

following **contributions** advance the research on Paraphrase Typology and provide novel, more in-depth knowledge about paraphrasing:

- A new paraphrase typology, presented in Chapter 5. I extended the existing typologies in such a way so that they could be applied both to paraphrase and non-paraphrase pairs. All paraphrase typologies prior to this thesis were only focused on texts that hold a paraphrasing relation. Extending the coverage of the typology to non-paraphrasing pairs was crucial for the empirical evaluation.
- A statistical corpus-based analysis presented in Chapter 5. I measured and compared the frequency distribution of paraphrase types in the paraphrase and non-paraphrase pairs in the ETPC corpus.
- An analysis of machine learning experiments presented in Chapter 6. I analyzed the performance of 11 different automated paraphrase identification systems. The data showed that the performance of the automated systems varies significantly based on the paraphrase types involved in each candidate paraphrase pair. These results suggest that paraphrase types are processed differently by automated paraphrase identification systems.

This thesis explored novel directions within the research on Paraphrase Typology. I presented the first empirical experiment that quantifies the difference in processing paraphrase types. The data allows to identify types that are easier or harder for the automated paraphrase identification systems. The proposed methodology is not limited to the paraphrasing textual meaning relation. It can easily be extended to other relations such as textual entailment or semantic textual similarity.

An empirical study on multiple textual meaning relations

The third **objective** of this thesis is *To empirically determine the interactions between Paraphrasing, Textual Entailment, Contradiction, and Semantic Similarity in a corpus of multiple textual meaning relations..* This objective has been addressed in the article Gold et al. [2019], presented in Chapter 7.

Textual meaning relations, such as Paraphrasing, Textual Entailment, and Semantic Textual Similarity are a popular topic within Natural Language Processing and Computational Linguistics. Traditionally, these meaning relations are studied in isolation. The research on them and the analysis of the interactions between them was very limited at the start of this dissertation.

In this thesis, I took a new look of the problem and broadened the area of study. I carried out a joint study on multiple textual meaning relations. The results

showed that it is possible to address the analysis of several meaning relations at the same time. The findings of the thesis emphasize that such analysis can benefit each individual relation. The following **contributions** enable the research in a novel direction, focused on multiple textual meaning relations:

- A new corpus creation methodology presented in Chapter 7. I proposed a novel methodology for creating a corpus that contains multiple textual meaning relations: paraphrasing, textual entailment, contradiction, textual similarity, and textual specificity.
- A new corpus presented in Chapter 7. To the best of my knowledge this is the first corpus containing pairs independently annotated for paraphrasing, textual entailment, contradiction, textual similarity, and textual specificity. Each meaning relation was annotated independently by 10 different annotators, to ensure the quality of the corpus.
- A statistical corpus analysis presented in Chapter 7. I measured and compared the frequency of each meaning relation in the corpus. I also analyzed the interactions, correlations, and overlap between the different textual meaning relations in the corpus. To the best of my knowledge, this is the first empirical comparison between paraphrasing, textual entailment, contradiction, textual similarity, and textual specificity.

The findings of this thesis have improved the understanding on important issues associated with each individual textual meaning relation and the way they interact with each other. Thanks to this study, some theoretical hypotheses and assumptions that exist in the literature have been empirically confirmed. I also reported some unexpected results:

- There is a negative statistical correlation between contradiction and textual entailment; and between contradiction and paraphrasing.
- There is a strong positive statistical correlation between uni-directional textual entailment and paraphrasing.
- In the corpus of study, paraphrasing is not equal to bi-directional textual entailment. This finding contradicts pre-existing theoretical hypotheses and assumptions.
- The data indicates that there is no statistical correlation between textual specificity and the other textual meaning relations. This also contradicts pre-existing hypothesis claiming that specificity should be strongly correlated with textual entailment.

- The analysis showed that paraphrasing, textual entailment, and contradiction have a strong statistical correlation with the degree of textual semantic similarity. Contrary to some previous studies, in my experiments pairs that contradict each other are perceived as similar.

This thesis emphasized the importance of a joint study on multiple textual meaning relations. The proposed methodology for corpus creation and analysis and the new corpus open new directions for future research.

A shared typology of textual meaning relations

The fourth **objective** of this thesis is *To propose and evaluate a novel shared typology of meaning relations. The shared typology would then be used as a conceptual framework for a joint research on meaning relations..* This objective has been addressed in the article Kovatchev et al. [2020], presented in Chapter 8.

In the recent years, several of the researchers working on paraphrasing, textual entailment, and semantic textual similarity independently argued that a single label is not sufficient to express a complex textual meaning relation. To address this problem they proposed various typologies, that is, lists of linguistic and reasoning phenomena involved in each textual meaning relation. At the beginning of this dissertation, each typology was focused on a single textual meaning relation and was not applicable to other relations.

This thesis showed that it is possible to have a single typology for multiple meaning relations. It also emphasized the advantages of a shared typology. The following **contributions** facilitate the further the research on a shared typology of textual meaning relations:

- The SHARel typology presented in Chapter 8. I propose a new typology, that is applicable to multiple textual meaning relations: paraphrasing, textual entailment, contradiction, textual specificity, and semantic similarity.
- A corpus based study presented in Chapter 8. I empirically validated the applicability of SHARel in a corpus annotation. The different meaning relations were compared in terms of the phenomena involved in each one of them. This comparison is more informative than measuring binary correlation or overlap.

This thesis has expanded the research on textual meaning relations. The SHARel typology is a step forward from the existing typologies - it is linguistically motivated and hierarchically organized. It contains both linguistic and reason-based types and has a wider coverage than any other typology. A shared typology of textual meaning relations provides some valuable insight into the workings of each