

Chapter 1

Semi-Automated Resolution of Inconsistency for a Harmonized Multiword Expression and Dependency Parse Annotation

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This paper presents a methodology for identifying and resolving various kinds of inconsistency in the context of merging dependency and multiword expression (MWE) annotations, to generate a dependency treebank with comprehensive MWE annotations. Candidates for correction are identified using a variety of heuristics, including an entirely novel one which identifies violations of MWE constituency in the dependency tree, and resolved by arbitration with minimal human intervention. Using this technique, we identified and corrected several hundred inconsistencies across both parse and MWE annotations, representing changes to a significant percentage (well over 10%) of the MWE instances in the joint corpus, and a large difference in MWE tagging performance relative to earlier versions.

1 Introduction

The availability of gold-standard annotations is important for the training and evaluation of a wide variety of NLP tasks, including the evaluation of depen-



dependency parsers (Buchholz & Marsi 2006). In recent years, there has been a focus on multi-annotation of a single corpus, such as joint syntactic, semantic role, named entity, coreference and word sense annotation in Ontonotes (Hovy et al. 2006) or constituency, semantic role, discourse, opinion, temporal, event and coreference (among others) annotation of the Manually Annotated Sub-Corpus of the ANC (Ide et al. 2010). As part of this, there has been an increased focus on harmonizing and merging existing annotated data sets as a means of extending the scope of reference corpora (Ide & Suderman 2007; Declerck 2008; Simi, Montemagni & Bosco 2015). This effort sometimes presents an opportunity to fix conflicting annotations, a worthwhile endeavour since even a small number of errors in a gold-standard syntactic annotation can, for example, result in significant changes in downstream applications (Habash et al. 2007). This paper presents the results of a harmonization effort for the overlapping STREUSLE annotation (Schneider, Onuffer, et al. 2014) of multiword expressions (“MWEs”: Baldwin & Kim (2010)) and dependency parse structure in the English Web Treebank (“EWT”: Bies et al. (2012)), with the long-term goal of building reliable resources for joint MWE/syntactic parsing (Constant & Nivre 2016).

As part of merging these two sets of annotations, we use analysis of cross-annotation and type-level consistency to identify instances of potential annotation inconsistency, with an eye to improving the quality of the component and combined annotations. It is important to point out that our approach to identifying and handling inconsistencies does not involve re-annotating the corpus; instead we act as arbitrators, resolving inconsistency in only those cases where human intervention is necessary. Our three methods for identifying potentially problematic annotations are:

- a cross-annotation heuristic that identifies MWE tokens whose parse structure is incompatible with the syntactic annotation of the MWE;
- a cross-type heuristic that identifies n -grams with inconsistent token-level MWE annotations; and
- a cross-type, cross-annotation heuristic that identifies MWE types whose parse structure is inconsistent across its token occurrences.

The first of these is specific to this harmonization process, and as far as we are aware, entirely novel. The other two are adaptations of an approach to improving syntactic annotations proposed by Dickinson & Meurers (2003). After applying these heuristics and reviewing the candidates, we identified hundreds of errors in MWE annotation and about a hundred errors in the original syntactic annotations. We make available a tool that applies these fixes in the process of joining the two annotations into a single harmonized, corrected annotation, and release the

harmonized annotations in the form of HAMSTER (the HArmonized Multiword and Syntactic TreE Resource): <https://github.com/eltimster/HAMSTER>. We also show, using a standard MWE tagger Schneider, Danchik, et al. (2014), that the application of these and other corpus fixes has a major effect on MWE identification performance, with almost a quarter of the error originally assumed to be tagger error is actually attributable to errors in the corpus.

2 Related Work

Our long-term goal is in building reliable resources for joint MWE/syntactic parsing. Explicit modelling of MWEs has been shown to improve parser accuracy (Nivre & Nilsson 2004; Finkel & Manning 2009; Korkontzelos & Manandhar 2010; Green, de Marneffe & Manning 2013; Vincze, Zsibrita & T. 2013; Candito & Constant 2014; Constant & Nivre 2016). Treatment of MWEs has typically involved parsing MWEs as single lexical units (Nivre & Nilsson 2004; Eryiğit, İlbay & Can 2011; Fotopoulou, Markantonatou & Giouli 2014), however this flattened, “words with spaces” (Sag et al. 2002) approach is inflexible in its coverage of MWEs where components have some level of flexibility.

The English Web Treebank (Bies et al. 2012) represents a gold-standard annotation effort over informal web text. The original syntactic constituency annotation of the corpus was based on hand-correcting the output of the Stanford Parser (Manning et al. 2014); for our purposes we have converted this into a dependency parse using the Stanford Typed Dependency converter (de Marneffe, MacCartney & Manning 2006). We considered the use of the Universal Dependencies representation (Nivre et al. 2016), however we noted that several aspects of that annotation (in particular the treatment of all prepositions as case markers dependent on their noun) make it inappropriate for joint MWE/syntactic parsing since it results in large numbers of MWEs that are non-contiguous in their syntactic structure (despite being contiguous at the token-level). As such, the Stanford Typed Dependencies are the representation which has the greatest currency for joint MWE/syntactic parsing work (Constant & Nivre 2016).

The STREUSLE corpus (Schneider, Onuffer, et al. 2014) is based entirely on the Reviews subset of the EWT, and comprises of 3,812 sentences representing 55,579 tokens. The annotation was completed by six linguists who were native English speakers. Every sentence was assessed by at least two annotators, which resulted in an average inter-annotator F1 agreement of 0.7. The idiosyncratic nature of MWEs lends itself to challenges associated with their interpretation, and this was readily acknowledged by those involved in the development of the STREUSLE

corpus (Hollenstein, Schneider & Webber 2016). Two important aspects of the MWE annotation are that it includes both contiguous and non-contiguous MWEs (e.g. *check * out*), and that it supports both weak and strong annotation; both of these are considered in scope for our inconsistency analysis. A variety of cues are employed to determine this associative strength. The primary factor relates to the degree in which the expression is semantically opaque and/or morpho-syntactically idiosyncratic. An example of a strong MWE would be *top notch*, as used in the sentence: *We stayed at a top notch hotel*. The semantics of this expression are not immediately predictable from the meanings of *top* and *notch*. On the other hand, the expression *highly recommend* is considered to be a weak expression as it is largely compositional — one can *highly recommend a product* — as indicated by the presence of alternatives such as *greatly recommend* which are also acceptable though less idiomatic. A total of 3,626 MWE instances were identified in STREUSLE, across 2,334 MWE types.

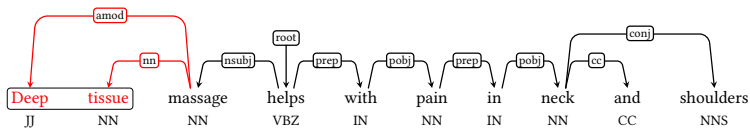


Figure 1: An example where the arc count heuristic is breached. *Deep tissue* has been labeled in the sentence here as an MWE in STREUSLE. *Deep* and *tissue* act as modifiers to *massage*, a term that has not been included as part of the MWE.

Other MWE-aware dependency treebanks include the various UD treebanks (Nivre et al. 2016), the Prague Dependency Treebank (Bejček et al. 2013), and others (Nivre & Nilsson 2004; Eryiğit, İlbay & Can 2011; Candito & Constant 2014). The representation of MWEs, and the scope of types covered by these treebanks, can vary significantly. For example, the internal syntactic structure may be flattened (Nivre & Nilsson 2004), or in the case of Candito & Constant (2014), allow for distinctions in the granularity of syntactic representation for regular vs. irregular MWE types.

The identification of inconsistencies in annotation requires comparisons to be made between similar instances that are labeled differently. Boyd, Dickinson & Meurers (2007) employed an alignment-based approach to assess differences in the annotation of n -gram word sequences in order to establish the likelihood of error occurrence. Other work in the syntactic inconsistency detection domain includes those related to POS tagging (Loftsson 2009; Eskin 2000; Ma et al. 2001) and parse structure (Ule & Simov 2004; Kato & Matsubara 2010). Dickinson &

Meurers (2003) outline various approaches for detecting inconsistencies in parse structure within treebanks.

In general, inconsistencies associated with MWE annotation fall under two categories: (1) *annotator error* (i.e. false positives and false negatives); and (2) ambiguity associated with the assessment of *hard cases*. While annotation errors apply to situations where a correct label can be applied but is not done so, hard cases are those where the correct label is inherently difficult to assign, and can be particularly relevant to certain classes of MWEs. For example, there may be considerable differences in inter-annotator agreement associated with assessing the relative transparency and associative strength of a non-fixed MWE.

3 Error Candidate Identification

3.1 MWE Syntactic Constituency Conflicts

The hypothesis that drives our first analysis is that for nearly all MWE types, the component words of the MWE should be syntactically connected, which is to say that every word is a dependent of another word in the MWE, except one word which connects the MWE to the rest of the sentence (or the root of the sentence). We can realise this intuition by using an arc count heuristic: for each labeled MWE instance we count the number of incoming dependency arcs that are headed by a term outside the MWE, and if the count is greater than one, we flag it for manual analysis. Figure 1 gives an example where the arc count heuristic is breached since both terms of the MWE *deep tissue* act as modifiers to the head noun that sits outside the MWE.

3.2 MWE Type Inconsistency

Our second analysis involves first collecting a list of all MWE types in the STREUSLE corpus, corresponding to lemmatized n -grams, possibly with gaps. We then match these n -grams across the same corpus, and flag any MWE type which has at least one inconsistency with regards to the annotation. That is, we extract as candidates any MWE types where there were at least two occurrences of the corresponding n -gram in the corpus that were incompatible with respect to their annotation in STREUSLE, including discrepancies in weak/strong designation. For non-contiguous MWE types, matches containing up to 4 words of intervening context between the two parts of the MWE type were included as candidates for further assessment.

3.3 MWE Type Parse Inconsistency

The hypothesis that drives our third analysis is that we would generally expect the internal syntax of an MWE type to be consistent across all its instances.¹ For each MWE type, we extracted the internal dependency structure of all its labeled instances, and flagged for further assessment any type for which the parse structure varied between at least two of those instances. Note that although this analysis is aimed at fixing parse errors, it makes direct use of the MWE annotation provided by STREUSLE to greatly limit the scope of error candidates to those which are most relevant to our interest.

4 Error Arbitration

Error arbitration was carried out by the authors (all native English speakers with experience in MWE identification), with at least two authors looking at each error candidate in most instances, and for certain difficult cases, the final annotation being based on discussion among all three authors. One advantage of our arbitration approach over a traditional token-based annotation was that we could enforce consistency across similar error candidates (e.g. *disappointed with* and *happy with*) and also investigate non-candidates to arrive at a consensus; where at all possible, our changes relied on precedents that already existed in the relevant annotation.

Arbitration for the MWE syntax conflicts usually involved identifying an error in one of the two annotations, and in most cases this was relatively obvious. For instance, in the candidate *...the usual lady called in sick hours earlier, called in sick* was correctly labeled as an MWE, but the parse incorrectly includes *sick* as a dependent of *hours*, rather than *called in*. An example of the opposite case is *...just to make the appointment ...*, where *make the* had been labeled as an MWE, an obvious error which was caught by our arc count heuristic. There were cases where our arc count heuristic was breached due to what we would view as a general inadequacy in the syntactic annotation, but we decided not to effect a change because the impact would be too far reaching; examples of this were certain discourse markers (e.g. *as soon as*), and infinitives (e.g. *have to complete* where the *to* is considered a dependent of its verb rather than of the other term in the MWE *have to*). The most interesting cases were a handful of non-contiguous MWEs where there was truly a discontinuity in the syntax between the two parts

¹ Noting that we would not expect this to occur between MWE instances of a given combination of words, and non-MWE combinations of those same words.

of the MWE, for instance *no amount of * can*. This suggests a basic limitation in our heuristic, although the vast majority of MWEs did satisfy it.

For the two type-level arbitrations, there were cases of inconsistency upheld by real usage differences (e.g. *a little house* vs. *a little tired*). We identified clear differences in usage first, and divided the MWE types into sets, excluding from further analysis non-MWE usages of MWE type *n*-grams. For each consistent usage of an MWE type, the default position was to prefer the majority annotation across the set of instances, except when there were other candidates that were essentially equivalent: for instance, if we had relied on majority annotation for *job * do* (e.g. *the job that he did*) it would have been a different annotation than *do * job* (e.g. *do a good job*), so we considered these two together. We treated contiguous and non-contiguous versions of the same MWE type in the same manner.

In the MWE type consistency arbitration, for cases where majority rules did not provide a clear answer and there was no overwhelming evidence for non-compositionality, we introduced a special internal label called *hard*. These correspond to cases where the usage is consistent and the inconsistency seems to be a result of the difficulty of the annotation item (as discussed earlier in Section 2), which extended also to our arbitration. Rather than enforce a specific annotation without strong evidence, or allow the inconsistency to remain when there is no usage justification for it, the corpus merging and correction tool gives the user the option to treat *hard* annotated MWEs in varying ways: the annotation may be kept unchanged, removed, converted to weak, or covered to *hard* for the purpose of excluding it from evaluation. Examples of hard cases include *go back*, *go in*, *more than*, *talk to*, *speak to*, *thanks guys*, *not that great*, *pleased with*, *have * option*, *get * answer*, *fix * problem*. On a per capita basis, inconsistencies are more common for non-contiguous MWEs relative to their contiguous counterparts, and we suspect that this is partially due to their tendency to be weaker, in addition to the challenges involved in correctly discerning the two parts, which are sometimes at a significant distance from each other.

Table 1 provides a summary of changes to MWE annotation at the MWE type and token levels. *Mixed* refer to MWEs that are heterogeneous in the associative strength between terms in the MWE (between weak and strong). Most of the changes in Table 1 (98% of the types) were the result of our type consistency analysis. Almost half of the changes involved the use of the *hard* label, but even excluding these (since only some of these annotations required actual changes in the final version of the corpus) our changes involve over 10% of the MWE tokens in the corpus, and thus represent a significant improvement to the STREUSLE

Table 1: Summary of changes to MWE annotation at the MWE type and token level

		No MWE	Weak	Strong	Mixed	Hard	TOTAL
Token	No MWE	—	55	136	6	151	348
	Weak	35	—	22	4	46	107
	Strong	44	42	—	9	70	165
	Mixed	2	4	3	12	2	23
	TOTAL	81	101	161	31	269	643
Type	No MWE	—	31	74	5	64	174
	Weak	31	—	13	4	35	83
	Strong	34	28	—	7	43	112
	Mixed	2	4	3	7	2	18
	TOTAL	67	63	90	23	144	387

annotation.

Relative to the changes to the MWE annotation, the changes to the parse annotation were more modest, but still not insignificant: for 161 MWE tokens across 72 types, we identified and corrected a dependency and/or POS annotation error. The majority of these (67%) were identified using the arc count heuristic. Note we applied the parse relevant heuristics after we fixed the MWE type consistency errors, ensuring that MWE annotations that were added were duly considered for parse errors.

5 Experiments

In this section we investigate the effect of the HAMSTER MWE inconsistency fixes on the task of MWE expression identification. For this we use the AMALGr MWE identification tool of Schneider, Danchik, et al. (2014), which was developed on the initial release of the STRUESLE (called then the CMWE).² AMALGr is a supervised structured perception model which makes use of external resources including 10 MWE lexicons as well as Brown cluster information. For all our experiments we use the default settings from Schneider, Danchik, et al. (2014),

² The key difference between the CMWE and STRUESLE is the inclusion of supersense tags. Though we hope to eventually include supersense information in the output of HAMSTER, supersenses are beyond the scope of the present work.

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Table 2: AMALGr f-scores for various versions of MWE annotation of EWT Reviews

Dataset	F-score
CMWE (Schneider, Danchik, et al. 2014)	0.594
STRUESLE 3.0	0.646
HAMSTER-original	0.691
HAMSTER-notMWE	0.682
HAMSTER-weak	0.694
HAMSTER-original-noeval	0.702
HAMSTER-weak-noeval	0.693
HAMSTER-original-test	0.671
HAMSTER-original-train	0.657

including the original train/test splits and automatic part-of-speech tagging provide by the ARK TweetNLP POS tagger (Owoputi et al. 2013) trained on the all non-review sections of the English Web Treebank. We note that in contrast to typical experiments in NLP, here we are holding *the approach* constant while varying the quality of the dataset, which provides an quantification of the extent to which errors in the dataset interfered with our ability to build or accurately evaluate models. Following Schneider, Danchik, et al. (2014), we report an F-score which is calculated based on links between words: a true positive occurs when two words which are supposed to appear together in an MWE do so as expected.

There are two baselines in Table 2: The first is the original performance of AMALGr as reported in Schneider, Danchik, et al. (2014) using CMWE (version 1.0 of this annotation), and the second is its performance using STRUESLE (version 3.0). Note that these involve exactly the same texts: the difference between these two numbers reflect other fixes to this dataset that have happened in the years since its initial release. The difference between two is quite substantial, roughly 0.05 f-score.

The rest of the table makes use of HAMSTERized versions of STRUESLE, which we refer to as simply HAMSTER. The options here mostly refer to our treatment of the hard annotation, which must be removed to make use of AMALGr. *-original* refers to a situation where we apply all fixes which result in the creation or removal of a standard STRUESLE label (*weak* and *strong*), but leave hard annotations as they were in the original corpus. *-notMWE* and *-weak* create ver-

sions of the corpus where all hard labels have been mapped to either nothing (no MWE) or weak MWEs, respectively. Another option we consider is -noeval, which involved tweaking the AMALGr evaluation script to exclude particular annotations (in this case hard) from evaluation altogether; that is, it does not matter what the model predicted for those words which are considered hard. Finally, -test and train refers to the situation where we apply our fixes only to texts only in one of either the test or training sets, respectively; this gives us a sense of whether the improved performance of model in HAMSTER datasets is primarily due to the removal of errors from the test set, or whether improving the consistency of the training set is playing a major role as well.

Our fixes result in roughly another 0.05 increase to f-score relative to STRUESLE 3.0, for a total of about 0.1 f-score difference relative to results using the original CMWE annotation of this corpus. With respect to options for phrases labeled as hard, treating them as nonMWEs seems to be a worse option than simply leaving them alone; the best explanation for this is probably that these hard cases are generally more similar to labelled MWE. Treating them as weak appears to a better strategy. Even better, though, might be to leave hard inconsistencies in the training set but exclude them from consideration during testing. The results using mixed training/test datasets indicate that the fixes to the test data are clearly more important, but the consistency across the two sets also accounts for a major part of the performance increase seen here.

Our second round of experiments look at exact match recall with respect to various subsets of the MWEs in the test set. Here we consider only the original STREUSLE and HAMSTERized version with hard MWEs unchanged. N is the number of MWEs labeled as that type in that version of the dataset. Our goal here is to get a sense of how our changes have affected the identification of specific kinds of MWE. weak versus strong is an obvious distinction (mixed MWE were considered strong), but even more relevant to what we have done here is whether or not the MWE appears both the training set and the test set. We are also interested in the status of multiword named entities (identified fairly reliably using proper noun tags in the gold-standard POS tags), which occur numerous in a corpus of reviews, but often as singletons, with a frequency of one. We would expect MWE which neither appear in our corpus nor are named entities (NE) to be relatively unaffected by our fixes, and among the most challenging MWEs to identify in general.

In Table 3 table AMALGr does better with the HAMSTER for most of the MWE subtypes considered here, the most striking difference occurs for the weak tag, reflecting a disproportionate amount of inconsistency, enough that the model built

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Table 3: AMALGr exact recall for different MWE subsets in original and HAMSTERized STRUESLE

MWE types	STRUESLE		HAMSTER	
	N	Recall	N	Recall
All	423	0.597	444	0.634
Strong	352	0.632	368	0.663
Weak	71	0.240	76	0.355
In training	178	0.777	208	0.801
Not in training	247	0.474	238	0.494
Named entity (NE)	52	0.735	52	0.716
Not NE, not in training	195	0.403	186	0.439

on the earlier version was apparently hesitant to apply the tag at all. Not only are MWEs with training instances tagged better after our fixes, but the set of such MWE tokens has noticeably increased with our fixes. There is a corresponding drop in those test instances without training data, which are clearly the most difficult to identify, particularly when named entities are excluded. The recall of named entities has actually dropped slightly, though since there are only 52 of these in test set, this corresponds to a single missed example and is probably not meaningful. Though the rationale in terms of higher-level semantics is clear, we wonder whether including NER as part of MWE identification may result in distorted view of the importance of MWE lexicons in token-level MWE identification. Here, we can see that among test-set-only MWEs, they stand out as being significantly easier than the rest, probably because they can be identified fairly reliably using only capitalization.

6 Discussion

Our three heuristics are useful because they identify potential errors with a high degree of precision. For the MWE type consistency analysis 77% of candidate types were problematic, and for parse type consistency, 63%. For the arc count heuristic, 54% of candidate types were ultimately changed: as mentioned earlier, many of the breaches involved systematic issues with annotation schema that we felt uncomfortable changing in isolation. By bringing these candidate instances to our attention, we were able to better focus our manual analysis effort, inclu-

ding in some cases looking across multiple related types, or even searching for specialist knowledge which could resolve ambiguities: for instance, in the example shown in Figure 1, though a layperson without reference material may be unsure whether it is *tissue* or *massage* which is considered to be *deep*, a quick online search indicates that the original EWT syntax is in error (*deep* modifies *tissue*).

However, it would be an overstatement to claim to have fixed all (or even almost all) the errors in the corpus. For instance, our type consistency heuristics only work when there are multiple instances of the same type, yet it is worth noting that 82% of the MWE types in the corpus are represented by a singleton instance. Our arc count heuristic can identify issues with singletons, but its scope is fairly limited. We cannot possibly identify missing annotations for types that were not annotated at least once. We might also miss certain kinds of systematic annotation errors, for instance those mentioned in De Smedt, Rosén & Meurer (2015), though that work focused on the use of mwe dependency labels which are barely used in the EWT, one of the reasons a resource like STREUSLE is so useful.

Our experiments with the AMALGr tool show that our fixes result in a major improvement in MWE identification. One particularly striking result is the fact that the errors identified in the annotation since its original release account for about a quarter of all error (as measured by f-score) in the original model trained on it. This error may affect relative comparisons between systems, and we should be skeptical of results previously drawn based on relatively small differences in MWE identification in earlier versions of the corpus. This amount of error is also unacceptable simply in terms of the obfuscation relative to the degree of absolute progress on the task. Beyond this specific effort, we believe, for annotation efforts in general and for MWEs in particular, we should move beyond a myopic focus on getting sufficient annotator agreement in initial annotation—the agreement in the original CWME was fairly reasonable—and instead develop protocols for semi-automated, type-level inconsistency detection as a default step before an annotation is released. In this work, we have shown how bringing in other kinds of annotation done over the same corpus can facilitate such rigorous error correction, as part of the harmonization process.

7 Conclusion

We have proposed a methodology for merging multiword expression and dependency parse annotations, to generate HAMSTER: a gold-standard MWE-annotated dependency treebank with high consistency. The heuristics used to enforce con-

sistency operate at the type- and cross-annotation level, and affected well over 10% of the MWEs in the new resource, resulting in a downstream change in MWE identification of roughly 0.05 f-score.

References

- Baldwin, Timothy & Su Nam Kim. 2010. Multiword expressions. In Nitin Indurkha & Fred J. Damerau (eds.), *Handbook of natural language processing, second edition*. Boca Raton, USA: CRC Press, Taylor & Francis Group.
- Bejček, Eduard, Eva Hajičová, Jan Hajič, Pavlína Jínová, Václava Kettnerová, Veronika Kolářová, Marie Mikulová, Jiří Mírovský, Anna Nedoluzhko, Jarmila Pánevová, Lucie Poláková, Magda Ševčíková, Jan Štěpánek & Šárka Zikánová. 2013. *Prague Dependency Treebank 3.0*. Charles University in Prague, UFAL.
- Bies, Ann, Justin Mott, Colin Warner & Seth Kulick. 2012. *English Web Treebank*. Tech. rep. LDC2012T13. Linguistic Data Consortium. <http://www ldc.upenn.edu/Catalog/%20catalogEntry.jsp?catalogId=LDC2012T13>.
- Boyd, Adriane, Markus Dickinson & Detmar Meurers. 2007. Increasing the recall of corpus annotation error detection. In *Proceedings of the sixth workshop on treebanks and linguistic theories (tlt 2007)*. Bergen, Norway. %5Curl%7Bhttp://decca.osu.edu/publications/boyd-et-al-07b.html%7D.
- Buchholz, Sabine & Erwin Marsi. 2006. CoNLL-X shared task on multilingual dependency parsing. In *Proceedings of the tenth conference on computational natural language learning (CoNLL-X '06)*, 149–164. New York City, USA. <http://dl.acm.org/citation.cfm?id=1596276.1596305>.
- Candito, Marie & Matthieu Constant. 2014. Strategies for contiguous multiword expression analysis and dependency parsing. In *Proceedings of the 52nd annual meeting of the association for computational linguistics (acl '14)*, 743–753. Baltimore, USA.
- Constant, Matthieu & Joakim Nivre. 2016. A transition-based system for joint lexical and syntactic analysis. In *Proceedings of the 54th annual meeting of the association for computational linguistics (acl '16)*, 161–171. Berlin, Germany.
- De Smedt, Koenraad, Victoria Rosén & Paul Meurer. 2015. Studying consistency in UD treebanks with INESS-Search. In *Proceedings of the fourteenth workshop on treebanks and linguistic theories (tlt14)*, 258–267. Warsaw, Poland.
- Declerck, Thierry. 2008. A framework for standardized syntactic annotation. In *Proceedings of the 2008 language resource and evaluation conference (lrec 08)*. Marrakech, Morocco.

- Dickinson, Markus & W. Detmar Meurers. 2003. Detecting inconsistencies in treebanks. In *Proceedings of the second workshop on treebanks and linguistic theories (tlt 2003)*. Växjö, Sweden.
- Eryiğit, Gülşen, Tugay İlbay & Ozan Arkan Can. 2011. Multiword expressions in statistical dependency parsing. In *Proceedings of the second workshop on statistical parsing of morphologically rich languages*, 45–55. Dublin, Ireland. <http://dl.acm.org/citation.cfm?id=2206359.2206365>.
- Eskin, Eleazar. 2000. Detecting errors within a corpus using anomaly detection. In *Proceedings of the 1st north american chapter of the association for computational linguistics conference*, 148–153. Seattle, USA. <http://dl.acm.org/citation.cfm?id=974305.974325>.
- Finkel, Jenny Rose & Christopher D. Manning. 2009. Joint parsing and named entity recognition. In *Proceedings of human language technologies: the 2009 annual conference of the north american chapter of the association for computational linguistics*, 326–334. Boulder, USA. <http://dl.acm.org/citation.cfm?id=1620754.1620802>.
- Fotopoulou, Aggeliki, Stella Markantonatou & Voula Giouli. 2014. Encoding MWEs in a conceptual lexicon. In *Proceedings of the 10th workshop on multiword expressions (mwe 2014)*. Gothenburg, Sweden.
- Green, Spence, Marie-Catherine de Marneffe & Christopher D. Manning. 2013. Parsing models for identifying multiword expressions. *Computational Linguistics* 39(1). 195–227. http://dx.doi.org/10.1162/COLI_a_00139. DOI:10.1162/COLI_a_00139
- Habash, Nizar, Ryan Gabbard, Owen Rambow, Seth Kulick & Mitchell P. Marcus. 2007. Determining case in Arabic: learning complex linguistic behavior requires complex linguistic features. In *Proceedings of the joint conference on empirical methods in natural language processing and computational natural language learning 2007 (emnlp-conll 2007)*, 1084–1092. Prague, Czech Republic.
- Hollenstein, Nora, Nathan Schneider & Bonnie Webber. 2016. Inconsistency detection in semantic annotation. In *Proceedings of the 2016 language resources and evaluation conference (lrec '16)*. Portorož, Slovenia.
- Hovy, Eduard, Mitchell Marcus, Martha Palmer, Lance Ramshaw & Ralph Weischedel. 2006. OntoNotes: the 90% solution. In *Proceedings of the main conference on human language technology conference of the north american chapter of the association of computational linguistics*, 57–60. New York City, USA.
- Ide, Nancy, Collin Baker, Christiane Fellbaum & Rebecca Passonneau. 2010. The Manually Annotated Sub-Corpus: a community resource for and by the people.

- In *Proceedings of the 48th annual meeting of the acl (acl 2010) – short papers*, 68–73. Uppsala, Sweden.
- Ide, Nancy & Keith Suderman. 2007. GrAF: a graph-based format for linguistic annotations. In *Proceedings of the linguistic annotation workshop*, 1–8. Prague, Czech Republic. <http://dl.acm.org/citation.cfm?id=1642059.1642060>.
- Kato, Yoshihide & Shigeki Matsubara. 2010. Correcting errors in a treebank based on synchronous tree substitution grammar. In *Proceedings of the acl 2010 conference short papers*, 74–79. Uppsala, Sweden.
- Korkontzelos, Ioannis & Suresh Manandhar. 2010. Can recognising multiword expressions improve shallow parsing? In *Human language technologies: the 2010 annual conference of the north american chapter of the association for computational linguistics (HLT '10)*, 636–644. Los Angeles, USA. <http://dl.acm.org/citation.cfm?id=1857999.1858088>.
- Loftsson, Hrafn. 2009. Correcting a POS-tagged corpus using three complementary methods. In *Proceedings of the 12th conference of the european chapter of the association for computational linguistics*, 523–531. Athens, Greece.
- Ma, Qing, Bao-Liang Lu, Masaki Murata, Michnori Ichikawa & Hitoshi Isahara. 2001. On-line error detection of annotated corpus using modular neural networks. In *International conference on artificial neural networks*, 1185–1192. Vienna, Austria.
- Manning, Christopher D., Mihai Surdeanu, John Bauer, Jenny Finkel, Steven J. Bethard & David McClosky. 2014. The Stanford CoreNLP natural language processing toolkit. In *Proceedings of the 52nd annual meeting of the association for computational linguistics: system demonstrations*, 55–60. Baltimore, USA.
- de Marneffe, Marie-Catherine, Bill MacCartney & Christopher D. Manning. 2006. Generating typed dependency parses from phrase structure parses. In *Proceedings of the 5th international conference on language resources and evaluation (lrec '06)*. Genova, Italy.
- Nivre, Joakim, Marie-Catherine de Marneffe, Filip Ginter, Yoav Goldberg, Jan Hajic, Christopher D Manning, Ryan McDonald, Slav Petrov, Sampo Pyysalo, Natalia Silveira, Reut Tsarfaty & Daniel Zeman. 2016. Universal Dependencies v1: a multilingual treebank collection. In *Proceedings of the 10th international conference on language resources and evaluation (lrec 2016)*, 1659–1666. Portorož, Slovenia.
- Nivre, Joakim & Jens Nilsson. 2004. Multiword units in syntactic parsing. In *Methodologies and evaluation of multiword units in real-world applications (memura)*. Lisbon, Portugal.

- Owoputi, Olutobi, Brendan O'Connor, Chris Dyer, Kevin Gimpel, Nathan Schneider & Noah A. Smith. 2013. Improved part-of-speech tagging for online conversational text with word clusters. In *Proceedings of the 15th annual conference of the north american chapter of the association for computational linguistics (naacl '13)*.
- Sag, Ivan A., Timothy Baldwin, Francis Bond, Ann Copestake & Dan Flickinger. 2002. Multiword expressions: a pain in the neck for NLP. In *Proceedings of the 3rd international conference on intelligent text processing and computational linguistics (cicling '02)*. Mexico City, Mexico.
- Schneider, Nathan, Emily Danchik, Chris Dyer & Noah A. Smith. 2014. Discriminative lexical semantic segmentation with gaps: running the MWE gamut. *Transactions of the Association for Computational Linguistics* 2. 193–206.
- Schneider, Nathan, Spencer Onuffer, Nora Kazour, Emily Danchik, Michael T. Mordowanec, Henrietta Conrad & Noah A. Smith. 2014. Comprehensive annotation of multiword expressions in a social web corpus. In *Proceedings of the ninth international conference on language resources and evaluation*, 455–461. Reykjavík, Iceland. http://www.lrec-conf.org/proceedings/lrec2014/pdf/521_Paper.pdf.
- Simi, Maria, Simonetta Montemagni & Cristina Bosco. 2015. Harmonizing and merging Italian treebanks: towards a merged Italian dependency treebank and beyond. In Roberto Basili, Cristina Bosco, Rodolfo Delmonte, Alessandro Moschitti & Maria Simi (eds.), *Harmonization and development of resources and tools for italian natural language processing within the PARLI project*, 3–23. Heidelberg, Germany: Springer. http://dx.doi.org/10.1007/978-3-319-14206-7_1. DOI:10.1007/978-3-319-14206-7_1
- Ule, Tylman & Kiril Simov. 2004. Unexpected productions may well be errors. In *Proceedings of the 2004 language resources and evaluation conference (lrec '04)*. Lisbon, Portugal.
- Vincze, Veronika, Janos Zsibrita & István Nagy T. 2013. Dependency parsing for identifying Hungarian light verb constructions. In *Proceedings of international joint conference on natural language processing (ijcnlp '13)*. Nagoya, Japan.