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## **Anchoring and Agreement in Syntactic Annotations**

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# Anchoring and Agreement in Syntactic Annotations

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## Abstract

We present a study on two key characteristics of human syntactic annotations: anchoring and agreement. Anchoring is a well known cognitive bias in human decision making, where judgments are drawn towards pre-existing values. We study the influence of anchoring on a standard approach to creation of syntactic resources where syntactic annotations are obtained via human editing of tagger and parser output. Our experiments demonstrate a clear anchoring effect and reveal unwanted consequences, including overestimation of parsing performance and lower quality of annotations in comparison with human-based annotations. Using sentences from the Penn Treebank WSJ, we also report systematically obtained inter-annotator agreement estimates for English dependency parsing. Our agreement results control for parser bias, and are consequential in that they are *on par* with state of the art parsing performance for English newswire. We discuss the impact of our findings on strategies for future annotation efforts and parser evaluations.<sup>1</sup>

## 1 Introduction

Research in NLP relies heavily on the availability of human annotations for various linguistic prediction tasks. Such resources are commonly treated as de facto “gold standards” and are used for both training

<sup>1</sup>The experimental data in this study will be made publicly available.

and evaluation of algorithms for automatic annotation. At the same time, human agreement on these annotations provides an indicator for the difficulty of the task, and can be instrumental for estimating upper limits for the performance obtainable by computational methods.

Linguistic gold standards are often constructed using pre-existing annotations, generated by automatic tools. The output of such tools is then manually corrected by human annotators to produce the gold standard. The justification for this annotation methodology was first introduced in a set of experiments on POS tag annotation conducted as part of the Penn Treebank project (Marcus et al., 1993). In this study, the authors concluded that tagger-based annotations are not only much faster to obtain, but also more consistent and of higher quality compared to annotations from scratch. Following the Penn Treebank, syntactic annotation projects for various languages, including German (Brants et al., 2002), French (Abeillé et al., 2003), Arabic (Maamouri et al., 2004) and many others, were annotated using automatic tools as a starting point. Despite the widespread use of this annotation pipeline, there is, to our knowledge, little prior work on syntactic annotation quality and on the reliability of system evaluations on such data.

In this work, we present a systematic study of the influence of automatic tool output on characteristics of annotations created for NLP purposes. Our investigation is motivated by the hypothesis that annotations obtained using such methodologies may be

subject to the problem of *anchoring*, a well established and robust cognitive bias in which human decisions are affected by pre-existing values (Tversky and Kahneman, 1974). In the presence of anchors, participants reason relative to the existing values, and as a result may provide different solutions from those they would have reported otherwise. Most commonly, anchoring is manifested as an alignment *towards* the given values.

Focusing on the key NLP tasks of POS tagging and dependency parsing, we demonstrate that the standard approach of obtaining annotations via human correction of automatically generated POS tags and dependencies exhibits a clear anchoring effect – a phenomenon we refer to as *parser bias*. Given this evidence, we examine two potential adverse implications of this effect on parser-based gold standards.

First, we show that parser bias entails substantial overestimation of parser performance. In particular, we demonstrate that bias towards the output of a specific tagger-parser pair leads to over-estimation of the performance of these tools relative to other tools. Moreover, we observe general performance gains for automatic tools relative to their performance on human-based gold standards. Second, we study whether parser bias affects the quality of the resulting gold standards. Extending the experimental setup of Marcus et al. (1993), we demonstrate that parser bias may lead to *lower* annotation quality for parser-based annotations compared to human-based annotations.

Furthermore, we conduct an experiment on inter-annotator agreement for POS tagging and dependency parsing which controls for parser bias. Our experiment on a subset of section 23 of the WSJ Penn Treebank yields agreement rates of 95.65 for POS tagging and 94.17 for dependency parsing. This result is significant in light of the state of the art tagging and parsing performance for English newswire. With parsing reaching the level of human agreement, and tagging surpassing it, a more thorough examination of evaluation resources and evaluation methodologies for these tasks is called for.

To summarize, we present the first study to measure and analyze anchoring in the standard parser-based approach to creation of gold standards for POS tagging and dependency parsing in NLP. We conclude that gold standard annotations that are

based on editing output of automatic tools can lead to inaccurate figures in system evaluations and lower annotation quality. Our human agreement experiment, which controls for parser bias, yields agreement rates that are comparable to state of the art automatic tagging and dependency parsing performance, highlighting the need for a more extensive investigation of tagger and parser evaluation in NLP.

## 2 Experimental Setup

### 2.1 Annotation Tasks

We examine two standard annotation tasks in NLP, POS tagging and dependency parsing. In the POS tagging task, each word in a sentence has to be categorized with a Penn Treebank POS tag (Santorini, 1990) (henceforth POS). The dependency parsing task consists of providing a sentence with a labeled dependency tree using the Universal Dependencies (UD) formalism (De Marneffe et al., 2014), according to version 1 of the UD English guidelines<sup>2</sup>. To perform this task, the annotator is required to specify the head word index (henceforth HIND) and relation label (henceforth REL) of each word in the sentence.

We distinguish between three variants of these tasks, *annotation*, *reviewing* and *ranking*. In the annotation variant, participants are asked to conduct annotation from scratch. In the reviewing variant, they are asked to provide alternative annotations for all annotation tokens with which they disagree. The participants are not informed about the source of the given annotation, which, depending on the experimental condition can be either parser output or human annotation. In the ranking task, the participants rank several annotation options with respect to their quality. Similarly to the review task, the participants are not given the sources of the different annotation options. Participants performing the annotation, reviewing and ranking tasks are referred to as annotators, reviewers and judges, respectively.

### 2.2 Annotation Format

All annotation tasks are performed using a CoNLL style text-based template, in which each word appears in a separate line. The first two columns of each line contain the word index and the word, re-

<sup>2</sup><http://universaldependencies.org/#en>

spectively. The next three columns are designated for annotation of POS, HIND and REL.

In the annotation task, these values have to be specified by the annotator from scratch. In the review task, participants are required to edit pre-annotated values for a given sentence. The sixth column in the review template contains an additional # sign, whose goal is to prevent reviewers from overlooking and passively approving existing annotations. Corrections are specified following this sign in a space separated format, where each of the existing three annotation tokens is either corrected with an alternative annotation value or approved using a \* sign. Approval of all three annotation tokens is marked by removing the # sign. The example below presents a fragment from a sentence used for the reviewing task, in which the reviewer approves the annotations of all the words, with the exception of “help”, where the POS is corrected from VB to NN and the relation label *xcomp* is replaced with *dobj*.

```
...
5  you          PRP    6    nsubj
6  need         VBP    3    ccomp
7  help         VB     6    xcomp # NN * dobj
...
```

The format of the ranking task is exemplified below. The annotation options are presented to the participants in a random order. Participants specify the rank of each annotation token following the vertical bar. In this sentence, the label *cop* is preferred over *aux* for the word “be” and *xcomp* is preferred over *advcl* for the word “Common”.

```
...
8  it           PRP    10   nsubjpass
9  is           VBZ    10   auxpass
10 planed       VBN    0    root
11 to          TO     15   mark
12 be          VB     15   aux-cop | 2-1
13 in          IN     15   case
14 Wimbledon  NNP    15   compound
15 Common      NNP    10   advcl-xcomp | 2-1
...
```

The participants used basic validation scripts which checked for typos and proper formatting of the annotations, reviews and rankings.

## 2.3 Evaluation Metrics

We measure both parsing performance and inter-annotator agreement using tagging and parsing evaluation metrics. This choice allows for a direct comparison between parsing and agreement results. In this context, POS refers to tagging accuracy. We utilize the standard metrics Unlabeled Attachment Score (UAS) and Label Accuracy (LA) to measure accuracy of head attachment and dependency labels. We also utilize the standard parsing metric Labeled Attachment Score (LAS), which takes into account both dependency arcs and dependency labels. In all our parsing and agreement experiments, we exclude punctuation tokens from the evaluation.

## 2.4 Corpora

We use sentences from two publicly available datasets, covering two different genres. The first corpus, used in the experiments in sections 3 and 4, is the First Certificate in English (FCE) Cambridge Learner Corpus (Yannakoudakis et al., 2011). This dataset contains essays authored by upper-intermediate level English learners<sup>3</sup>.

The second corpus is the WSJ part of the Penn Treebank (WSJ PTB) (Marcus et al., 1993). Since its release, this dataset has been the most commonly used resource for training and evaluation of English parsers. Our experiment on inter-annotator agreement in section 5 uses a random subset of the sentences in section 23 of the WSJ PTB, which is traditionally reserved for tagging and parsing evaluation.

## 2.5 Annotators

We recruited five students at MIT as annotators. Three of the students are linguistics majors and two are engineering majors with linguistics minors. Prior to participating in this study, the annotators completed two months of training. During training, the students attended tutorials, and learned the annotation guidelines for PTB POS tags, UD guidelines, as well as guidelines for annotating challenging syntactic structures arising from grammatical errors. The students also annotated individually six

<sup>3</sup>The annotation bias and quality results reported in sections 3 and 4 use the original learner sentences, which contain grammatical errors. These results were replicated on the error corrected versions of the sentences.

practice batches of 20-30 sentences from the English Web Treebank (EWT) (Silveira et al., 2014) and FCE corpora, and resolved annotation disagreements during group meetings.

Following the training period, the students annotated a treebank of learner English (Berzak et al., 2016) over a period of five months, three of which as a full time job. During this time, the students continued attending weekly meetings in which further annotation challenges were discussed and resolved. The annotation was carried out for sentences from the FCE dataset, where both the original and error corrected versions of each sentence were annotated and reviewed. In the course of the annotation project, each annotator completed approximately 800 sentence annotations, and a similar number of sentence reviews. The annotations and reviews were done in the same format used in this study. With respect to our experiments, the extensive experience of our participants and their prior work as a group strengthen our results, as these characteristics reduce the effect of anchoring biases and increase inter-annotator agreement.

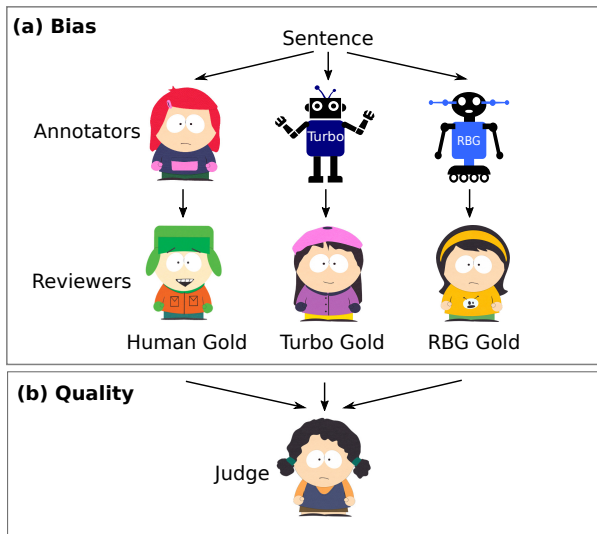
### 3 Parser Bias

Our first experiment is designed to test whether expert human annotators are biased towards POS tags and dependencies generated by automatic tools. We examine the common out-of-domain annotation scenario, where automatic tools are often trained on an existing treebank in one domain, and used to generate initial annotations to speed-up the creation of a gold standard for a new domain. We use the EWT UD corpus as the existing gold standard, and a sample of the FCE dataset as the new corpus.

#### Procedure

Our experimental procedure, illustrated in figure 1(a) contains a set of 360 sentences (6,979 tokens) from the FCE, for which we generate three gold standards: one based on human annotations and two based on parser outputs. To this end, for each sentence, we assign *at random* four of the participants to the following annotation and review tasks. The fifth participant is left out to perform the quality ranking task described in section 4.

The first participant annotates the sentence from scratch, and a second participant reviews this an-



**Figure 1:** Experimental setup for parser bias (a) and annotation quality (b) on 360 sentences (6,979 tokens) from the FCE. For each sentence, five human annotators are assigned at random to one of three roles: annotation, review or quality assessment. In the bias experiment, presented in section 3, every sentence is annotated by a human, Turbo parser (based on Turbo tagger output) and RBG parser (based on Stanford tagger output). Each annotation is reviewed by a different human participant to produce three gold standards of each sentence: “Human Gold”, “Turbo Gold” and “RBG Gold”. The fifth annotator performs a quality assessment task described in section 4, which requires to rank the three gold standards in cases of disagreement.

notation. The overall agreement of the reviewers with the annotators is 98.24 POS, 97.16 UAS, 96.3 LA and 94.81 LAS. The next two participants review parser outputs. One participant reviews an annotation generated by the Turbo tagger and parser (Martins et al., 2013). The other participant reviews the output of the Stanford tagger (Toutanova et al., 2003) and RBG parser (Lei et al., 2014). The taggers and parsers were trained on the gold annotations of the EWT UD treebank, version 1.1. Both parsers use predicted POS tags for the FCE sentences.

Assigning the reviews to the human annotations yields a human based gold standard for each sentence called “Human Gold”. Assigning the reviews to the tagger and parser outputs yields two parser-based gold standards, “Turbo Gold” and “RBG Gold”. We chose the Turbo-Turbo and Stanford-RBG tagger-parser pairs as these tools obtain comparable performance on standard evaluation bench-

	<b>Turbo</b>				<b>RBG</b>			
	POS	UAS	LA	LAS	POS	UAS	LA	LAS
<b>Human Gold</b>	95.32	87.29	88.35	82.29	95.59	87.19	88.03	82.05
<b>Turbo Gold</b>	<b>97.62</b>	<b>91.86</b>	<b>92.54</b>	<b>89.16</b>	96.64	89.16	89.75	84.86
Error Reduction %	49.15	35.96	35.97	38.79	23.81	15.38	14.37	15.65
<b>RBG Gold</b>	96.43	88.65	89.95	84.42	<b>97.76</b>	<b>91.22</b>	<b>91.84</b>	<b>87.87</b>
Error Reduction %	23.72	10.7	13.73	12.03	49.21	31.46	31.83	32.42

**Table 1:** Annotator bias towards taggers and parsers on 360 sentences (6,979 tokens) from the FCE. Tagging and parsing results are reported for the Turbo parser (based on the output of the turbo Tagger) and RBG parser (based on the output of the Stanford tagger) on three gold standards. Human Gold are manual corrections of human annotations. Turbo Gold are manual corrections of the output of Turbo tagger and Turbo parser. RBG Gold are manual corrections of the Stanford tagger and RBG parser. Error reduction rates are reported relative to the results obtained by the two tagger-parser pairs on the Human Gold annotations. Note that (1) The parsers perform equally well on Human Gold. (2) Each parser performs better than the other parser on its own reviews. (3) Each parser performs better on the reviews of the other parser compared to its performance on Human Gold. The differences in (2) and (3) are statistically significant with  $p \ll 0.001$  using McNemar’s test.

marks, while yielding substantially different annotations due to different training algorithms and feature sets. For our sentences, the agreement between the Turbo tagger and Stanford tagger is 96.97 POS. The agreement between the Turbo parser and RBG parser based on the respective tagger outputs is 90.76 UAS, 91.6 LA and 87.34 LAS.

### Parser Specific and Parser Shared Bias

In order to test for parser bias, in table 1 we compare the performance of the Turbo-Turbo and Stanford-RBG tagger-parser pairs on our three gold standards. First, we observe that while these tools perform equally well on Human Gold, each tagger-parser pair performs better than the other on its own reviews. These *parser specific* performance gaps are substantial, with an average of 1.15 POS, 2.63 UAS, 2.34 LA and 3.88 LAS between the two conditions. This result suggests the presence of a bias towards the output of specific tagger-parser combinations. The practical implication of this outcome is that a gold standard created by editing an output of a parser is likely to boost the performance of that parser in evaluations and over-estimate its performance relative to other parsers.

Second, we note that the performance of each of the parsers on the gold standard of the other parser is still higher than its performance on the human gold standard. The average performance gap between these conditions is 1.08 POS, 1.66 UAS, 1.66 LA and 2.47 LAS. This difference suggests an annotation bias towards *shared* aspects in the predictions

of taggers and parsers, which differ from the human based annotations. The consequence of this observation is that irrespective of the specific tool that was used to pre-annotate the data, parser-based gold standards are likely to result in higher parsing performance relative to human-based gold standards.

Taken together, the parser specific and parser shared effects lead to a dramatic overall average error reduction of 49.18% POS, 33.71% UAS, 34.9% LA and 35.61% LAS on the parser-based gold standards compared to the human-based gold standard. To the best of our knowledge, these results are the first systematic demonstration of the tendency of the common approach of parser-based creation of gold standards to yield biased annotations and lead to overestimation of tagging and parsing performance.

## 4 Annotation Quality

In this section we extend our investigation to examine the impact of parser bias on the quality of parser-based gold standards. To this end, we perform a manual comparison between human-based and parser-based gold standards.

Our quality assessment experiment, depicted schematically in figure 1(b), is a ranking task. For each sentence, a randomly chosen judge, who did not annotate or review the given sentence, ranks disagreements between the three gold standards Human Gold, Turbo Gold and RBG Gold, generated in the parser bias experiment in section 3.

Table 2 presents the preference rates of judges

Human Gold Preference %	POS	HIND	REL
Turbo Gold	64.32*	63.96*	61.5*
# disagreements	199	444	439
RBG Gold	56.72	61.38*	57.73*
# disagreements	201	435	440

**Table 2:** Human preference rates for a human-based gold standard Human Gold over the two parser-based gold standards Turbo Gold and RBG Gold. # disagreements denotes the number of tokens that differ between Human Gold and the respective parser-based gold standard. Statistically significant values for a two-tailed Z test with  $p < 0.01$  are marked with \*. Note that for both tagger-parser pairs, human judges tend to prefer human-based over parser-based annotations.

for the human-based gold standard over each of the two parser-based gold standards. In all three evaluation categories, human judges tend to prefer the human-based gold standard over both parser-based gold standards. This result demonstrates that the initial reduced quality of the parser outputs compared to human annotations indeed percolates via anchoring to the resulting gold standards.

The analysis of the quality assessment experiment thus far did not distinguish between cases where the two parsers agree and where they disagree. In order to gain further insight into the relation between parser bias and annotation quality, we break down the results reported in table 2 into two cases which relate directly to the *parser specific* and *parser shared* components of the tagging and parsing performance gaps observed in the parser bias results reported in section 3. In the first case, called “parser specific approval”, a reviewer approves a parser annotation which disagrees both with the output of the other parser and the Human Gold annotation. In the second case, called “parser shared approval”, a reviewer approves a parser output which is shared by both parsers but differs with respect to Human Gold.

Table 3 presents the judge preference rates for the Human-Gold annotations in these two scenarios. We observe that cases in which the parsers disagree are of substantially worse quality compared to human-based annotations. However, in cases of agreement between the parsers, the resulting gold standards do not exhibit a clear disadvantage relative to the Human Gold annotations.

This result highlights the crucial role of parser

Human Gold Preference %	POS	HIND	REL
Turbo specific approval	85.42*	78.69*	80.73*
# disagreements	48	122	109
RBG specific approval	73.81*	77.98*	77.78*
# disagreements	42	109	108
Parser shared approval	51.85	58.49*	51.57
# disagreements	243	424	415

**Table 3:** Breakdown of the Human preference rates for the human-based gold standard over the parser-based gold standards in table 2, into cases of agreement and disagreement between the two parsers. Parser specific approval are cases in which a parser output approved by the reviewer differs from both the output of the other parser and the Human Gold annotation. Parser shared approval denotes cases where an approved parser output is identical to the output of the other parser but differs from the Human Gold annotation. Statistically significant values for a two-tailed Z test with  $p < 0.01$  are marked with \*. Note that parser specific approval is substantially more detrimental to the resulting annotation quality compared to parser shared approval.

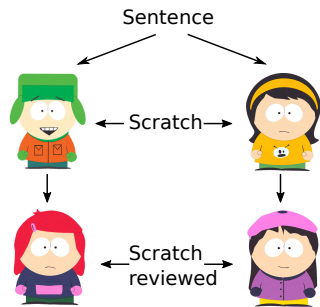
specific approval in the overall preference of judges towards human-based annotations in table 2. Furthermore, it suggests that annotations on which multiple state of the art parsers agree are of sufficiently high accuracy to be used to save annotation time without substantial impact on the quality of the resulting resource. In section 7 we propose an annotation scheme which leverages this insight.

## 5 Inter-annotator Agreement

Agreement estimates in NLP are often obtained in annotation setups where both annotators edit the same automatically generated input. However, in such experimental conditions, anchoring can introduce cases of spurious disagreement as well as spurious agreement between annotators due to alignment of one or both participants towards the given input. The initial quality of the provided annotations in combination with the parser bias effect observed in section 3 may influence the resulting agreement estimates. For example, in Marcus et al. (1993) annotators were shown to produce POS tagging agreement of 92.8 on annotation from scratch, compared to 96.5 on reviews of tagger output.

Our goal in this section is to obtain estimates for inter-annotator agreement on POS tagging and dependency parsing that control for parser bias, and

as a result, reflect more accurately human agreement on these tasks. We thus introduce a novel pipeline based on human annotation only, which eliminates parser bias from the agreement measurements. Our experiment extends the human-based annotation study of Marcus et al. (1993) to include also syntactic trees. Importantly, we include an additional review step for the initial annotations, designed to increase the precision of the agreement measurements by reducing the number of errors in the original annotations.



**Figure 2:** Experimental setup for the inter-annotator agreement experiment. 300 sentences (7,227 tokens) from section 23 of the PTB-WSJ are annotated and reviewed by four participants. The participants are assigned to the following tasks *at random* for each sentence. Two participants annotate the sentence from scratch, and the remaining two participants review one of these annotations each. Agreement is measured on the annotations (“scratch”) as well after assigning the review edits (“scratch reviewed”).

For this experiment, we use 300 sentences (7,227 tokens) from section 23 of the PTB-WSJ, the standard test set for English parsing in NLP. The experimental setup, depicted graphically in figure 2, includes four participants randomly assigned for each sentence to annotation and review tasks. Two of the participants provide the sentence with annotations from scratch, while the remaining two participants provide reviews. Each reviewer edits one of the annotations independently, allowing for correction of annotation errors while maintaining the independence of the annotation sources. We measure agreement between the initial annotations (“scratch”), as well as the agreement between the reviewed versions of our sentences (“scratch reviewed”).

The agreement results for the annotations and the reviews are presented in table 4. The initial agree-

ment rate on POS annotation from scratch is higher than in (Marcus et al., 1993). This difference is likely to arise, at least in part, due to the fact that their experiment was conducted at the beginning of the annotation project, when the annotators had a more limited annotation experience compared to our participants. Overall, we note that the agreement rates from scratch are relatively low. The review round raises the agreement on all the evaluation categories due to elimination of annotation errors present in the original annotations.

	POS	UAS	LA	LAS
scratch	94.78	93.07	92.3	88.32
scratch reviewed	<b>95.65</b>	<b>94.17</b>	<b>94.04</b>	<b>90.33</b>

**Table 4:** Inter-annotator agreement on 300 sentences (7,227 tokens) from the PTB-WSJ section 23. “scratch” is agreement on independent annotations from scratch. “scratch reviewed” is agreement on the same sentences after an additional independent review round of the annotations.

Our post-review agreement results are consequential in light of the current state of the art performance on tagging and parsing in NLP. For more than a decade, POS taggers have been achieving over 97% accuracy with the PTB POS tag set on the PTB-WSJ test set. For example, the best model of the Stanford tagger reported in Toutanova et al. (2003) produces an accuracy of 97.24 POS on sections 22-24 of the PTB-WSJ. These accuracies are above the human agreement in our experiment.

With respect to dependency parsing, recent parsers obtain results which are on par or higher than our inter-annotator agreement estimates. For example, Weiss et al. (2015) report 94.26 UAS and Andor et al. (2016) report 94.61 UAS on section 23 of the PTB-WSJ using an automatic conversion of the PTB phrase structure trees to Stanford dependencies (De Marneffe et al., 2006). These results are not fully comparable to ours due to differences in the utilized dependency formalism and the automatic conversion of the annotations. Nonetheless, we believe that the similarities in the tasks and evaluation data are sufficiently strong to indicate that dependency parsing for standard English newswire may be reaching human agreement levels.



## 6 Related Work

The term “anchoring” was coined in a seminal paper by Tversky and Kahneman (1974), which demonstrated that numerical estimation can be biased by uninformative prior information. Subsequent work across various domains of decision making confirmed the robustness of anchoring using both informative and uninformative anchors (Furnham and Boo, 2011). Pertinent to our study, anchoring biases were also demonstrated when the participants were domain experts, although to a lesser degree than in the early anchoring experiments (Wilson et al., 1996; Mussweiler and Strack, 2000).

Prior work in NLP examined the influence of pre-tagging (Fort and Sagot, 2010) and pre-parsing (Skjærholt, 2013) on human annotations. Our work introduces a systematic study of this topic using a novel experimental framework as well as substantially more sentences and annotators. Differently from these studies, our methodology enables characterizing annotation bias as anchoring and measuring its effect on tagger and parser evaluations.

Our study also extends the POS tagging experiments of Marcus et al. (1993), which compared inter-annotator agreement and annotation quality on manual POS tagging in annotation from scratch and tagger-based review conditions. The first result reported in that study was that tagger-based editing increases inter-annotator agreement compared to annotation from scratch. Our work provides a novel agreement benchmark for POS tagging which reduces annotation errors through a review process while controlling for tagger bias, and obtains agreement measurements for dependency parsing. The second result reported in Marcus et al. (1993) was that tagger-based edits are of higher quality compared to annotations from scratch when evaluated against an additional independent annotation. We modify this experiment by introducing ranking as an alternative mechanism for quality assessment, and adding a review round for human annotations from scratch. Our experiment demonstrates that in this configuration, parser-based annotations are of *lower* quality compared to human-based annotations.

Several estimates of expert inter-annotator agreement for English parsing were previously reported. However, most such evaluations were conducted us-

ing annotation setups that can be affected by an anchoring bias (Carroll et al., 1999; Rambow et al., 2002; Silveira et al., 2014). A notable exception is the study of Sampson and Babarczy (2008) who measure agreement on annotation from scratch for English parsing in the SUSANNE framework (Sampson, 1995). The reported results, however, are not directly comparable to ours, due to the use of a substantially different syntactic representation, as well as a different agreement metric. Their study further suggests that despite the high expertise of the annotators, the main source of annotation disagreements was annotation errors. Our work alleviates this issue by using annotation reviews, which reduce the number of erroneous annotations while maintaining the independence of the annotation sources. Experiments on non-expert dependency annotation from scratch were previously reported for French, suggesting low agreement rates (79%) with an expert annotation benchmark (Gerdes, 2013).

## 7 Discussion

We present a systematic study of the impact of anchoring on POS and dependency annotations used in NLP, demonstrating that annotators exhibit an anchoring bias effect towards the output of automatic annotation tools. This bias leads to an artificial boost of performance figures for the parsers in question and results in lower annotation quality as compared with human-based annotations.

Our analysis demonstrates that despite the adverse effects of parser bias, predictions that are shared across different parsers do not significantly lower the quality of the annotations. This finding gives rise to the following *hybrid annotation* strategy as a potential future alternative to human-based as well as parser-based annotation pipelines. In a hybrid annotation setup, human annotators review annotations on which several parsers agree, and complete the remaining annotations from scratch. Such a strategy would largely maintain the annotation speed-ups of parser-based annotation schemes. At the same time, it is expected to achieve annotation quality comparable to human-based annotation by avoiding parser specific bias, which plays a pivotal role in the reduced quality of single-parser reviewing pipelines.

Further on, we obtain, to the best of our knowl-

edge for the first time, syntactic inter-annotator agreement measurements on WSJ-PTB sentences. Our experimental procedure reduces annotation errors and controls for parser bias. Despite the detailed annotation guidelines, the extensive experience of our annotators, and their prior work as a group, our experiment indicates rather low agreement rates, which are below state of the art tagging performance and on par with state of the art parsing results on this dataset. We note that our results do not necessarily reflect an upper bound on the achievable syntactic inter-annotator agreement for English newswire. Higher agreement rates could in principle be obtained through further annotator training, refinement and revision of annotation guidelines, as well as additional automatic validation tests for the annotations. Nonetheless, we believe that our estimates reliably reflect a realistic scenario of expert syntactic annotation.

The obtained agreement rates call for a more extensive examination of annotator disagreements on parsing and tagging. Recent work in this area has already proposed an analysis of expert annotator disagreements for POS tagging in the absence of annotation guidelines (Plank et al., 2014). Our annotations will enable conducting such studies for annotation with guidelines, and support extending this line of investigation to annotations of syntactic dependencies. As a first step towards this goal, we plan to carry out an in-depth analysis of disagreement in the collected data, characterize the main sources of inconsistent annotation and subsequently formulate further strategies for improving annotation accuracy. We believe that better understanding of human disagreements and their relation to disagreements between humans and parsers will also contribute to advancing evaluation methodologies for POS tagging and syntactic parsing in NLP, an important topic that has received only limited attention thus far (Schwartz et al., 2011; Plank et al., 2015).

Finally, since the release of the Penn Treebank in 1992, it has been serving as the standard benchmark for English parsing evaluation. Over the past few years, improvements in parsing performance on this dataset were obtained in small increments, and are commonly reported without a linguistic analysis of the improved predictions. As dependency parsing performance on English newswire may be reaching

human expert agreement, not only new evaluation practices, but also more attention to noisier domains and other languages may be in place.

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## References

- Anne Abeillé, Lionel Clément, and François Toussenet. 2003. Building a treebank for french. In *Treebanks*, pages 165–187. Springer.
- Daniel Andor, Chris Alberti, David Weiss, Aliaksei Severyn, Alessandro Presta, Kuzman Ganchev, Slav Petrov, and Michael Collins. 2016. Globally normalized transition-based neural networks. In *Proceedings of ACL*, pages 2442–2452.
- Yevgeni Berzak, Jessica Kenney, Carolyn Spadine, Jing Xian Wang, Lucia Lam, Keiko Sophie Mori, Sebastian Garza, and Boris Katz. 2016. Universal dependencies for learner english. In *Proceedings of ACL*, pages 737–746.
- Sabine Brants, Stefanie Dipper, Silvia Hansen, Wolfgang Lezius, and George Smith. 2002. The tiger treebank. In *Proceedings of the workshop on treebanks and linguistic theories*, volume 168.
- John Carroll, Guido Minnen, and Ted Briscoe. 1999. Corpus annotation for parser evaluation. *arXiv preprint cs/9907013*.
- Marie-Catherine De Marneffe, Bill MacCartney, Christopher D Manning, et al. 2006. Generating typed dependency parses from phrase structure parses. In *Proceedings of LREC*, volume 6, pages 449–454.
- Marie-Catherine De Marneffe, Timothy Dozat, Natalia Silveira, Katri Haverinen, Filip Ginter, Joakim Nivre, and Christopher D Manning. 2014. Universal stanford dependencies: A cross-linguistic typology. In *Proceedings of LREC*, pages 4585–4592.
- Karèn Fort and Benoît Sagot. 2010. Influence of pre-annotation on pos-tagged corpus development. In *Proceedings of the fourth linguistic annotation workshop*, pages 56–63.

- Adrian Furnham and Hua Chu Boo. 2011. A literature review of the anchoring effect. *The Journal of Socio-Economics*, 40(1):35–42.
- Kim Gerdes. 2013. Collaborative dependency annotation. *DepLing 2013*, 88.
- Tao Lei, Yu Xin, Yuan Zhang, Regina Barzilay, and Tommi Jaakkola. 2014. Low-rank tensors for scoring dependency structures. In *Proceedings of ACL*, volume 1, pages 1381–1391.
- Mohamed Maamouri, Ann Bies, Tim Buckwalter, and Wigdan Mekki. 2004. The penn arabic treebank: Building a large-scale annotated arabic corpus. In *NEMLAR conference on Arabic language resources and tools*, volume 27, pages 466–467.
- Mitchell P Marcus, Mary Ann Marcinkiewicz, and Beatrice Santorini. 1993. Building a large annotated corpus of english: The penn treebank. *Computational linguistics*, 19(2):313–330.
- André FT Martins, Miguel Almeida, and Noah A Smith. 2013. Turning on the turbo: Fast third-order non-projective turbo parsers. In *Proceedings of ACL*, pages 617–622.
- Thomas Mussweiler and Fritz Strack. 2000. Numeric judgments under uncertainty: The role of knowledge in anchoring. *Journal of Experimental Social Psychology*, 36(5):495–518.
- Barbara Plank, Dirk Hovy, and Anders Søgaard. 2014. Linguistically debatable or just plain wrong? In *Proceedings of ACL: Short Papers*, pages 507–511.
- Barbara Plank, Héctor Martínez Alonso, Željko Agić, Danijela Merkle, and Anders Søgaard. 2015. Do dependency parsing metrics correlate with human judgments? In *Proceedings of CoNLL*.
- Owen Rambow, Cassandre Creswell, Rachel Szekely, Harriet Taber, and Marilyn A Walker. 2002. A dependency treebank for english. In *Proceedings of LREC*.
- Geoffrey Sampson and Anna Babarczy. 2008. Definitional and human constraints on structural annotation of english. *Natural Language Engineering*, 14(04):471–494.
- Geoffrey Sampson. 1995. English for the computer: Susanne corpus and analytic scheme.
- Beatrice Santorini. 1990. Part-of-speech tagging guidelines for the penn treebank project (3rd revision). *Technical Reports (CIS)*.
- Roy Schwartz, Omri Abend, Roi Reichart, and Ari Rappoport. 2011. Neutralizing linguistically problematic annotations in unsupervised dependency parsing evaluation. In *Proceedings of ACL*, pages 663–672.
- Natalia Silveira, Timothy Dozat, Marie-Catherine De Marneffe, Samuel R Bowman, Miriam Connor, John Bauer, and Christopher D Manning. 2014. A gold standard dependency corpus for english. In *Proceedings of LREC*, pages 2897–2904.
- Arne Skjærholt. 2013. Influence of preprocessing on dependency syntax annotation: speed and agreement. *LAW VII & ID*.
- Kristina Toutanova, Dan Klein, Christopher D Manning, and Yoram Singer. 2003. Feature-rich part-of-speech tagging with a cyclic dependency network. In *Proceedings of NAACL*, pages 173–180.
- Amos Tversky and Daniel Kahneman. 1974. Judgment under uncertainty: Heuristics and biases. *Science*, 185(4157):1124–1131.
- David Weiss, Chris Alberti, Michael Collins, and Slav Petrov. 2015. Structured training for neural network transition-based parsing. In *Proceedings of ACL*, pages 323–333.
- Timothy D Wilson, Christopher E Houston, Kathryn M Etling, and Nancy Brekke. 1996. A new look at anchoring effects: basic anchoring and its antecedents. *Journal of Experimental Psychology: General*, 125(4):387.
- Helen Yannakoudakis, Ted Briscoe, and Ben Medlock. 2011. A new dataset and method for automatically grading ESOL texts. In *Proceedings of ACL*, pages 180–189.