Using BERT to Examine Intransitive Subjecthood

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Abstract

Often times transitive verbs undergo an alternation to become intransitive, and the object becomes the subject.

He broke the door. → The door broke.

I use BERT (Devlin et al., 2018), a large contextual language model of English, to show that whether or not intransitive subjects "act/feel/seem" more subject-y depends not only on the subject itself, but also the type of intransitive verb.

1 Introduction & Background

1.1 Transitive/Intransitive Verbs

Linguists (especially when thinking about semantics) often place words into discrete grammatical categories, which feels at odds with the way we use language.

For example, with transitive verbs, linguists place a label of Subject/Agent on the noun performing action, or Object on the noun receiving action. In the sentence "He broke the cup",the subject is "he" and the object is "the cup".

While transitive verbs have both an Agent and an Object, intransitive verbs only have an [Intransitive] Subject

Placing only one label (Subject) to the argument of intransitive verbs in all situations feels much too general, since intransitive subjects can often feel more like objects in their use, since the verb is something happening to them.

One way we can quantify this effect for examination is by using large language models. These are trained on large amounts of text data, so they can shed some light on how we use language.

1.2 Language Modelling and BERT

Computational language models are designed to understand structure of language. These models are usually meant to optimize for predicting the next word given some past sentence fragment.

Early models such as Naive Bayes use raw probabilities from large corpora of training data to predict the most likely word given the last n word succession.

More modern methods place each word into a vector space by nudging word vectors closer together when they appear near each other in text, and push apart other word vectors that don't appear together often. This means that words that appear near each other in the embedding space are similar, since they occur together frequently.

One issue with this is that some words have different meanings depending on their context. For example the word *bank* has very different meanings in the two sentences *"I made a deposit at the bank"* and *"I swam to the bank and got out of the river."*

Modern models first use the static embedding vectors for each word in a sentence, then modify each word's embedding vector using the words around it to adjust for context.

Contextual language models have been shown to pick up lots of structure, including verbs, and which nouns are subjects and objects of each verb (Clark et al., 2019; Papadimitriou et al., 2021).

Bidirectional Encoder Representations from Transformers (BERT) is one of the most widely used large contextual language models today, and is a strong tool for analyzing how we use language (Devlin et al., 2018).

In fact, researchers have previously examined intransitive subjecthood across different factors us-

ing BERT! (Papadimitriou et al., 2021) showed that intransitive subjects are less subject-y than agents, but still consistently more subject-y than they are object-y. In addition, they show that across languages, inanimate objects are less subject-y than animate objects. They also show that intransitive subjects are less subject-y in ergative languages than absolutive languages.

1.3 Hypothesis

My goal is to show that subjecthood is graded not only by the animacy of the noun or ergativity of the language, but also the type of verb! My hypothesis is that verbs that undergo certain alternations (changing patterns from transitive to intransitive) will have more subject-y subjects than others.

1.4 Verb Types

There are many different types of verbs, and some act differently than others. These different verbs act differently, can be used in different ways, and often have different ways of changing structure when transitive vs intransitive.

One well-respected classification of verbs into verb types based on their alternation properties is found in Appendix A of *Unaccusativity: At the Syntax-Lexical Semantics Interface* (Levin et al., 1995). They divide verbs into eight overarching classes:

1. Verbs of Emission:
   Burn, whistle, smell, leak,...
2. Verbs of inherently directed motion:
   Arrive, depart, enter, rise,...
3. Verbs of manner of motion:
   Roll, bounce, run, waddle,...
4. Verbs of existence and appearance:
   Exist, prosper, open, appear...
5. Verbs of spatial configuration:
   Balance, hang, loom, open,...
6. Verbs of disappearance:
   Die, disappear, expire, vanish,...
7. Externally caused verbs of change of state:
   Break, bend, cook, awake,...
8. Internally caused verbs of change of state:
   Rust, bloom, erode, rot,...

Our hypothesis is that subjecthood is graded more for some verb types than others. One way to examine this is to see how subject-y the intransitive subject BERT embeddings are for each language and compare.

2 Methodology

To test our hypothesis, we follow the approach of (Papadimitriou et al., 2021).

We first train a classifier model using BERT embeddings to tell whether each argument of transitive verbs is the subject (denoted A) or the object (denoted O). This small linear classifier will learn to separate subjects and objects using a hyperplane. This means in semantic space, there are clusters for subjects and objects, and our model can differentiate between them.

We then test our classifier on intransitive subjects. This means our classifier has never seen intransitive verbs before, and thus is predicting subject/object based on its experience of where both subjects and objects lie in the embedding space.

If our classifier predicts that the intransitive subject is an object, this implies that the intransitive subject lands closer to the other objects than subjects in the embedding subspace. Keep in mind, the embedding space is learned using large corpora of text, and thus closely mirror human interpretation of language.

Our method is thus to:

1. Train a classifier on transitive verbs to predict whether nouns are A or O
2. Use our classifier to predict whether intransitive subjects are A or O
3. Compare predictions by verb class. Are more intransitive subjects predicted A for some verb classes?

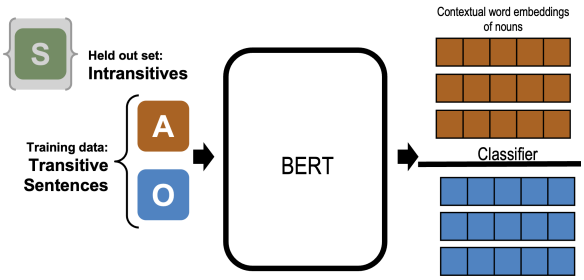

Figure 1: Methodology

2.1 Data

To train and test the graded subjecthood classifiers, I followed the training regime of (Papadimitriou et al., 2021) and used Universal Dependencies (UD) Treebank data for English. UD Treebank data has annotations for grammar (parts of speech, morphological features, and syntactic dependencies), so it is already labelled and easy to use to test our hypothesis.

We use both the training and testing data split of UD Treebank English data for evaluating on S verb/noun examples. This is because we train only on S/O examples, so the S examples in the training set are not seen until testing.

Note that there are very few type 8 verbs (Internally caused verbs of change of state) in the testing/training data, so those are omitted from the results.

3 Results

It's clear that verb class contributes somewhat significantly to how subject-y intransitive verbs are. There is noticeable difference in both percentage of verbs predicted as Subject and confidence in predicting Subject.

Results are shown in full in Figure 2. Notice that results are organized by "layer". The layer is the depth within the BERT model, where early layers are likely less contextual and less complex than later layers.

We see that generally verbs of type 2, 3, 4, 5, or 7 are much less subject-y than verbs of type 1 or 6. Not only does the model predict that verb types 1 and 6 lie in the Agent cluster more often, it also has higher confidence that they lie in the A cluster. In fact, our classifier is often more confident that type 1 verbs (of emission) are subjects than even transitive subjects!

I'm making all code available publicly. A GitHub repo[1] contains the code adapted from (Papadimitriou et al., 2021), whereas a Google Colab notebook[2] was used to run experiments.

[1]https://github.com/elipugh/deep-subjecthood

[2]https://colab.research.google.com/drive/1yKZgJuyPQuiGADOdt1laHC-BltW59bRn?usp=sharing

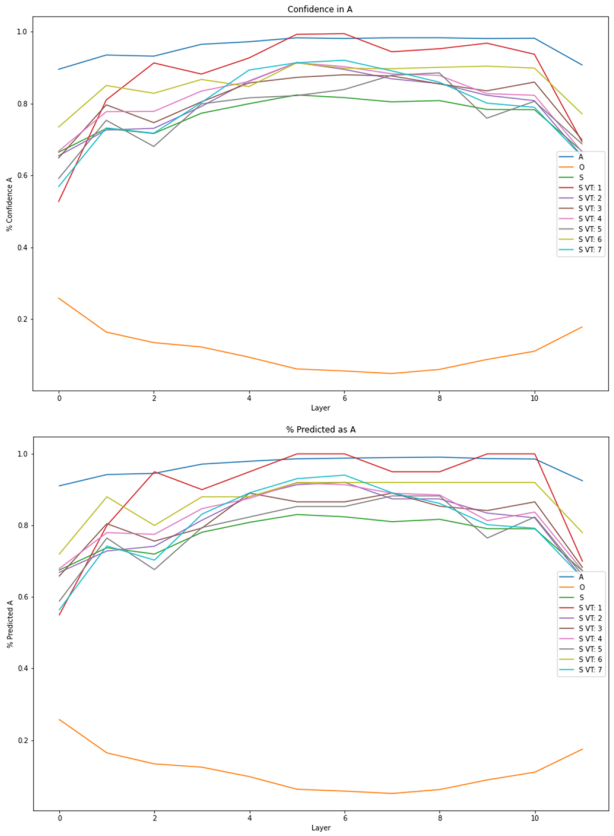

Figure 2: Confidence, Prediction % of A by type

4 Discussion

Notice that though it's clear that verb-type affects the degree of subjecthood, all verb types are still consistently more subject-y than the average intransitive subject. Why is this?

This is a shortcoming of our dataset. There are only a small number of labelled verbs in Unaccusativity (Levin et al., 1995), and thus most of the data we test on does not contribute to any of the verb class results. This tells us that, on average, verbs not listed in Unaccusativity have subjects that are harder to pin down.

Why might this be? It's very possible that verbs not found in Unaccusativity are not as common, and thus have unique word embeddings that cause our classifier to struggle. This might explain a decrease in predictions toward A as well as a decrease in confidence, since the classifier hasn't been exposed to these uncommon verbs before.

In order to paint a more comprehensive picture, it's important to test on more data, and hopefully with more labels.

This additional insight could come from the in-

clusion of a large corpus such as the Corpus of Contempory American English (CoCA) (Davies, 2008), which is significantly more comprehensive.

In addition, it might help to label more verbs by their verb type. This could be done using VerbNet (Schuler and Palmer, 2005), which contains detailed information about verbs in American English, including which alternations they undergo.

Though this work is certainly not an incredibly thorough exploration, it does show certainly that intransitive verb types do contribute to how subject-y their intransitive subjects are.

In the future, not only do I hope to use more data for stronger and more comprehensive results, I also plan to split concretely by alternation. I hope to see which alternations most affect subjecthood, and gain some insight into how the structuring of verb form changes also change subject traits.

5 Conclusion

Previously (Papadimitriou et al., 2021) showed that verb animacy and language ergativity affect how subject-y intransitive subjects are. In this work, I show that verb type also plays a big role.

Though limited by a small text corpora and incomplete labelling, it's clear that intransitive verb types 1 and 6 (Verbs of Emission and Disappearance) have much more subject-y intransitive subjects than other verbs.

In the upcoming weeks I hope to show that this is also dependent not only by category of verb, but also which alternations the verb undergoes.

This also goes to show that it's important that we not only label intransitive subjects as "intransitive subjects", but we should also distinguish between those that are referred to by different types of verb, and at different grades of subjecthood. This is not only more specific and useful, but more closely aligns with our usage of language, as shown by our language modelling experiments.

While often linguists attempt to classify parts of speech into categories for study, it's important to remember that language is imprecise, open to interpretation, and can convey a multidimensional spectrum of meaning. When examining it, we should treat as such, whether it be intransitive subjects, or any other part of our language.

References

Kevin Clark, Urvashi Khandelwal, Omer Levy, and Christopher D. Manning. 2019. What does BERT look at? an analysis of bert's attention. *CoRR*, abs/1906.04341.

Mark Davies. 2008. The corpus of contemporary american english (coca).

Jacob Devlin, Ming-Wei Chang, Kenton Lee, and Kristina Toutanova. 2018. BERT: pre-training of deep bidirectional transformers for language understanding. *CoRR*, abs/1810.04805.

Beth Levin, Malka Rappaport Hovav, and Samuel Jay Keyser. 1995. *Unaccusativity: At the syntax-lexical semantics interface*, volume 26. MIT press.

Isabel Papadimitriou, Ethan A. Chi, Richard Futrell, and Kyle Mahowald. 2021. Multilingual bert, ergativity, and grammatical subjecthood. Proceedings of the Society for Computation in Linguistics: Vol. 4 , Article 51.

Karin Kipper Schuler and Martha S. Palmer. 2005. *Verbnet: A Broad-Coverage, Comprehensive Verb Lexicon*. Ph.D. thesis, USA. AAI3179808.