

Chapter 5

Analysis and Insights from the PARSEME Shared Task dataset

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The PARSEME Shared Task on the automatic identification of verbal multiword expressions (VMWEs) was the first collaborative study on the subject to cover a wide and diverse range of languages. One observation that emerged from the official results is that participating systems performed similarly on each language but differently across languages. That is, intra-language evaluation scores are relatively similar whereas inter-language scores are quite different. We hypothesise that this pattern cannot be attributed solely to the intrinsic linguistic properties in each language corpus, but also to more practical aspects such as the evaluation framework, characteristics of the test and training sets as well as metrics used for measuring performance. This chapter takes a close look at the shared task dataset and the systems' output to explain this pattern. In this process, we produce evaluation results for the systems on VMWEs that only appear in the test set and contrast them with the official evaluation results, which include VMWEs that also occur in the training set. Additionally, we conduct an analysis aimed at estimating the relative difficulty of VMWE detection for each language. This analysis consists of a) assessing the impact on performance of the ability, or lack thereof, of systems to handle discontinuous and overlapped VMWEs, b) measuring the relative sparsity of sentences with at least one VMWE, and c) interpreting the performance of each system with respect to two baseline systems: a system that simply tags every verb as a VMWE, and a dictionary lookup system. Based on our data analysis, we assess the suitability of the official evaluation methods, specifically the token-based method, and propose to use Cohen's kappa score as an additional evaluation method.



1 Introduction

Multiword expressions (MWEs) have been studied extensively due to the fact that many natural language processing (NLP) pipelines depend on their correct identification and processing (Sag et al. 2002). However, there has been relatively little work on *Verbal* MWEs (VMWEs). The PARSEME¹ Shared Task on VMWEs (Savary et al. 2017) was the first initiative focusing on the problem of identifying VMWEs for a relatively large number of languages, 18 in total. This initiative produced an array of annotated training and test sets for each language. Using these training sets, shared task participants developed and trained VMWE-identification systems, which were then evaluated on separate test sets also produced by PARSEME.

Several patterns have emerged from the evaluation results in this pioneering shared task. One is that individual systems tend to perform very differently across languages (inter-language performance) and yet different systems performed similarly in most languages (intra-language performance). In particular, participating systems scored highest on Farsi, Romanian, Czech and Polish, and lowest on Swedish, Hebrew, Lithuanian and Maltese, whilst ranging somewhere in between for the rest of the languages. It has been observed that the inter-language performance is positively correlated with the proportion of VMWEs shared by the training and test sets in each language (Maldonado et al. 2017). This observation suggests that the reported systems' performance and ranking could potentially be dependent on the proportion of shared VMWEs across languages. At the very least, it is clear that inter-language performance differences cannot be attributed to linguistic differences among languages alone, but to particularities of the dataset that interplay with these linguistic differences.

This chapter conducts a detailed data analysis of the PARSEME dataset and the official systems' submissions in order to try to understand how these particularities impact systems' performance and to propose possible modifications to the dataset in order to balance out said particularities among the language corpora.

To this end, we start our discussion in §2 by computing statistics for each language to get a sense of their differences. We then measure the relative difficulty in identifying VMWEs in each language corpus by focusing on three factors that could potentially pose challenges to the systems: 1) the relative sparsity of VMWEs in each language corpus (by measuring the proportion of sentences with and without VMWEs); 2) the prevalence and significance of discontinuous VMWEs and embedded (or overlapped) VMWEs; and 3) corpus similarity and

¹<http://parseme.eu>

homogeneity measures between the training and test portions for each language section. We observe that the importance of these factors varies across languages: while some are inherent to each language’s linguistic properties (e.g., proportion of continuous vs discontinuous VMWEs or the dominant category of VMWEs in a language), others (e.g., relative sparsity of VMWEs) can be controlled by altering the size of the training and test sets, the proportion of shared VMWEs between these two sets, and, in general, the homogeneity of the distribution of VMWEs in these sets for each of the languages.

We then turn our attention to the shared task official evaluation scores on the participating systems in §3 and §4. In §3, we focus on the effect of the proportion of shared VMWEs between the training and test sets in each language corpus. We evaluate the systems on shared VMWEs and on VMWEs occurring exclusively in the test set. We also introduce two baseline systems (a system that simply tags every verb as a VMWE and a simple dictionary look-up system) and observe that the performance of the participating systems follows trends that the performance of these baselines shows.

In §4, we concentrate on the evaluation metrics used in the shared task: one that measures the ability of retrieving full VMWEs (MWE-based evaluation) and another that gives credit to systems on partially identified VMWEs (Token-based evaluation). We observe that the Token-based evaluation measure gives more weight to long VMWEs and, in addition, can be exploited by a system that simply detects verbs. Lastly, we use Cohen’s κ inter-annotator agreement measure as an evaluation metric based on the intuition that it provides a ‘chance-corrected’ degree of similarity between a system output and a gold standard.

In §5, we conclude that the PARSEME VMWE dataset is a valuable resource for evaluating VMWE identification systems as long as certain variables are controlled for and purpose-specific evaluation frameworks are considered. We also propose avenues for future work.

Before we delve into the analysis and discussion, it should be mentioned that systems were considered to be participating in one of two separate tracks under the original shared task rules: a) an open track in which participants were free to use any external data (other than the training data provided) to train and develop their systems, and b) a closed track, where participants were allowed to use the provided training data only. Given that only one system (LATL) participated in the open track and for only one language (French), this chapter completely ignores the open/closed distinction and compares all systems on the same evaluation scores.

2 Shared task dataset

This section explores several numerical properties of the dataset developed for the shared task in order to gain an insight into differences among languages and to identify potential *difficulty factors* in the corpora. We consider difficulty factors to be corpus-specific characteristics (such as corpus size, sparsity of VMWEs or corpus heterogeneity) that could potentially hinder an algorithm’s ability to identify VMWEs. We assess a factor’s degree of difficulty by observing the overall systems’ performance on languages that present the factor in question, in comparison to languages that do not present that factor. The performance of the systems is measured by the official shared task evaluation F1 scores, shown in Table 1. That table also contains the averages all systems’ scores for a given language (*avg* column) and the ranks of the languages according to these averages (*rk* column). Recall that two evaluation modalities were measured in the shared task: MWE-based evaluation, which counts as a success the matching of a full VMWE, and Token-based evaluation, which gives partial credit to partially matched VMWEs. Figure 1 summarises these scores per language as box plots.

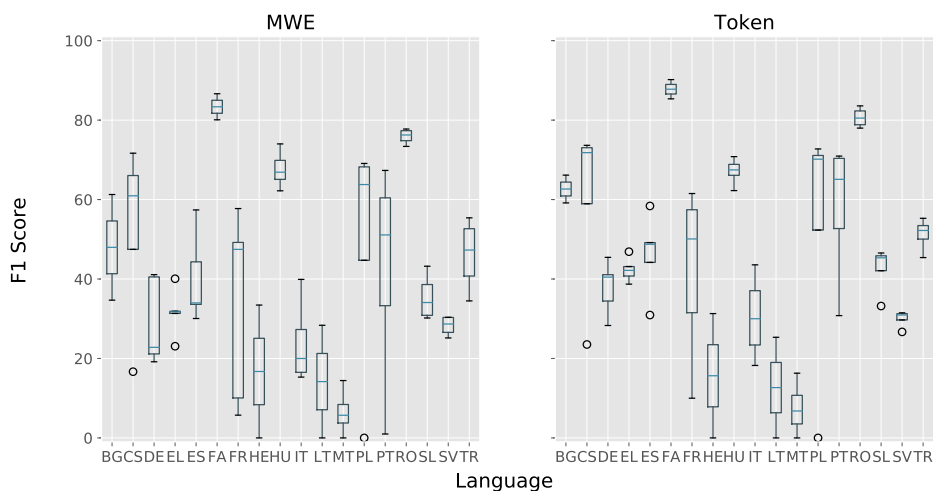


Figure 1: Box plots summarising F1 scores achieved by all systems on each language, using the MWE-based and Token-based evaluation modalities

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Table 1: F1 evaluation scores by language and system with averages (avg), rank (rnk) in Token-based, MWE-based and Cohen’s κ evaluations. Baselines: dictionary look-up (BD) and verb detection (BV).

		ADAPT	LATL	LIF	MUMULS	RACAI	SEZGED	TRANSITION	avg	rnk	BD	BV
BG	Token-based				59.16			66.15	62.66	4	47.44	
	MWE-based				34.68			61.27	47.98	6	34.67	
	Cohen’s κ				21.36			53.57	37.47	6	21.27	
CS	Token-based	72.86			23.52	70.76		73.65	60.20	5	64.34	20.41
	MWE-based	57.72			16.67	64.18		71.67	52.56	4	51.91	0
	Cohen’s κ	46.49			8.82	55.04		64.36	43.68	5	37.87	-18.54
DE	Token-based	40.48			34.45	28.30	45.45	41.09	37.95	13	40.70	28.52
	MWE-based	22.80			21.14	19.17	40.53	41.10	28.95	13	41.34	9.22
	Cohen’s κ	5.86			5.01	5.82	24.97	26.44	13.62	16	26.42	-15.49
EL	Token-based	43.14			42.17	38.71	40.75	46.88	42.33	12	34.16	9.14
	MWE-based	31.34			23.08	31.74	31.88	40.07	31.62	12	21.81	0.02
	Cohen’s κ	23.28			12.46	25.2	22.9	31.57	23.08	11	9.46	-7.41
ES	Token-based	49.17			48.75	30.93	44.18	58.39	46.28	9	50.97	15.56
	MWE-based	44.33			33.62	30.06	33.99	57.39	39.88	9	44.22	0
	Cohen’s κ	35.84			21.18	23.41	17.81	48.83	30.91	9	32.7	-13.41
FA	Token-based	85.36						90.20	87.78	1	65.75	47.73
	MWE-based	80.08						86.64	83.36	1	55.92	0
	Cohen’s κ	63.13						74.77	68.95	2	22.71	-50.01
FR	Token-based	61.52	54.61	10.00	29.40	50.09	33.64	60.28	42.79	10	45.73	18.28
	MWE-based	50.88	47.46	10.82	9.29	47.55	5.73	57.74	32.78	11	38.42	0.21
	Cohen’s κ	40.12	33.77	7.98	-4.75	38.74	-14.42	48.98	21.49	13	24.19	-15.99
HE	Token-based				0.00			31.30	15.65	16	33.80	
	MWE-based				0.00			33.44	16.72	16	37.44	
	Cohen’s κ				0.00			27.74	13.87	14	32.69	
HU	Token-based	66.10			68.86	62.26	70.81	67.47	67.10	3	68.13	12.49
	MWE-based	66.89			62.21	65.08	74.01	69.87	67.61	3	68.09	2.44
	Cohen’s κ	50.6			42.13	49.45	60.04	52.03	50.85	3	49.01	-35.81
IT	Token-based	25.11			18.24	34.90		43.57	30.46	14	37.85	14.4
	MWE-based	23.09			16.90	15.31		39.90	23.80	15	29.03	0
	Cohen’s κ	14.26			10.01	-10.01		25.33	9.9	17	8.27	-14.44
LT	Token-based				0.00			25.33	12.67	17	28.85	
	MWE-based				0.00			28.35	14.18	17	30.08	
	Cohen’s κ				0.00			27.25	13.62	15	28.82	
MT	Token-based	8.87			0.00	4.69		16.29	7.46	18	11.42	6.79
	MWE-based	6.41			0.00	5.00		14.44	6.46	18	6.75	0.02
	Cohen’s κ	3.5			0.00	2.99		6.6	3.27	18	-5.25	-5.74
PL	Token-based	72.74			69.77		0.00	70.56	53.27	7	74.40	18.33
	MWE-based	67.95			59.61		0.00	69.09	49.16	5	69.98	0
	Cohen’s κ	61.53			51.33		0.00	62.72	43.9	4	63.46	-15.01
PT	Token-based	70.18			60.01		30.79	70.94	57.98	6	59.97	14.32
	MWE-based	58.14			44.05		0.99	67.33	42.63	8	54.49	0
	Cohen’s κ	51.35			35.98		-11.52	62.03	34.46	7	46.35	-11.86
RO	Token-based	81.90			83.58	77.99		79.12	80.65	2	63.76	11.51
	MWE-based	73.38			77.21	77.75		75.31	75.91	2	57.74	0
	Cohen’s κ	71.28			75.35	76.12		73.18	73.98	1	53.75	-7.32
SL	Token-based	45.06			45.62	33.20		46.55	42.61	11	28.47	0.08
	MWE-based	37.08			31.08	30.19		43.22	35.39	10	21.65	0
	Cohen’s κ	29			20.49	23.45		33.17	26.53	10	5.23	-0.07
SV	Token-based	31.49			26.69	31.19		30.70	30.02	15	8.94	13.23
	MWE-based	30.32			25.17	27.03		30.36	28.22	14	7.32	0
	Cohen’s κ	24.44			20.78	16.56		24.75	21.63	12	-5.62	-10.29
TR	Token-based	52.85			45.40	51.59		55.28	51.28	8	16.60	10.45
	MWE-based	42.83			34.49	51.76		55.40	46.12	7	5.95	0
	Cohen’s κ	25.88			19.05	38.88		42.14	31.49	8	-8.57	-17.81
avg	Token-based	53.79	54.61	10.00	40.71	41.12	36.86	54.10			43.40	16.08
	MWE-based	46.22	47.46	10.82	29.81	38.71	25.50	52.37			37.60	0.79
	Cohen’s κ	36.44	33.77	7.98	20.56	30.82	11.82	43.64			24.6	-16.92

2.1 Corpora sizes, VMWE sparsity and frequency distributions

We start by discussing the sizes of the training and test portions in each language corpus, depicted in Figure 2. Sizes are measured in terms of the total number of sentences. Traditionally, corpora sizes are discussed in terms of number of words, rather than number of sentences. We use number of sentences instead for a variety of reasons: 1) Each language corpus in the dataset consists of a collection of individual sentences. So the sentence is a natural unit to describe the dataset. 2) A sentence is expected to have a single main verb. On average, we can expect to have a little more than one verb per sentence. However, we would like to know what this average is for the case of *verbal* MWEs (VMWEs). That is, we would like to know how sparse VMWEs are in a given language corpus, and what impact this sparsity may have. 3) Measures such as the rate of VMWEs per n tokens could also be used, but are less linguistically motivated. Finally, 4) the training-to-test size ratios in terms of number of words are largely the same in this dataset as in terms of number of sentences.

Notice that Romanian and Czech have by far the largest training sets, dwarfing corpora of all other languages. This seems to work in favour of these two languages as, on average, Romanian ranked 2nd place in both evaluation modalities and Czech ranked at 4th and 5th places in the MWE-based and Token-based modalities, respectively. Swedish is the language with the smallest training set (only 200 sentences). The average F1 score of systems participating in Swedish is around 30% for both evaluation modalities. Indeed, the size of the training set is somewhat positively correlated with the average system evaluation scores for each language. The Pearson correlation coefficients for MWE-based and Token-based evaluations are 0.33 and 0.35, respectively.

The size of the test set relative to its corresponding training set varies widely across languages. The test-to-training proportions vary from 8% to 60% for most languages, except for Maltese (79%), Spanish (85%) and most notably, Swedish, with a test set about 8 times larger than its training set.² Although both Maltese and Swedish performed rather poorly (Maltese actually ranked last), there is no clear pattern between the test-to-training proportion of a language corpus and the performance of systems. In fact, Spanish ranked exactly in the middle at 9th place. These proportions were found to be mildly negatively correlated against MWE-based and Token-based evaluations: -0.20 and -0.23, respectively (Pearson correlation coefficients).

²200 training sentences vs. 1600 test sentences, making the proportion of the training set almost invisible in Figure 2

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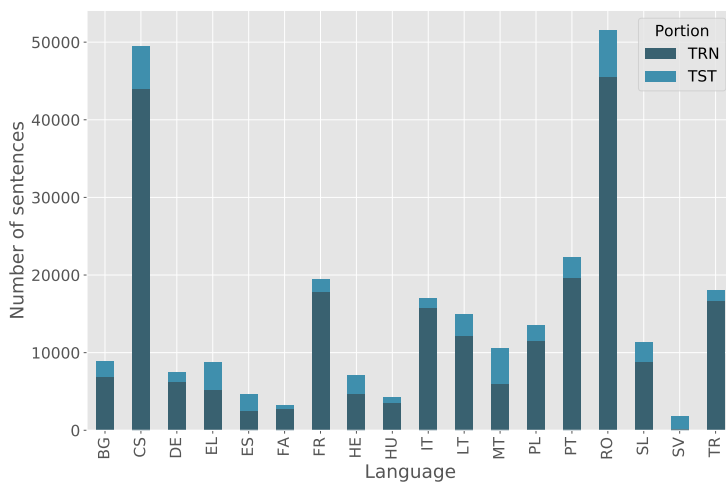


Figure 2: Relative sizes (in sentences) of the training and test portions of each language corpus.

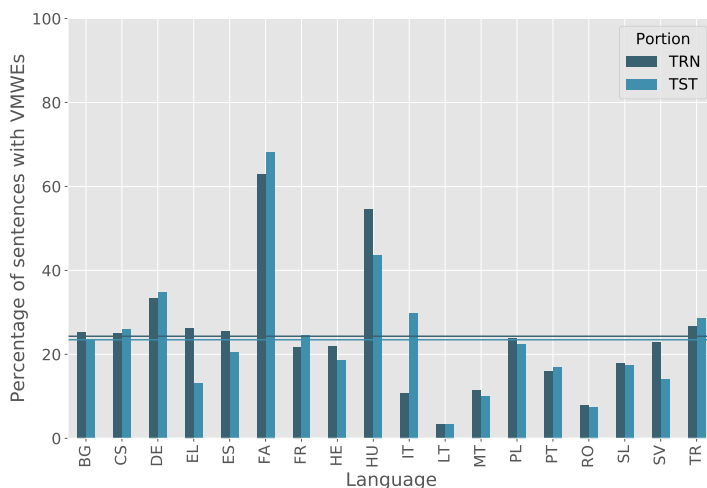


Figure 3: VMWE Sparsity – Percentage of sentences with VMWEs; horizontal lines depict average percentages across languages for training (TRN) and test (TST) sets, respectively.

Figure 3 shows how sparse VMWEs are in the language corpora. VMWE sparsity can be understood as the inverse of the proportion of sentences that have at least one VMWE. The figure shows the proportion of VMWEs within each set (training and test) using percentages. The graphs show that language corpora differ widely in their VMWE sparsity. The overall proportion average (depicted by the two horizontal lines in the figure) is 24% and 23% for the training and test sets, respectively. Only Farsi and Hungarian are well above this average, and German is slightly above. For most languages, the vast majority of sentences do not contain a single VMWE. Whilst sentences without VMWE examples are indeed needed by machine learning algorithms, too few examples could hinder learning processes due to class imbalance. Indeed, there is a strong positive correlation between the proportion of sentences with VMWEs and the average system evaluation scores: 0.58 Pearson correlation coefficient against MWE-based evaluation and 0.56 against Token-based evaluation. Lithuanian and Maltese are the two lowest scoring languages in both evaluation modalities (see Table 1 and Figure 1). They are two of the three languages with the highest VMWE sparsity. The third language is Romanian, which turns out to be the second highest scoring language. Romanian is, as previously mentioned, the language with the largest amount of training data. The Romanian corpus' large volume seems to outweigh its high VMWE sparsity in systems' performance.

Another feature which seems to help systems perform well in the Romanian corpus is the frequency distribution of its VMWEs, as shown in Figure 4. This figure shows how many VMWE types occur at each VMWE frequency and how many of those VMWEs are successfully retrieved by the systems on the test portion of each language corpus. The grey bars on each chart show the total number of VMWE types occurring at each frequency inscribed on the x axis. The coloured bars count the number of VMWE types at each frequency that were fully detected by each system. This figure shows that Romanian VMWEs are *well distributed*: whilst Romanian hapax legomena (VMWEs occurring only once) dominate with 208 instances, there are many VMWEs with higher frequencies. The total number of VMWEs that occur more than once is 292, with frequencies up to 31 well represented. By contrast, 88 Lithuanian VMWEs appear only once and the rest, 12 of them, just twice! For Maltese, 82.57% of its VMWEs are hapax legomena. The remaining 17.43% have frequencies between 2 and 9. In short, VMWEs in the Lithuanian and Maltese corpora are not as well distributed by frequency as those in the Romanian corpus. The less frequent a VMWE is, the less opportunities a system has to learn it. So if the majority of VMWEs in a corpus are of low frequency (as in Lithuanian and Maltese), it will be harder for a system to learn them, which will lead to potentially low performance scores for the system.

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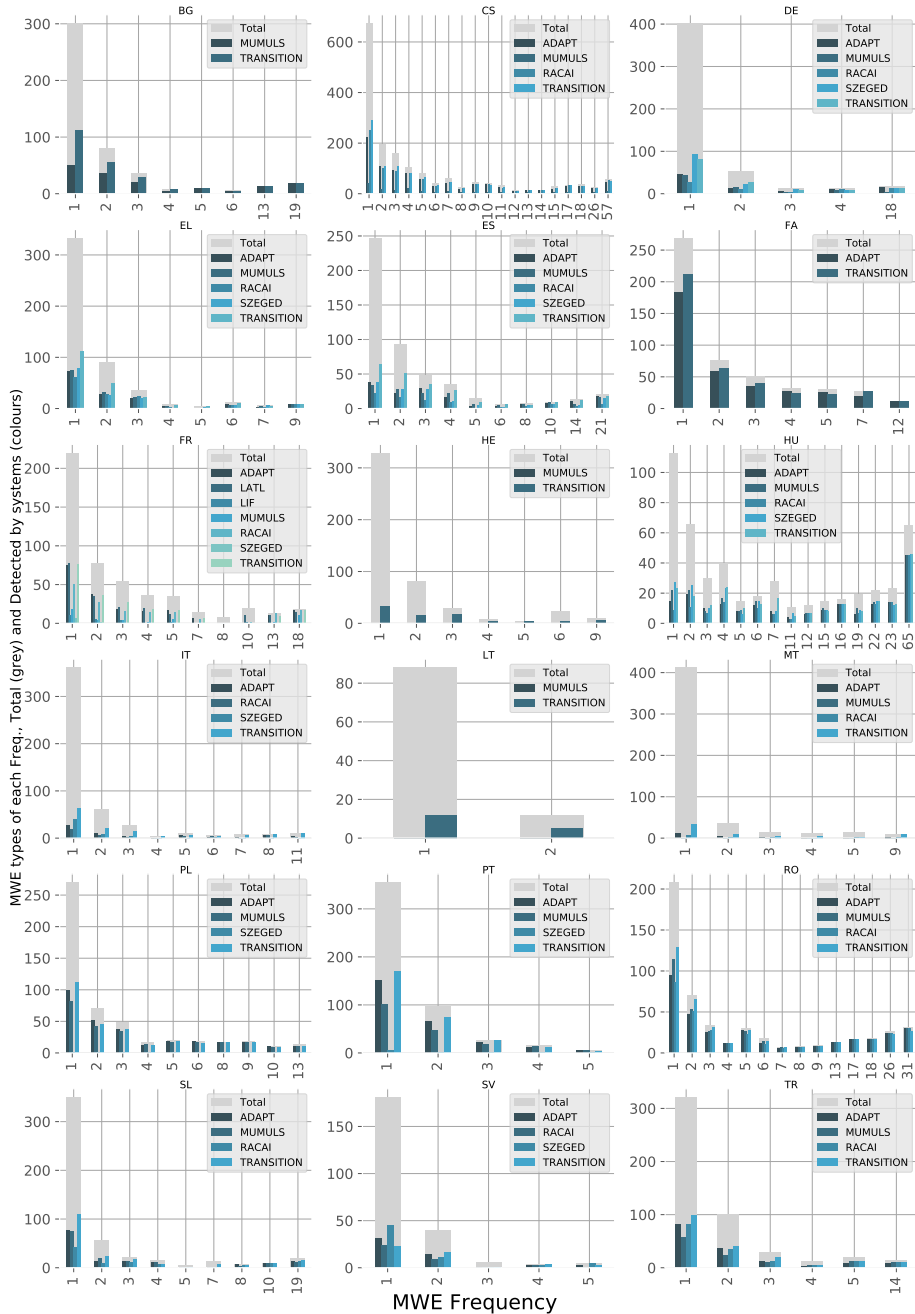


Figure 4: Distribution of VMWEs of different frequencies on the test set (grey bars) and the proportion of such VMWEs detected by systems (coloured bars) based on full MWE-based detection.

As an aside, the grey bars in Figure 4 show, for most languages, that the majority of VMWEs are hapax legomena and that the number of VMWEs occurring more frequently decreases dramatically as their frequency increases. This is the hallmark of the Zipfian distribution, which is something to be expected with lexical phenomena (Manning & Schütze 1999: pp. 22–6). This is not the usual way in which this distribution is traditionally plotted from data. However, it can be seen that most charts follow it approximately.

The issue of *frequency distribution* is important. Hungarian and Spanish are modest in size in comparison with Lithuanian and Maltese (see Figure 2), and yet the systems perform better in the former languages (especially in Hungarian) than in the latter languages. Figure 4 reveals that both Hungarian and Spanish are well distributed by frequency. Hungarian, despite having a smaller test set, is in fact even better distributed by frequency and has a lower VMWE sparsity (Figure 3) than Spanish. It obtains a 67 average F1 score whereas Spanish gets an F1 score average of 40–46, in both evaluation modalities (see *avg* column in Table 1).

From these observations, we can point out that language corpora with small amounts of training data, especially when combined with high VMWE sparsity and a poor frequency distribution, tend to obtain low scores in most systems. So increasing the size of training and test data is definitely a recommendation to follow. VMWE sparsity can be reduced by simply trying to balance out sentences with VMWEs against sentences without VMWEs. However, corpus designers should be cautious of doing this, as it could lead to a corpus that does not reflect the real distribution of VMWEs in the language and/or domain in question. Perhaps, it should be the task of system developers to design systems capable of coping with the natural VMWE imbalance/sparsity in a language corpus.³ Improving the VMWE frequency distribution in language corpora could also help systems. Ensuring that several examples of each VMWE type are included in the training data will be a challenge, however, due to the natural Zipfian tendency of a majority of VMWEs to appear only once in any given corpus. We propose offsetting this tendency by aiming to compile a corpus where the total frequency of VMWE types that occur *frequently enough* outnumber the total frequency of VMWE types that occur *less frequently*. That is, if θ is the minimum frequency a VMWE needs to have in order to be considered to have *enough frequency*,⁴ then we could ensure that the language corpus satisfies the condition:

³Systems could, for example, run a classifier to distinguish sentences that contain VMWEs from sentences that do not, and train/run their VMWE extractors only on sentences that do.

⁴ θ , a minimum desirable frequency, is a parameter to be set empirically, with $\theta = 2$ a reasonable default value.

$$(1) \quad \sum_{v_i \in \{f(v_j) \geq \theta\}} f(v_i) > \sum_{v_k \in \{f(v_j) < \theta\}} f(v_k)$$

where $f(v)$ is the frequency of VMWE v in the corpus. Note that a corpus with a good VMWE frequency distribution cannot be created by simply increasing the size of the corpus, but by better selecting sentences that are good examples of as many VMWEs as possible.

2.2 VMWEs shared between the training and test sets

Maldonado et al. (2017) noticed that the proportion of VMWEs shared between the training set and the test set of a language corpus is strongly positively correlated with the performance scores achieved by participating systems on that language test set (see also Savary et al. 2018 [this volume] §6.3). The most likely explanation is that when evaluated on the test set, machine learning systems would tend to perform better on VMWE examples they encountered in the training set (i.e. exact VMWEs that systems have already *seen* during training) than on VMWE examples that systems encounter for the first time in testing. The higher the proportion of shared/seen VMWEs is in one language, the higher a machine learning system can be expected to perform on that language. Figure 5 depicts this relationship by plotting the score achieved by each system on each language against the proportion of shared/seen VMWEs in that language. The languages on the x axis are sorted and labelled by this proportion. Notice the near-linear relationship between this proportion and the system scores.

It is of interest to evaluate systems on non-shared/unseen VMWEs only. This can be done by using the official systems' outputs, which were kindly provided to us by the shared task organisers. In order to evaluate unseen VMWEs only, the labels for seen VMWEs in the systems' outputs and the gold standards were cleared (i.e. changed to the underscore '_' flag) so that they would be ignored by the official evaluation scripts. Figure 6 shows the systems' performance scores when evaluated in this manner on unseen VMWEs only. Notice that the x axis was kept from Figure 5 to enable an easy visual comparison between both figures.

The first thing to notice is that all systems' scores go down dramatically for all languages. Notice however that for Farsi, the TRANSITION and ADAPT scores do not fall as dramatically as in the other languages. At first glance, this can be associated with the density of annotated instances of VMWEs in the Farsi corpus, i.e., Farsi has the lowest VMWE sparsity in the dataset (as discussed in §2.1). On the other hand, the second least VMWE-sparse language, Hungarian,

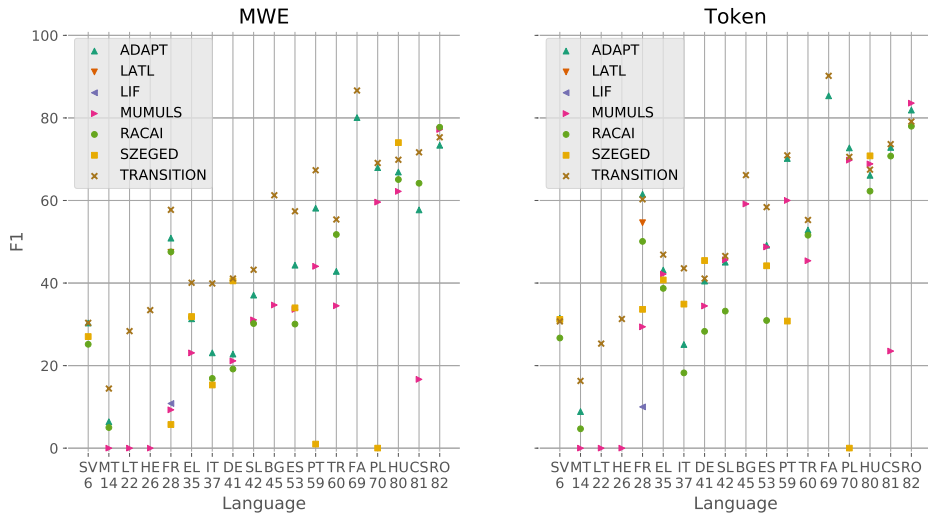


Figure 5: System evaluation scores (MWE-based, left; Token-based, right) for each language against the proportion (percentage) of test VMWEs seen during training

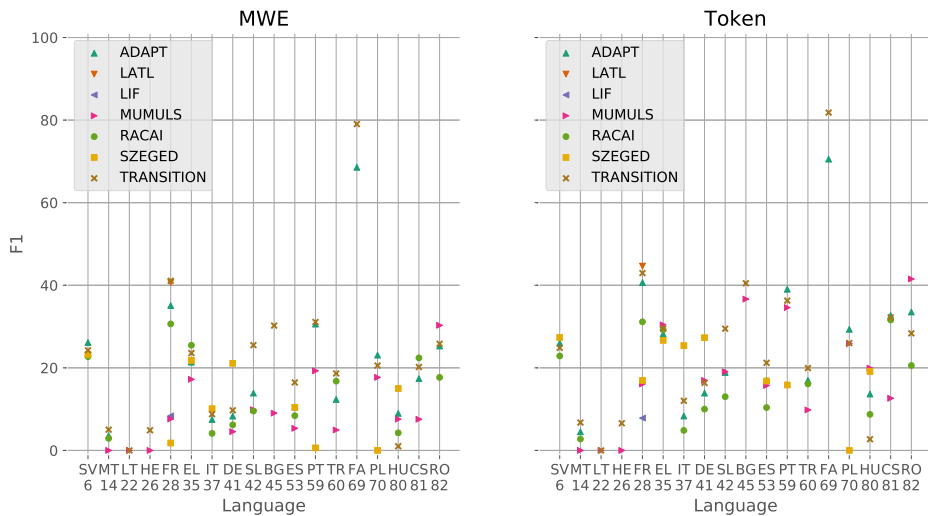


Figure 6: System evaluation scores (MWE-based, left; Token-based, right) on non-shared/unseen VMWEs only

did not fare nearly as well in this unseen VMWE evaluation. Taking a closer look at Farsi VMWEs, we observe that they show a higher level of *collostructional regularity*⁵ compared to VMWEs in other languages. We observe that 86% of Farsi VMWEs are of length 2 and the last token in all Farsi VMWEs is always a verbs, while this is not the case for other languages such as Hungarian. In addition, verbs constitute a relatively small vocabulary in Farsi and as a consequence, the same set of verbs are used repeatedly in various VMWEs. For example, the 2,707 annotated VMWEs in the Farsi training set end with verbs of 46 different lemmas, and the 500 annotated instances in the test set end with 34 lemmas. Among these 34 different lemmas, only 4 do not appear in the training set. Last but not least, most of these verb lemmas are strong indicators of the presence of VMWEs, too. The overall occurrences of these lemmas in the Farsi corpus is 6,969, from which 3,207 are part of a VMWE, i.e., nearly half of them (46%). More precisely, 16 of these lemmas (with 29 occurrences) appear only as constituents of VMWEs; most importantly, for the most frequent lemma in VMWEs (the past and present forms of the infinitive کردن /kærdæn/ ‘to make/to do’, a light verb, which appears as the verb in 1,096 VMWEs) this proportion is 97% (i.e., out of 1,128 occurrences of this verb, only 32 do not surface as VMWE). To this, we can add observations concerning syntactic patterns in which VMWEs are used, e.g., the light verb کردن /kærdæn/ usually forms a transitive VMWE in which the non-verbal component of the VMWEs appear right after the adposition را /ra/ (i.e., which signals the presence of the syntactic object). We maintain that these exemplified regularities can justify the obtained results over the Farsi corpus.

In general, however, it is fair to expect that systems will tend to perform worse on VMWEs they did not see in training.

2.3 Discontinuous VMWEs and embedded/overlapped VMWEs

Two innovations in the PARSEME shared task were discontinuous VMWEs and embedded or overlapped VMWEs (see Savary et al. 2018 [this volume] §6.3).

Figure 7 shows that for most languages, the majority of VMWEs are continuous. For Czech and Turkish, there is about a 50–50 proportion between continuous and discontinuous VMWEs. For many other languages, the proportion of discontinuous VMWEs is considerable (German, Greek, French, Polish, Portuguese, Romanian, Slovenian). There is therefore a clear advantage in designing systems capable of detecting discontinuous VMWEs.

⁵Degree to which words tend to form (appear with) grammatical constructions (Stefanowitsch & Gries 2003).

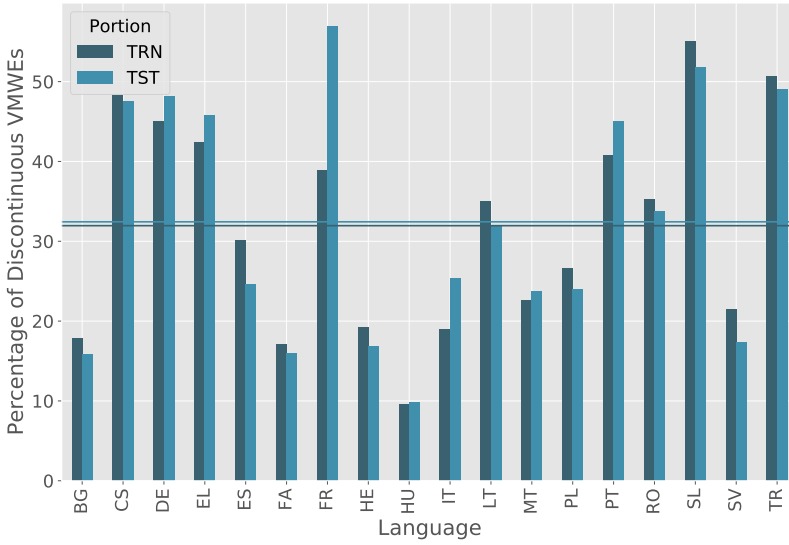


Figure 7: Percentage of discontinuous VMWEs across language corpora.

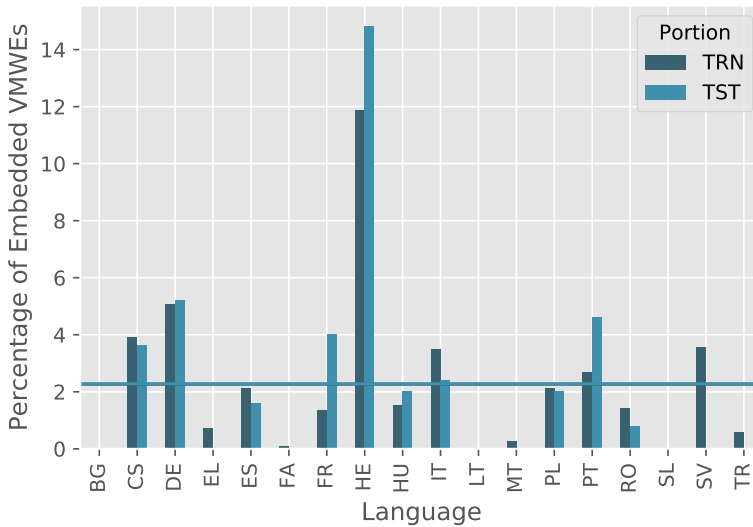


Figure 8: Proportion of Embedded/Overlapped VMWEs across language corpora.

The proportion of embedded/overlapped VMWEs, shown in Figure 8, is very low across languages, with an average of around 2.3% in both training and test portions. Hebrew is the language with the highest rate of embedded VMWEs at only 12–14.5%. Some languages do not even register a single embedded VMWE. Because of these low numbers, a system not designed to deal with embedded VMWEs will not be severely penalised. We therefore do not consider embedded VMWEs to be a difficulty factor in this dataset, with the exception of Hebrew.

2.4 Relative training-test corpus heterogeneity

The evaluation paradigm followed in the PARSEME shared task dictates that systems must be evaluated on a strictly unseen test set, guaranteeing fairness to all participating system developers. However, a valid expectation is that the data that systems will be tested on should be roughly of the same kind as the data they were trained on. The training and test portions of a language corpus should be fairly homogeneous.

Kilgarriff & Rose (1998) introduced a statistical metric to estimate the similarity of two corpora of similar size by computing the χ^2 score of the n most frequent words in the corpora. The lower this score, the less variability between the corpora and thus the more similar they are. They also adapted this similarity score to measure the homogeneity of a single corpus by computing χ^2 scores on pairs of similarly sized partitions of the corpus and averaging the individual χ^2 scores. The lower this averaged score is, the more homogeneous the corpus is deemed to be. Here, we adapt this homogeneity score in order to estimate the homogeneity between the training and test sets of a language corpus. This is done by computing similarity scores of training set partitions against similarly-sized test set partitions and averaging them together to obtain a single cross-set homogeneity score. The higher this score is, the more heterogeneous the training and test sets are. In order to allow comparisons across languages, this cross-set homogeneity score is normalised by dividing it by the average of the within-training set and within-test set homogeneity scores, calculated from the training and test sets separately. We call the result of this division, the *heterogeneity ratio of a language corpus*. Table 2 sorts the languages by their heterogeneity ratio. The detailed algorithm used is listed in Algorithm 1.

French comes out on top. Its heterogeneity ratio of 4.31 can be interpreted as the number of times that the training-test sets are more heterogeneous than the training and test sets on their own. This suggests that the French test was not derived from the same sources as the training set, or at least not in the same proportions.

Table 2: Heterogeneity ratios between training and test sets

FR	TR	IT	PT	RO	CS	PL	HU	LT	DE	FA	BG	SL	ES	SV	HE	EL	MT
4.31	2.89	2.53	2.03	2.03	1.92	1.77	1.73	1.62	1.59	1.56	1.51	1.39	1.28	1.25	1.18	1.15	1.03

Algorithm 1 Computing a language heterogeneity ratio

```

1:  $R \leftarrow$  number of repetitions
2:  $n \leftarrow$  number of words in a partition
3:  $hr\_sum \leftarrow 0$ 
4:  $r \leftarrow 0$ 
5: while  $r < R$  do
6:    $trn \leftarrow$  partition_set( $n$ , shuffle_sentences(training_set))
7:    $tst \leftarrow$  partition_set( $n$ , shuffle_sentences(test_set))
8:
9:   ▶ Cross homogeneity:
10:   $s \leftarrow 0$ 
11:   $c \leftarrow 0$ 
12:  for  $i = 1$  to  $|trn|$  do
13:    for  $j = 1$  to  $|tst|$  do
14:       $s \leftarrow s + \text{corpus\_similarity}(partition_i, partition_j)$ 
15:       $c \leftarrow c + 1$ 
16:   $cross \leftarrow s/c$ 
17:
18:  ▶ Within-training homogeneity:
19:   $s \leftarrow 0$ 
20:   $c \leftarrow 0$ 
21:  for  $i = 1$  to  $|trn|$  do
22:    for  $j = i + 1$  to  $|trn|$  do
23:       $s \leftarrow s + \text{corpus\_similarity}(partition_i, partition_j)$ 
24:       $c \leftarrow c + 1$ 
25:   $within\_trn \leftarrow s/c$ 
26:
27:  ▶ Within-test homogeneity:
28:   $s \leftarrow 0$ 
29:   $c \leftarrow 0$ 
30:  for  $i = 1$  to  $|tst|$  do
31:    for  $j = i + 1$  to  $|tst|$  do
32:       $s \leftarrow s + \text{corpus\_similarity}(partition_i, partition_j)$ 
33:       $c \leftarrow c + 1$ 
34:   $within\_tst \leftarrow s/c$ 
35:
36:  ▶ Heterogeneity ratio:
37:   $hr \leftarrow cross / ((within\_trn + within\_tst) / 2)$ 
38:   $hr\_sum \leftarrow hr\_sum + hr$ 
39:
40:   $r \leftarrow r + 1$ 
41: return  $hr\_sum / R$ 

```

French is followed by Turkish, Italian, Portuguese and Romanian, with ratios around 2. The rest of the languages are closer to 1, reflecting a more balanced/homogeneous partitioning between the training and the test corpora. Notice however that systems participating in French, Turkish, Italian, Portuguese and Romanian did relatively well despite their heterogeneity. Nonetheless, adopting a similar corpus selection and balancing policy across languages, like mixing the corpora before splitting them into training and test portions in comparable proportions, could be a way to put all languages on a similar footing.

3 Participating systems and baselines

This section focuses on the actual systems in the competition and introduces two baseline systems: (i) a dictionary lookup-based system that attempts to match known VMWEs against the test set, (ii) a system that flags every verb in the test set as a VMWE.

3.1 Overview of participating systems

Seven systems participated in the PARSEME shared task. Their performance was presented and discussed in §2, although not individually. The techniques employed by the different systems can be summarised as follows:

- ADAPT (Maldonado et al. 2017) uses a Conditional Random Fields (CRF) sequence labelling approach to identify the tokens of VMWEs. The features that helped most were dependency-based: the token’s head, dependency relation with the head and the head’s part of speech (POS) tag, along with standard bigram and trigram features commonly used in named-entity recognisers. The ADAPT system did not attempt to classify VMWEs by category. An extended version of this system is described in Moreau et al. (2018 [this volume]).
- RACAI (Boroş et al. 2017) also employs a CRF sequence labelling approach using lemma and POS tag features. However, this system conducts the VMWE identification task in two steps: head labelling (identifying the verb) and tail labelling (identifying the words linked to the head). The RACAI system does attempt to classify the VMWEs by their category.
- MUMULS (Klyueva et al. 2017) also models the VMWE identification problem as a sequence labelling task, but using a recurrent neural network via

the TensorFlow package. As input features, they build embeddings of 100 dimensions from the concatenation of a token's surface form, lemma and POS tag.

- TRANSITION (Al Saied et al. 2017) is a greedy transition-based system of the kind typically used in parsing. This system does not have a syntax prediction module, however, and focuses on the lexical analysis phase of the parsing mechanism. An extended version of this system is described in Saied et al. (2018 [this volume]).
- LIF (Savary et al. 2017) also employs a probabilistic transition-based technique. The team focused on French light-verb constructions.
- SZEGED (Simkó et al. 2017) trains a dependency parser on a modified training set in which the dependency relation label of tokens belonging to a VMWE were relabelled with the corresponding VMWE category label. Simkó et al. (2018 [this volume]) describes an extended version of this system.
- LATL (Nerima et al. 2017) uses a rule-based constituent parser that prioritises parsing alternatives of known collocations, and uses its parsing features to detect known collocations even if they are in a different word order or if they are discontinuous.

Not all systems participated in all languages. French was the language covered by most systems. The languages least covered were Bulgarian, Hebrew, Lithuanian (covered only by MUMULS and TRANSITION) and Farsi (covered by ADAPT and TRANSITION). Since only raw surface tokens and no syntactic dependency information or POS tags were provided for Bulgarian, Hebrew and Lithuanian, most system developers decided not to cover them. The systems that covered most languages were TRANSITION (all 18 languages), ADAPT (15), MUMULS (15), RACAI (12) and SZEGED (9). LATL and LIF focused on French only.

In Token-based evaluation, ADAPT ranked first on two languages (French and Polish), while MUMULS and SZEGED ranked first on Romanian and Hungarian, respectively. In MWE-based evaluation, TRANSITION beat all systems in all languages, except Hungarian (won by SZEGED) and Romanian (won by RACAI and very closely followed by MUMULS).

The ADAPT and the RACAI systems are clearly related, as are the TRANSITION and the LIF systems. These four systems, along with the MUMULS system, are all probabilistic sequence labelling methods, although quite different in their

implementation details. It is interesting to see that, on average (see bottom row in Table 1), ADAPT and TRANSITION performed very similarly in the Token-based evaluation, while MUMULS and RACAI also performed very similarly in the same average evaluation.

3.2 Baseline systems

This section proposes two types of baseline systems that put into perspective the participating systems' performance. One such baseline system is a simple dictionary lookup, which collects all VMWEs encountered during training and simply attempts to match collected VMWEs in the test set. The other is a baseline system which flags every verb as a VMWE. More details on these two baselines and their results are described in what follows.

Dictionary lookup baseline The implemented system is very simplistic: it attempts to match VMWE lemmas from the training file in the test file sequentially. If lemmas are not available, then the token's surface form is used. Discontinuous VMWEs are matched in the test file as long as they appear in the same order as in the training file: intervening words are ignored when collecting VMWEs from the training file and when matching VMWEs in the test file. If one VMWE appears in more than one word order in the training file, each word order will be considered to be a separate VMWE. Tokens are marked as belonging to a VMWE only if a full match is detected; partial matches are not flagged. This is to avoid making too many, potentially spurious, partial matches. Embedded/overlapped VMWEs are attempted by using separate VMWE matching automata.

Notice that the maximum performance that can be achieved by this lookup system is determined by the proportion of shared VMWEs between the training and the test set in a language corpus. This proportion of shared VMWEs, indicated as percentages under the language labels in Figure 5 and Figure 6, is thus the maximum recall such a system can achieve.

The actual F1 score for the dictionary lookup system described here appears in the BD column in Table 1. It is evident from this table that this simple baseline is quite competitive, beating some of the participating systems in several languages. In fact, it beat all systems on both evaluation modalities in Hebrew, Lithuanian and Polish, and on MWE-based evaluation in German.

Verb baseline As mentioned earlier, this system simply flags each verb in the test set as a VMWE. Column BV in Table 1 shows the F1 scores for the verb baseline. Notice that no scores are supplied for Bulgarian, Hebrew and Lithuanian.

This is because no POS tag was provided in these languages’ datasets. So we omit them from this discussion.

For BV, notice that the Token-based F1 scores range between 10 to 47 for most languages. This is a relatively high score range. Table 3 provides precision and recall details for these Token-based scores.

Table 3: Token-based scores for the Verb baseline

Language	CS	DE	EL	ES	FA	FR	HU	IT	MT	PL	PT	RO	SL	SV	TR
P-token	13.57	20.87	5.14	9.58	48.64	11.52	9.29	8.87	3.74	11.42	8.55	6.61	4.17	7.8	6.54
R-token	41.13	45.02	40.85	41.49	46.86	44.13	19.08	38.26	36.81	46.31	44.1	44.3	44.59	43.59	25.97
F1-token	20.41	28.52	9.14	15.56	47.73	18.28	12.49	14.4	6.79	18.33	14.32	11.51	7.63	13.23	10.45

Notice that this baseline’s recall directly depends on each language’s proportion of sentences with VMWEs (see Figure 3). Recall is particularly high with most languages scoring around the 40-point mark. We interpret this result as indicating that Token-based scores tend to overestimate systems’ performance. We elaborate on this issue in §4. The recall values in Hungarian and Turkish are considerably lower than in the rest of the languages. This is because there is a large proportion of VMWEs in these languages that are not tagged with a *verb* POS tag (this baseline exploits that tag): 74% of VMWEs in Hungarian and 50% of VMWEs in Turkish do not have a single token with a *verb* POS tag. Different teams make different decisions as to what MWEs constitute *verbal* MWEs. For example, the Hungarian team informed us that they flag nominalised verbs as VMWEs, even if they are not functioning as verbs anymore.

Given that the verb baseline only labels a single word (a verb) and that VMWEs are made up of at least two words (the verb plus at least another word), the reader might find it puzzling that, in Table 1, the verb baseline (BV) has non-zero MWE-based scores on a few languages. The MWE-based evaluation modality only rewards full MWE matches, not partial matches. How is it possible to get non-zero scores on full MWE matches for single-word labels which surely will never form a full match, given that the minimum length of a full VMWE is two words? It turns out that there are VMWEs of one-word length in some languages. This is usually due to linguistic reasons specific to each language in which a single word is considered composed of more than one unit. In Spanish, for example, reflexives can sometimes appear separated from the verb and sometimes postfixed to the verb: *ella se levanta temprano* ‘she gets up early’ vs. *es difícil levantarse temprano* ‘getting up early is hard’. Both, *se levanta* and *levantarse*, are considered to be VMWEs.

4 Evaluation methods

As previously mentioned, system performance was measured on two modalities: MWE-based evaluation and Token-based evaluation. Whilst the MWE-based evaluation is an all-or-nothing measure, which might unfairly penalise systems that partially identify correct VMWEs, the Token-based evaluation is intended to compensate for this coarse penalisation by giving partial credit for every word of the identified VMWE. Thus, it is reasonable to expect systems to perform better on Token-based evaluation than on MWE-based evaluation. Indeed, Table 1 shows that for the most part, Token-based scores are higher than MWE-based scores within every system-language combination, including baseline systems.

By definition, every single VMWE will involve a verb. So, the verb baseline system is able to make gains on the Token-based F1 score by increasing recall, at the expense of reducing precision. However, if the dataset were less unbalanced (i.e. if it had less VMWE sparsity), the verb baseline would also increase its precision. In addition, the Token-based evaluation gives more weight to longer VMWEs than shorter ones. Matching one VMWE of say four tokens gets the same credit as matching two VMWEs of two tokens each. More credit should perhaps be given for matching more (even if partially) VMWEs than for matching fewer, longer VMWEs.

Even though Token-based scores are expected to be higher than MWE-based scores, the system rankings differ across modalities. Because of these issues, we cannot categorically say that system *A*, which scored higher than system *B* in Token-based evaluation, is better at detecting partial VMWEs. It could well be that system *A* is good at identifying simple verbs and/or long and formulaic VMWEs but not necessarily at detecting partial VMWEs. One solution would be giving a fraction of a point corresponding to the proportion of a matched VMWE, as well as subtracting a fraction of a point proportional to matched non-VMWE tokens.

On a slightly different note, we would like to propose an alternative evaluation metric: Cohen’s κ measure, which is commonly used to measure inter-annotator agreement. We use it here to measure the degree to which systems agree with gold standards. The obtained κ score is similar to the MWE-based F1 score, but with a correction that removes the possible bias from chance agreement.

We compare the similarity between systems’ rankings given by the averaged results per language per performance measure, by reporting their Spearman’s rank correlation ρ and Pearson’s moment correlation. As shown in Table 4, the rankings and assigned scores to systems remain very similar across performance

measures. However, overall, the Token-based and MWE-based measures show the highest correlation (both in terms of ranking, ρ , and the relative magnitude of the assigned scores, r). With respect to Cohen’s κ , while it yields a ranking more similar to the MWE-based measure, the distribution of the assigned Cohen’s κ scores are more similar to the token-based method (i.e., their linear relationship signified by r).

Table 4: Similarity of systems’ ranking per performance measure: Spearman’s ρ and Pearson’s r are reported to show similarity between systems’ ranking per performance measure.

Measure	Measure	ρ	r
Token-based	MWE-based	98.14	97.48
Token-based	Cohen’s κ	94.06	93.28
MWE-based	Cohen’s κ	96.75	97.18

4.1 On Using the Cohen’s κ as an evaluation score

The use of the F1 score, i.e., the harmonic mean of precision and recall, for evaluation can be biased unless certain criteria are met, e.g. that the distribution of annotated instances in the test and training data are identical. Since in the PARSEME shared task, the VMWE identification task is reduced to a binary classification problem, Cohen’s κ can be used reliably to obtain a measure of performance that can, at least, cancel out the influence of certain sources of bias. In particular, it penalises the overall score of the systems by the expected chance agreement (as done in the computation of inter-annotator agreement) and takes into account a notion of true negative rate in the overall evaluation of systems (Powers 2012; 2015).

The count of true negative outputs and subsequently true negative rate, however, cannot be computed directly from the evaluation setup and the test set. Simply put, we do not know how many “*is this a VMWE?*” questions are answered by a system⁶ (or human annotators) in order to perform the identification task on a test set (or to manually annotate a corpus). Hence, further assumptions about the problem setting are required to devise the number of true negatives in the respective evaluation contingency table. Here, likewise (Savary et al. 2017), we assume

⁶This discussion also implies a way to justify the better performance of transition-based systems, i.e., the total number of classification problems in these systems is often less than in non-transition-based systems.

that the total number of stimuli, i.e., the total number of “*is this a VMWE?*” questions to complete a VMWE identification problem, is approximately equivalent to the number of verbs in the test set (or the corpus which must be annotated).

Given the abovementioned assumption for a test set, let v be the number of verbs in the set that are not part of a VMWE. For a system, we define tp and fp as being the number of correctly and incorrectly identified VMWEs, respectively, and fn as the number of VMWEs in the test set that are not identified by the system. If

$$(2) \quad t = tp + fp + fn + v$$

we compute

$$(3) \quad p_0 = \frac{tp + v}{t}$$

$$p_e = p_0 + p_1$$

in which

$$(4) \quad p_0 = \frac{(tp + fp) \times (tp + fn)}{t^2}$$

$$p_1 = \frac{(fn + v) \times (fp + v)}{t^2}$$

Finally, we compute Cohen’s κ :

$$(5) \quad \kappa = \frac{1 - p_0}{1 - p_e}$$

and report it as an additional performance measure. Evidently, the suggested method can be refined and improved, e.g., by taking the partial matches between VMWEs (particularly the verbal part) into account.

5 Conclusions

This chapter analysed different statistical properties of the language corpora used in the PARSEME shared task. We found that having large training sets allows

systems to better learn to identify VMWEs. But size is not the whole story. High VMWE sparsity can hinder a system's performance. However, it can be offset by a large training corpus and, even better, by ensuring that the corpus has many examples of a majority of VMWEs, a property we call good VMWE frequency distribution. Romanian seems to be the language corpus that hits the sweet spot: it is large in size (training and test portions) and it has a good frequency distribution, even if it suffers from high VMWE sparsity.

This chapter also showed that the higher the proportion of VMWEs shared between training and test sets, the better the systems will perform. We also saw that it is advisable to design systems capable of detecting discontinuous VMWEs, but we observed that systems would not be significantly penalised for ignoring embedded VMWEs. There was no clear pattern on the effect of the training-to-test proportions on systems' performance. Shuffling corpora before splitting into training and test portions will also reduce its heterogeneity ratio and help put all languages on a similar footing.

On the evaluation front, we found the token-based evaluation method to overestimate the performance of systems. As future work, the authors will investigate alternative partial-matching measures, especially those that favour number of the detected VMWEs over their lengths. And finally, this chapter described the use of Cohen's κ metric to produce less biased estimations of systems' performance.

We would also like to recommend shared task organisers to consider application scenarios of the VMWE identification task. Different application scenarios will dictate different evaluation criteria, corpus selection and priorities. For example, if VMWEs are being identified to compile a dictionary, perhaps recall should be favoured over precision. If the application is to identify a few but good VMWEs examples for a language learning system, then precision should be favoured. Evaluation could also be done *in vivo* in actual parsing or machine translation systems, which is something the authors will seek to investigate as future work.

The quality of the analysis presented here depends directly on the quality of the annotated data. Whilst the annotation guidelines try to be as universal as possible, we have found that significant differences in annotation approach remain. For example, at least one language team annotated MWEs derived from verbs that do not function as verbs (e.g., nominalised verbs). So we hope that this work can spark a discussion in the community as to what constitutes a VMWE more precisely. Is it simply a MWE that involves a word of verbal origin (even if it does not function as a verb anymore) or must it be a MWE involving a verb that still functions as a verb?

The authors hope that the insights and recommendations included in this chapter inform future editions of the shared task. At the same time, the authors plan, as future work, to repeat the analysis presented here on the second edition of this dataset, which is being prepared at the time of writing. This will help us determine to what extent our observations generalise to new datasets.

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Abbreviations

AVG	average
BD	baseline: dictionary lookup
BV	baseline: verb detection
CRF	conditional random fields
F1	F1 score aka F-measure
κ	Cohen's inter-annotation agreement measure
MWE	multiword expression
POS	part of speech
r	Pearson's correlation coefficient
ρ	Spearman's rank correlation coefficient
RNK	rank
TRN	training
TST	test
VMWE	verbal multiword expression

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