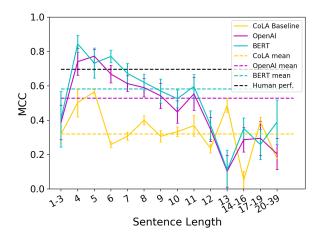


Figure 3: Performance (MCC) on the CoLA analysis set by sentence length.

Comparing Models Comparing within-feature performance of the three encoders to their overall performance, we find they have differing strengths and weaknesses. BERT and GPT generally far outperform the CoLA baseline, with BERT performing best in most cases. BERT and GPT have a particularly large advantage in sentences involving long-distance dependencies. They outperform the CoLA baseline by an especially wide margin on BIND: REFL, which involves establishing a dependency between a reflexive and its antecedent (Bo tries to love himself), as well as 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 BiL-STM used by the CoLA baseline, the Transformer uses a self-attention mechanism that associates all pairs of words regardless of distance.

In some specific instances, we do not observe the usual pattern of BERT outperforming GPT and both far outperforming the CoLA baseline, revealing possible idiosyncrasies of the sentence representations 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*).

### 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 representation. 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 by 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 to determine the extent to which these features impact the quality of sentence representations.

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# **A** Appendix Overview

This appendix contains detailed descriptions of the 15 major features and 63 minor features appearing in the annotated CoLA analysis set, along with illustrative examples. The full list of features is given in Table 2 of the paper, repeated here as Table 5. Examples that are drawn from the analysis set show the line number in parentheses.

# **B** Simple

## **B.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, adjuncts, or auxiliaries on DPs or the VP.

- (1) Included
  - a. John owns the book. (37)
  - b. \*Us love they. (47)
  - c. The needle poked the cloth. (183)
- (2) Excluded
  - a. Cynthia nibbled on the carrot. (200)
  - b. John ate his noodle quietly. (239)

### C Pred (Predicates)

## C.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.

### C.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)

# C.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 Jackend-off, 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)

# D Adjunct

## D.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)

### D.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).

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

Table 5: Major features and their associated minor features (with number of occurrences n).

## (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)
- c. Purpose VPs
  - (i) We need another run to win. (769)

## (10) Excluded

- a. PP arguments
  - (i) \*Sue gave to Bill a book. (42)
  - (ii) Everything you like is on the table. (736)
- b. S-adjuncts
  - (i) John lost the race, unfortunately.

# D.3 NP-Adjunct

These are adjuncts modifying noun phrases. Adjuncts are (usually) optional, and they do not change the category of the expression they modify. Single-word prenominal adjectives are excluded, as are relative clauses (this has another category).

#### (11) Included

a. PP-adjuncts

- (i) \*Tom's dog with one eye attacked Frank's with three legs. (676)
- (ii) They were going to meet sometime on Sunday, but the faculty didn't know when. (565)
- b. Phrasal adjectives
  - (i) As a statesman, scarcely could he do anything worth mentioning. (292)
- c. Verbal modifiers
  - (i) The horse raced past the barn fell. (900)

# (12) Excluded

- a. Prenominal Adjectives
  - (i) It was the policeman met that several young students in the park last night. (227)
- b. Relative Clauses
- c. NP arguments

# D.4 Temporal

These are adjuncts of VPs and NPs that specify a time or modify tense or aspect or frequency of an event. Adjuncts are (usually) optional, and they do not change the category of the expression they modify.

### (13) Included

- Short adverbials (never, today, now, always)
  - (i) \*Which hat did Mike quip that she never wore? (95)

- b. PPs
  - (i) Fiona might be here by 5 o'clock. (426)
- c. When
  - (i) I inquired when could we leave. (520)

# **D.5** Locative (Locative Adjuncts)

These are adjuncts of VPs and NPs that specify a location of an event or a part of an event, or of an individual. Adjuncts are (usually) optional, and they do not change the category of the expression they modify.

# (14) Included

- a. Short adverbials
- b. PPs
  - (i) The bed was slept in. (298)
  - (ii) \*Anson demonized up the Khyber (479)
  - (iii) Some people consider dogs in my neighborhood dangerous. (802)
  - (iv) Mary saw the boy walking toward the railroad station. (73)
- c. Where
  - (i) I found the place where we can relax. (307)

## (15) Excluded

- a. Locative arguments
  - (i) \*Sam gave the ball out of the basket. (129)
  - (ii) Jessica loaded boxes on the wagon. (164)
  - (iii) I went to Rome.

# D.6 Misc Adjunct (Miscellaneous Adjuncts)

These are adjuncts of VPs and NPs not described by some other category (with the exception of (6-7)), i.e. not temporal, locative, or relative clauses. Adjuncts are (usually) optional, and they do not change the category of the expression they modify.

#### (16) Included

- a. Beneficiary
  - (i) \*I know which book Jos didn't read for class, and which book Lilly did it for him. (58)
- b. Instrument
  - (i) Lee saw the student with a telescope. (770)
- c. Comitative

- (i) Joan ate dinner with someone but I don't know who. (544)
- d. VP adjuncts
  - (i) Which article did Terry file papers without reading? (431)
- e. Purpose
  - (i) We need another run to win. (769)

# E Argument Types

# E.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 argments where not all three arguments are DPs
  - (i) We want John to win (28)

# E.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 proposition. 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)

# E.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 proposition. 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)

# E.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)

# E.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)

# F Arg Altern (Argument Alternations)

## F.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].

### F.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)
- f. Transitive noun
  - (i) I sensed his eagerness. (155)
- g. Expletive insertion
  - (i) \*It loved Sandy. (949)

## (28) Excluded

a. Ted was bitten by the spider. (613)

# F.3 Add Arg (Added Arguments)

These are VPs in which a non-canonical argument of the verb has been added. These cases are clearer to identify where the additional argument is a DP. In general, PPs which mark locations, times, beneficiaries, or purposes should be analyzed as adjuncts, while PPs marking causes can be considered arguments. See Pylkkänen (2008).

# (29) Included

- a. Extra argument
  - (i) \*Linda winked her lip. (202)
  - (ii) Sharon fainted from hunger. (204)
  - (iii) I shaved myself. (526)
- b. Causative
  - (i) \*I squeaked the door. (207)
- c. Expletive insertion
  - (i) There is a monster in Loch Ness. (928)
  - (ii) It annoys people that dogs bark. (943)
- d. Benefactive
  - (i) Martha carved the baby a toy out of wood. (139)

### F.4 Passive

The passive voice is marked by the demotion of the subject (either complete omission or to a byphrase) and the verb appearing as a past participle. In the stereotypical construction there is an auxiliary *be* verb, though this may be absent. See Kim and Sells (2008, p.175-190), Collins (2005), and Sag et al. (2003, p.311-333).

### (30) Included

- a. Verbs
  - (i) The earth was believed to be round. (157)
- b. Psuedopassive
  - (i) The bed was slept in. (298)
- c. Past participle adjuncts
  - (i) The horse raced past the barn fell. (900)

# **G** Imperative

# **G.1** Imperative

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

## (31) Included

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

# **H** Binding

# H.1 Binding: Refl (Binding of Reflexives)

These are cases in which a reflexive (non-possessive) pronoun, usually bound by an antecedent. See Sportiche et al. (2013, p.163-186) and Sag et al. (2003, p.203-226).

### (32) Included

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

# H.2 Binding:Other (Binding of Other Pronouns)

These are cases in which a non-reflexive pronoun appears along with its antecedent. This includes donkey anaphora, quantificational binding, and bound possessives, among other bound pronouns. See Sportiche et al. (2013, p.163-186) and Sag et al. (2003, p.203-226).

#### (33) Included

- a. Bound possessor
  - (i) The children admire their mother. (382)
- b. Quantificational binding
  - (i) Everybody gets on well with a certain relative, but often only his therapist knows which one. (562)
- c. Bound pronoun

(i) \*We gave us to the cause. (747)

# **I** Question

# I.1 Matrix Q (Matrix Questions)

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

### (34) Included

- a. Wh-question
  - (i) Who always drinks milk? (684)
- b. Polar question
  - (i) Did Athena help us? (486)

# I.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

# I.3 Pied Piping

These are phrasal Wh-phrases, in which the whword 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)

## I.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)

### I.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)

# J Comp Clause (Complement Clauses)

# J.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)

## J.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)
- c. It bothers me that John coughs. (314)
- d. Clefts
  - (i) It was a brand new car that he bought. (347)

# J.3 CP Arg - NP/AP (CP Arguments of NPs and APs)

These are complement clauses acting as an argument of a noun or adjective. See Kim and Sells (2008, pp.91-94).

### (44) Included

- a. Under NP
  - (i) Do you believe the claim that somebody was looking for something? (99)
- b. Under AP
  - (i) \*The children are fond that they have ice cream. (842)

## J.4 Non-Finite CP

These are complement clauses with a non-finite matrix verb. Often, the complementizer is for, or there is no complementizer. See Adger (2003, pp.252-253,256-260).

### (45) Included

- a. For complementizer
  - (i) I would prefer for John to leave. (990)
- b. No Complementizer
  - (i) Mary intended John to go abroad. (48)
- c. Ungrammatical

- (i) Heidi thinks that Andy to eat salmon flavored candy bars. (363)
- d. V-ing
  - (i) Only Churchill remembered Churchill giving the Blood, Sweat and Tears speech. (469)

# J.5 No C-izer (No Complementizer)

These are complement clauses with no overt complementizer.

### (46) Included

- a. Complement clause
  - (i) I'm sure we even got these tickets! (325)
  - (ii) He announced he would marry the woman he loved most, but none of his relatives could figure out who. (572)
- b. Relative clause
  - (i) The Peter we all like was at the party (484)

## J.6 Deep Embed (Deep Embedding)

These are sentences with three or nested verbs, where VP is not an aux or modal, i.e. with the following syntax: [S ...[VP ...[VP ...[VP ...]VP ...]VP ...]

# (47) Included

- a. Embedded VPs
  - (i) Max seemed to be trying to force Ted to leave the room, and Walt, Ira. (657)
- b. Embedded clauses
  - (i) I threw away a book that Sandy thought we had read. (713)

## **K** Aux (Auxiliaries)

# K.1 Neg (Negation)

Any occurrence of negation in a sentence, including sentential negation, negative quantifiers, and negative adverbs.

## (48) Included

- a. Sentential
  - (i) I can't remember the name of somebody who had misgivings. (123)
- b. Quantifier

- (i) No writer, and no playwright, meets in Vienna. (124)
- c. Adverb
  - (i) They realised that never had Sir Thomas been so offended. (409)

### K.2 Modal

Modal verbs (*may*, *might*, *can*, *could*, *will*, *would*, *shall*, *should*, *must*). See Kim and Sells (2008, pp.152-155).

## (49) Included

- a. John can kick the ball. (280)
- b. As a statesman, scarcely could he do anything worth mentioning. (292)

### (50) Excluded

- a. Pseudo-modals
  - (i) Sandy was trying to work out which students would be able to solve a certain problem. (600)

## K.3 Aux (Auxiliaries)

Auxiliary verbs (e.g. *be, have, do*). See Kim and Sells (2008, pp.149-174).

#### (51) Included

- a. They love to play golf, but I do not. (290)
- b. The car was driven. (296)
- c. he had spent five thousand dollars. (301)

#### (52) Excluded

- a. Pseudo-auxiliaries
  - (i) \*Sally asked if somebody was going to fail math class, but I can't remember who. (589)
  - (ii) The cat got bitten. (926)

### K.4 Psuedo-Aux (Pseudo Auxiliaries)

These are predicates acting as near-auxiliary (e.g. get-passive) or near-modals (e.g. willing)

# (53) Included

- a. Near-auxiliaries
  - (i) \*Mary came to be introduced by the bartender and I also came to be. (55)
  - (ii) \*Sally asked if somebody was going to fail math class, but I can't remember who. (589)
  - (iii) The cat got bitten. (926)
- b. Near-modals
  - (i) Clinton is anxious to find out

which budget dilemmas Panetta would be willing to tackle in a certain way, but he won't say in which. (593)

(ii) Sandy was trying to work out which students would be able to solve a certain problem. (600)

## L to-VP (Infinitival VPs)

### L.1 Control

These are VPs with control verbs, where one argument is a non-finite to-VP without a covert subject co-indexed with an argument of the matrix verb. See Adger (2003, pp.252,266-291), Sportiche et al. (2013, pp.203-222), and Kim and Sells (2008, pp.125-148).

## (54) Included

- a. Intransitive subject control
  - (i) \*It tries to leave the country. (275)
- b. Transitive subject control
  - (i) John promised Bill to leave. (977)
- c. Transitive object control
  - (i) I want her to dance. (379)
  - (ii) John considers Bill to be silly. (1040)

# (55) Excluded

- a. VP args of NP/AP
  - (i) This violin is difficult to play sonatas on. (114)
- b. Purpose
  - (i) There is a bench to sit on. (309)
- c. Subject VPs
  - (i) To please John is easy. (315)
- d. Argument present participles
  - (i) Medea denied poisoning the phoenix. (490)
- e. Raising
  - (i) Anson believed himself to be handsome. (499)

### L.2 Raising

These are VPs with raising predicates, where one argument is a non-finite to-VP without a covert subject co-indexed with an argument of the matrix verb. Unlike control verbs, the coindexed argument is not a semantic argument of the raising predicate. See Adger (2003, pp.260-266), Sportiche et al. (2013, pp.203-222), and Kim and Sells (2008, pp.125-148).

### (56) Included

- a. Subject raising
  - (i) Under the bed seems to be a fun place to hide. (277)
- b. Object raising
  - (i) Anson believed himself to be handsome. (499)
- c. Raising adjective
  - (i) John is likely to leave. (370)

# L.3 VP+Extraction (VPs with Extraction)

These are embedded infinitival VPs containing a (non-subject) gap that is filled by an argument in the upper clause. Examples are purpose-VPs and tough-movement. See Kim and Sells (2008, pp.246-252).

## (57) Included

- a. Tough-movement
  - (i) \*Drowning cats, which is against the law, are hard to rescue. (79)
- b. Infinitival relatives
  - (i) \*Fed knows which politician her to vote for. (302)
- c. Purpose
  - (i) the one with a red cover takes a very long time to read. (352)
- d. Other non-finite VPs with extraction
  - (i) As a statesman, scarcely could he do anything worth mentioning. (292)

# L.4 VP arg - NP/AP (VP Arguments of NPs and APs)

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

# (58) Included

- a. Raising adjectives
  - (i) John is likely to leave. (370)
- b. Control adjectives
  - (i) The administration has issued a statement that it is willing to meet a student group, but I'm not sure which one. (604)
- c. Control nouns
  - (i) As a teacher, you have to deal simultaneously with the administration's pressure on you to succeed, and the children's to be a nice guy. (673)
- d. Purpose VPs

(i) there is nothing to do. (983)

# L.5 Non-Finite VP Misc (Miscellaneous Infinitival VPs)

These are miscellaneous non-finite VPs.

### (59) Included

- a. I saw that gas can explode. (222)
- b. Gerunds/Present participles
  - (i) \*Students studying English reads Conrad's Heart of Darkness while at university. (262)
  - (ii) Knowing the country well, he took a short cut. (411)
  - (iii) John became deadly afraid of flying. (440)
- c. Subject VPs
  - (i) To please John is easy. (315)
- d. Nominalized VPs
  - (i) \*What Mary did Bill was give a book. (473)

## (60) Excluded

a. to-VPs acting as complements or modifiers of verbs, nouns, or adjectives

# M N, Adj (Nouns and Adjectives)

# M.1 Deverbal (Deverbal Nouns and Adjectives)

These are nouns and adjectives derived from verbs.

## (61) Included

- a. Deverbal nouns
  - (i) \*the election of John president surprised me. (1001)
- b. Light verbs
  - (i) The birds give the worm a tug. (815)
- c. Gerunds
  - (i) If only Superman would stop flying planes! (773)
- d. Event-wh
  - (i) What the water did to the bottle was fill it. (33)
- e. Deverbal adjectives
  - (i) His or her least known work. (95)

## M.2 Rel NP (Relational Nouns)

Relational nouns are NPs with an obligatory (or existentially closed) argument. A particular relation holds between the members of the extension

of NP and the argument. The argument must be a DP possessor or a PP. See Kim and Sells (2008, pp.82-83).

### (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 cooking? (442)
- Measure nouns
  - (i) I bought three quarts of wine and two of Clorox. (667)
- d. Possessed relational nouns
  - (i) \*John's mother likes himself. (484)

## (63) Excluded

- a. Nouns with PP modifiers
  - (i) Some people consider dogs in my neighborhood dangerous. (802)

# M.3 Trans-NP (Transitive NPs)

Transitive (non-relational) nouns take a VP or CP argument. See Kim and Sells (2008, pp.82-83).

# (64) Included

- a. VP argument
  - (i) the attempt by John to leave surprised me. (1003)
- b. CP argument
  - (i) \*Which report that John was incompetent did he submit? (69)
- c. QP argument
  - (i) That is the reason why he resigned. (313)

# M.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)

# M.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)

## M.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)

# M.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)

# N S-Syntax (Sentence-Level Syntax)

### N.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)

# N.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

# N.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)

# N.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)

# N.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 diagram of a snake's fang. (677)
- c. Correlative
  - (i) \*As you eat the most, you want the least. (5)

# N.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)

### N.7 S-adjunct (Sentence-Level Adjuncts)

These are adjuncts modifying sentences, sentencelevel 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)

# O Determiner

### 0.1 Quantifier

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

# (77) Included

- a. Quantifiers
  - (i) \*Every student, and he wears socks, is a swinger. (118)
  - (ii) We need another run to win. (769)
- b. Partitive

(i) \*Neither of students failed. (265)

### **O.2** Partitive

These are quantifiers that take PP arguments, and measure nouns. See Kim and Sells (2008, pp.109-118).

### (78) Included

- a. Quantifiers with PP arguments
  - (i) \*Neither of students failed. (265)
- b. Numerals
  - (i) One of Korea's most famous poets wrote these lines. (294)
- c. Measure nouns
  - (i) I bought three quarts of wine and two of Clorox. (667)

# O.3 NPI/FCI (Negative Polarity and Free Choice Items)

These are negative polarity items (any, ever, etc.) and free choice items (any). See Kadmon and Landman (1993).

## (79) Included

- a. NPI
  - (i) Everybody around here who ever buys anything on credit talks in his sleep. (122)
  - (ii) I didn't have a red cent. (350)
- b. FCI
  - (i) Any owl hunts mice. (387)

# **O.4** Comparative

These are comparative constructions. See (Culicover and Jackendoff, 1999).

# (80) Included

- a. Correlative
  - (i) The angrier Mary got, the more she looked at pictures. (9)
  - (ii) They may grow as high as bamboo. (337)
  - (iii) I know you like the back of my hand. (775)

# P Violations

### P.1 Sem Violation (Semantic Violations)

These are sentences that include a semantic violation, including type mismatches, violations of selectional restrictions, polarity violations, definiteness violations.

## (81) Included

- a. Volation of selectional restrictions
  - (i) \*many information was provided. (218)
  - (ii) \*It tries to leave the country. (275)
- b. Aspectual violations
  - (i) \*John is tall on several occasions. (540)
- c. Definiteness violations
  - (i) \*It is the problem that he is here. (1018)
- d. Polarity violations
  - (i) Any man didn't eat dinner. (388)

# P.2 Infl/Agr violation (Inflection and Agreement Violations)

These are sentences that include a violation in inflectional morphology, including tense-aspect marking, or agreement.

# (82) Included

- a. Case
  - (i) \*Us love they. (46)
- b. Agreement
  - \*Students studying English reads Conrad's Heart of Darkness while at university. (262)
- c. Gender
  - (i) \*Sally kissed himself. (339)
- d. Tense/Aspect
  - (i) \*Kim alienated cats and beating his dog. (429)

## P.3 Extra/Missing Word

These are sentences with a violation that can be identified with the presence or absence of a single word.

#### (83) Included

- a. Missing word
  - (i) \*John put under the bathtub. (247)
  - (ii) \*I noticed the. (788)
- b. Extra word
  - (i) \*Everyone hopes everyone to sleep. (467)
  - (ii) \*He can will go (510)