A DEPENDENCY GRAMMAR BASED SEMANTICS FOR COPULAR COMPARATIVES

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ABSTRACT

A DEPENDENCY GRAMMAR BASED SEMANTICS FOR COPULAR COMPARATIVES

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Comparative constructions are rich in semantic content, which makes them important for natural language understanding research and technology. A widely used grammar formalism and parser is The Stanford Dependency scheme which aims to provide a simple and strightforward description of grammatical relations. The Universal Dependecies project extends this aim to reach cross-linguistically consistent annotations for many languages. For some complicated constructions like comparatives, a more syntactically motivated dependency representation would be beneficial for easier semantic interpretation. The thesis intends to provide such representation for English copular comparatives including their interatction with prepositional phrases. We show that a compositional semantics is possible for the structures we provide. We also propose a semantic interpretation scheme for comparatives that is directly derived from the dependency structures. We computationally implement the proposals of the thesis in a system that detects various types of copular comparatives and computes their semantic interpretations.

Keywords: dependency parsing, Stanford Dependencies, Universal Dependencies, semantics, comparatives, syntax

ÖZ

KOŞAÇLI KARŞILAŞTIRMALI CÜMLELER İÇİN BAĞIMSAL DİLBİLGİSİ TEMELLİ BİR SEMANTİK

Köksal, Asiye Tuba
Yüksek Lisans, Bilişsel Bilimler Programı
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Karşılaştırmalı cümle yapıları, anlamsal içerik bakımından zengindir; bu da onları dilleri anlama araştırmaları ve teknolojileri için önemli kılmaktadır. Stanford Dependencies programı, yaygın olarak kullanılan bir gramer formalizmidir ve gramer ilişkilerinin basit ve sade bir tanımını yapmayı amaçlar. Universal Dependencies projesi, bu amacı birçok dilde diller arası tutarlı açıklamalara ulaşmak için genişletmektedir. Karşılaştırmalı cümlerler gibi bazı karmaşık yapılar için, daha sözdizimsel olarak motive olmuş bir bağımsal dilbilgisi gösterimi, daha kolay anlamsal çıkarım yapabilmek adına faydalı olacaktır. Tez, İngilizce koşaçlı karşılaştırmalı cümleler ve bu cümlelerin ilgeçlerle etkileşimleri için bağımsal dilbilgisi temelli bir gösterimi sağlamayı hedeflemektedir. Sağladığımız yapılar için kompozisyonsal bir semantiğin mümkün olduğunu da göstermekteyiz. Ayrıca bağımsal dilbilgisi yapılarından doğrudan türetilen karşılaştırma cümleleri için anlamsal bir yorumlama yöntemi de öneriyoruz. Tez önerilerini çeşitli koşaçlı karşılaştırmalı cümle türlerini tespit eden ve anlamsal yorumlarını hesaplayan bir sistemde hesaplıyoruz.

Anahtar Kelimeler: bağımsal dilbilgisi, koşaçlı karşılaştırmalı cümleler, anlam bilimi, sözdizim

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CHAPTER 1

INTRODUCTION

1.1 Thesis and Motivation

Grading is a very basic and inherent part of humans' understanding of the environment and a helpful tool for finding the place of one and the others in that environment. Sapir (1944) interprets grading as a psychological process which exists even before the notion of counting or numbers and says that "judgments of quantity in terms of measure or in terms of number always presuppose, explicitly or implicitly, preliminary judgments of grading". One of the ways of expressing grading is through comparatives. Comparative construction is proposed to be a test for determining if an adjective is inherently gradable or not (Kennedy, 2004). That is, if an adjective is inherently gradable, then it can be used in comparatives, otherwise it cannot. For example, sentence (1) bears no meaning since *dead* is not a gradable adjective (metaphoric or idiomatic uses are excluded).

(1) Giordano Bruno is more dead than Galileo. (Kennedy, 2004)

Gradable adjectives, which can be used in comparative constructions, are said to "express properties that support orderings" and "be analyzed as expressions that map their arguments onto abstract representations of measurement" (Kennedy, 2004). When the positive form of an adjective is used, say *expensive*, what counts as expensive is contextually determined. Expensive, being a gradable adjective, intrinsically carries a measure function that takes its arguments and maps them to a degree. For a sentence like *This dress is expensive*, predicate *expensive* has a $price(x)$ function, as part of its meaning, which takes *this dress* as its argument and maps it to a degree on a scale of price where the degree is fixed contextually. Unlike the positive form of an adjective, the comparative form explicitly fixes the degree to which the adjective maps its arguments, because of the relative relationship between the main clause and the comparative clause. In the sentence *This dress is more expensive than that one*, the degree of expensiveness that $price(this\ dress)$ maps to, is not determined contextually anymore since it has to stand in a particular position relative to the degree of expensiveness which $price(that\ dress)$ maps to. Kennedy (2004) suggests that the comparative morpheme (*more*) denotes a relation between two sets of degrees which are provided by main and comparative clauses. Examples (2) and (3) show how comparative morpheme (*more*) fixes the degree of expensiveness on the scale of price. For the first example, the boundaries of *expensive* are dependent on the contextually determined value of d_s, however for the second sentence since the price of *that dress* and *5 dollars* are fixed on the scale of price, the price of *this dress* is also fixed relatively.

(2) This dress is expensive.

a. $price(d_1) \geq d_s$

(3) This dress is 5 dollars more expensive than that one.

a. $price(d_1) \geq price(d_2) + 5\ dollars$

The semantic extraction of comparatives is quite important for text understanding because one of the most natural and common ways of evaluating an entity is to compare it with some other. As a result of this, in any kind of text, there will probably be comparative sentences, where extracting and resolving them is crucial for a better understanding of the text. However comparatives are also quite difficult to process by automated methods, because they can occur in a variety of syntactic constructions which are fairly different from each other. In the following examples, which are noted by Friedman (1989), different structures that can be formed with comparatives can be seen.

(4) More men buy than write books.

(5) We are more for than against the plan.

(6) More guests than we invited visited us.

(7) More visitors came than usual.

(8) A taller man than John visited us.

(9) John is taller than 6 ft.

(10) A man taller than John visited us.

Comparatives are broadly categorized into three groups with respect to the part of speech category of the component in the sentence which has the grading property as part of its meaning, namely: adjectival, adverbial and nominal comparatives. In this thesis, we aimed to detect and analyze adjectival and nominal copular (rooted by *be*) comparatives with and without prepositional comparees by a rule-based method. We used PubMed articles to collect the sentences in our dataset and Stanford CoreNLP toolkit (dependency parser and POS tagger) to extract the relations which later on helped us to discover the regularities in the data that are the basis of our ruleset. Finally, by using the ruleset, we extracted semantic relations of comparison as the comparees (the items compared), the direction and the dimension of the comparison.

We preferred the dependency parser over the phrase structure parser, because it is easier to observe the relations of modifier-modified or predicate-argument by means of a dependency tree. The assumption that syntactic structure can be explained by the binary asymmetrical relations between words is the core argument of dependency grammar (de Marneffe & Nivre, 2019). The relation set between two words is asymmetric in the sense that one word, the *dependent*, complements or modifies the other, the *head*. The insensitivity of dependency grammar to the order of the words in a sentence makes it a good candidate for detecting crosslinguistic similarities or differences, which is not the case for phrase structure grammars. The same characteristic is also beneficial for capturing the syntactic structure of flexible word ordered languages. This yielded the significant advances in the development of both dependency parsers (McDonald et al. (2005), Nivre et al. (2007), (Martins et al., 2013), Chen & Manning (2014),Kiperwasser & Goldberg (2016)) and dependency treebanks for many languages (Hajic et al. (2001), Hajic et al. (2001), Buch-Kromann (2003), Oflazer et al. (2003)). Also, it has been argued that dependency trees, when compared to phrase structure trees, support an easier semantic interpretation, since they set direct connections between predicates and their arguments (de Marneffe & Nivre, 2019).

The main motivation of the thesis is to reach a more syntactically motivated dependency representation of English copular comparative structures for easier semantic extraction. This motivation is realized especially for copular comparatives with prepositional comparees in the scope of the thesis. Another motivation is to show even though the comparative sentences can occur in a wide range of syntactic constructions, they have regularities in their structures which can be detected by rule-based algorithms.

1.2 Outline

The thesis consists of seven main chapters: Introduction, Comparative Construction in English, The Stanford Dependency Scheme, Previous Approaches to Comparative Detection, The Proposal, The Implementation and Conclusion.

Introduction, Comparative Construction in English, The Stanford Dependency Scheme and Previous Approaches to Comparative Detection chapters explain the motivation, background and the basic tools of the thesis. We discussed our approach in chapters The Proposal, The Implementation and Conclusion.

CHAPTER 2

COMPARATIVE CONSTRUCTION IN ENGLISH

2.1 A Brief Introduction to Comparatives

Comparison may be expressed in many ways, but in English, there is a reserved construction specific to comparison, which is inflectionally marked and comes with a special kind of subordinate clause. The inflectional categories are named as *comparative* and *superlative forms* and the subordinate clause preceded by *than* is *comparative clause*. Pullum & Huddleston (2002) mention four major kinds of comparative construction: *scalar-non-scalar* and *equality-inequality* (Table 2.1).

	EQUALITY	INEQUALITY
SCALAR	Kim is as old as Pat.	Kim is older than Pat.
NON-SCALAR	I took the same bus as last time.	I took a different bus from last time.

Table 2.1: Comparative Types (Pullum & Huddleston, 2002)

Scalar comparisons denote relative positions on a scale enabled by gradable adjectives, such as *old* in above, unlike the non-scalar comparisons which denote identity and likeness over non-gradable quantities. The inflectionally marked comparatives are in scalar and inequality category with the subtypes of *superiority* and *inferiority* and the first is marked either synthetically (*-er*) or analytically (*more*) and the second is marked only analytically (*less*). Both superiority and inferiority are expressed on a scale with a direction which depends on the lexical item that denotes the superiority or inferiority and both point out the comparison but the direction is provided by the meaning of the lexical item (Pullum & Huddleston, 2002). For example, both *taller* and *shorter* refer to some points on the scale of *height*, but in opposite directions.

Another distinction within the comparatives which also involves the categories discussed above is between *term* and *set comparisons* (Table 2.2 and 2.3). In term comparisons, there are two terms, one of which is syntactically subordinate to the other and the first is expressed in the subordinate clause whereas the latter is in matrix clause. For example, in *Sue is better than Ed*, *Ed* is the first term which stands in a subordinate clause and *Sue* is the second term in matrix clause. Additionally, the set comparisons express comparison in a set with a member prevailing the others in the set.

	EQUALITY	INEQUALITY
SCALAR	Sue is as good as Ed.	Sue is better than the other two.
NON-SCALAR	Sue is in the same class as Ed.	Sue goes to a different school from Ed.

Table 2.2: Term Comparison (Pullum & Huddleston, 2002)

	EQUALITY	INEQUALITY
SCALAR	Sue and Ed are equally good.	Sue is the best of the three.
NON-SCALAR	Sue and Ed are in the same class.	Sue and Ed go to different schools.

Table 2.3: Set Comparison (Pullum & Huddleston, 2002)

Pullum & Huddleston (2002) mention that comparative clauses can only occur in term comparisons in which they are associated with the term in subordinate clause. For example, in (11), *better* is a synthetic comparative adjective denoting superiority (scalar-inequality) and the clause *I did* is the comparative clause (or comparative complement) which is a syntactically distinct construction headed by *than* appearing only in term comparisons.

(11) She played better than I did.

The second term in term comparisons may be occupied by a clause as in (11), or it can also be a noun phrase as in (12).

(12) She played better than her sister.

Pullum & Huddleston (2002) say that "whether a comparative clause or not, the form expressing the secondary term has the syntactic function of complement" and in the case of our framework, which is limited to copular comparatives with comparative clause (*than+clause* or *than*+phrase), the secondary term will always be the complement of *than* which itself is governed by the comparative morpheme (*-er* or *more*).

Comparative phrase is defined as the phrase containing a comparative governor by Pullum & Huddleston (2002) and the comparative governor is limited to the comparative morpheme (*-er* or *more*) in our framework. In (13), *a more serious problem than you think* is the comparative phrase and even though the comparative governor *more* modifies *serious*, *problem* is the head of this phrase, so the comparative phrase is headed by the noun.

(13) This may be a more serious problem than you think. (Pullum & Huddleston, 2002)

Accordingly, comparatives can also be classified with respect to the linguistic category of *X* in the phrase of *more X than Y*. *X* may be an adjective, an adverb or a noun as in the below examples.

(14) Bill is taller than Jill. (Adjectival Comparative)

(15) Bill read more books than Jill. (Nominal Comparative)

(16) Bill runs faster than Jill. (Adverbial Comparative)

2.2 The types of the comparatives we deal with

In this chapter, we discuss the structure of sentences that we intended to analyze; namely, adjectival and nominal copular comparatives with phrasal complements as in examples (17) and (18).

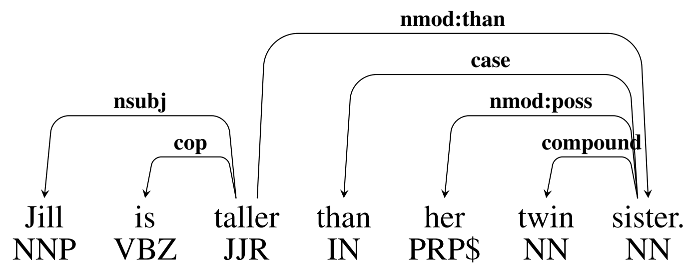
(17) The boy in reds is taller than his friend. (Adjectival-copular)

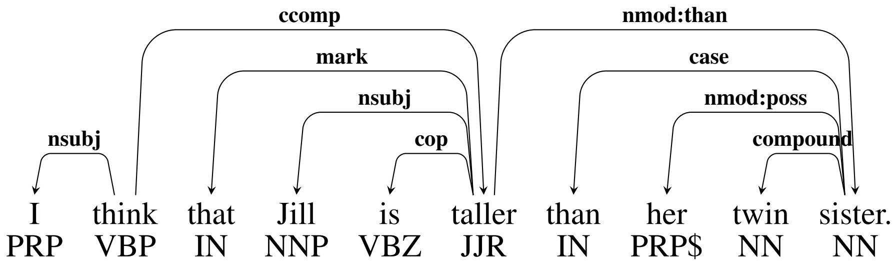
(18) The boy in reds is a more reliable person than his friend. (Nominal-copular)

After we parsed our dataset with Stanford CoreNLP (using dependency parser with *enhanced++ dependencies* and POS tagger), we searched for recurring dependency structures so that by using these structures we can create our ruleset which automatically identifies comparative sentences with the root *be* and *than* clause (comparative clause). The most recurring parses that we used to generate our ruleset are discussed in the following paragraphs in detail.

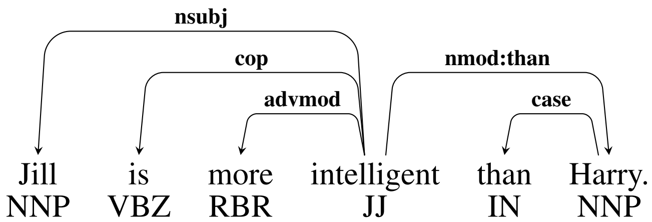
Kübler et al. (2009) say, “The basic assumption underlying all varieties of dependency grammar is the idea that syntactic structure essentially consists of words linked by binary, asymmetrical relations called dependency relations". Such a relation is set between a head (governor) and a dependent (child) with a label showing the dependency type. For example, in (19), *Jill* is the dependent of the head *taller* with the dependency type *nominal subject* (nsubj). The dependency structure in (19) can occur, for instance in a *that clause* without a change in the core structure as in (20) which is important for our purposes since we aim to detect recurring structures occurring with comparatives.

(19)

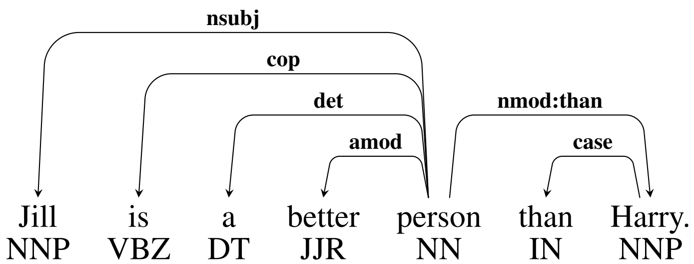


(20) 

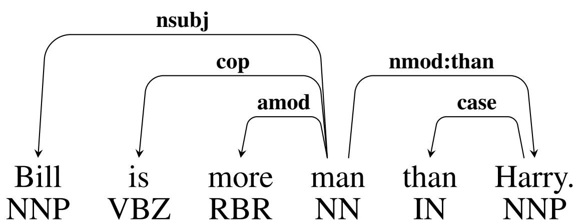
In (19), it is the adjective (*tall*) whose gradability is saturated by comparative morpheme (*more*) and accordingly, this type of comparatives are called *adjectival comparatives*, which can also be in analytical form as in the sentence below.

(21) 

Similarly, if the head of the phrase which takes the comparative modification is a noun, then it is named as *nominal comparative*, i.e (22).

(22) 

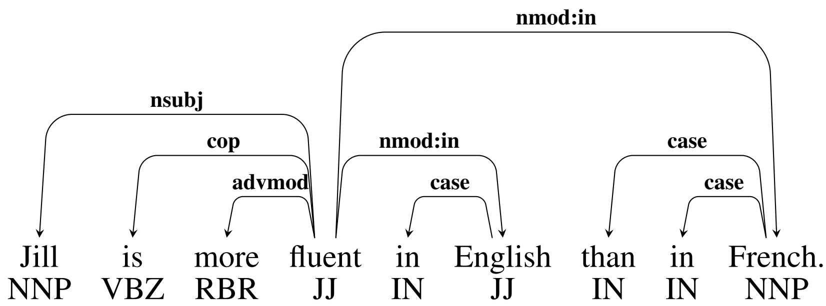
There are also idiomatic uses of nominal comparatives as in the example below.

(23) 

The comparative element in the sentence can also be an adverb and such structures are called *adverbial comparatives*, however the adverbial comparatives are not possible with copular roots because in *Jill is faster than Marry*, *faster* is an adjective by contrast with *faster* in (24) which is the adverbial modifier of the verb.

(24) Jill runs faster than Marry.

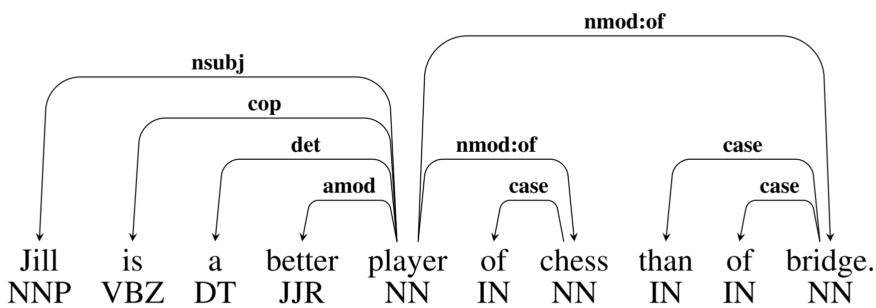
The comparees in comparative sentences may also be prepositional phrases as well as the noun phrases mentioned above. For example, in sentence (25), *in French* and *in English* are being compared to each other with respect to the *Jill's fluency*.



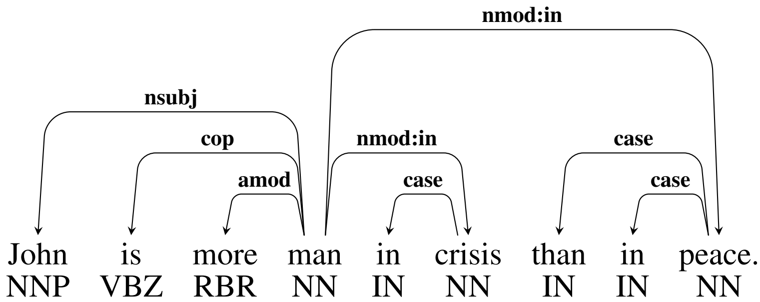
(25)

The comparative clause always designates the 'standard of comparison' and behaves as one of the comparees, and in the copular comparative sentences with nominal comparees, the second comparee fills the subject position of the sentence. For example, in (22), *Jill* and *Harry* are the comparees and the former is the subject of the sentence and as usual, the latter forms the comparative clause by following *than*. Unlike the case with nominal comparees, in the sentences with prepositional comparees, the second comparee cannot be found in the subject position, but acts as a complement of the comparative head. This time, the subject plays the role of the frame for the comparison. In (25), the subject *Jill* is not a comparee as before, but it specifies the boundaries of the fluency in the regarding languages.

The prepositional comparees can occur with any kind of comparatives. Within the scope of the copular comparatives, it can occur with adjectivals as we discussed above and also with nominals as will be discussed below.



(26)

(27) 

Similar to adjectivals, both in (26) and (27), the comparees are the prepositional phrases and the subjects are again the frames of the comparison. In (27), for example, *John's manhood* is compared in two different situations, *in crisis* and *in peace*.

On this basis, we will argue that there are two different *more*s; the one which takes two noun phrases as comparees and the other which takes two prepositional comparees and a frame of comparison (Section 5.2).

CHAPTER 3

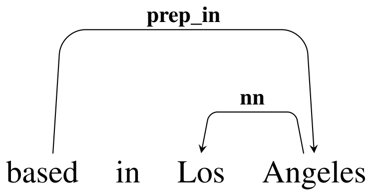
THE STANFORD DEPENDENCY SCHEME

de Marneffe et al. (2006) proposed a rule-based system to extract dependency parses of English sentences from phrase structure parses, which then was integrated in Stanford Parser. They define their goal as to be practical rather than theoretical with the essence that structural configurations are used to define grammatical roles. They put emphasis on NP-internal relations for the reason that such relations are an inherent part of corpus texts and so the real-world applications. Therefore, Stanford dependency scheme (SD scheme) is remarked to be designed to provide simple, straightforward descriptions of grammatical relationships which facilitate semantic analysis even for non-linguist users who work in the natural language understanding tasks. Accordingly, (de Marneffe & Manning, 2008) specified their design principles as follows.

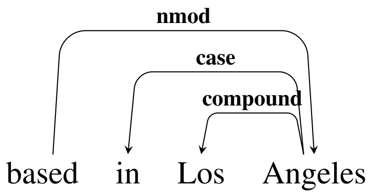
1. Everything is represented uniformly as some binary relation between two words.
2. Relations should be semantically contentful and useful to applications.
3. Where possible, relations should use notions of traditional grammar for easier comprehension by users.
4. Underspecified relations should be available to deal with the complexities of real text.
5. Where possible, relations should be between content words, not indirectly mediated via function words.
6. The representation should be spartan rather than overwhelming with linguistic details.

Based upon these design principles, SD scheme takes auxiliaries, complementizers, prepositions as dependents and does not tend to make argument-adjunct distinction. It provides two options: (i) that every word is a node and, (ii) that certain words, such as prepositions, are collapsed into relations and are not represented by nodes. For example, in (28) preposition *in* is collapsed into the relation between *based* and *Angeles* by labeling the relation as *prep_in*.

(28) Bell, based in Los Angeles, makes and distributes electronic, computer and building products. (de Marneffe & Manning, 2008)

(29) 

The Stanford dependency scheme is aimed to be improved to capture and understand cross-linguistic similarities, under the name of Universal Stanford Dependencies (USD) (de Marneffe et al., 2014). In their paper, they proposed a taxonomy of grammatical relations to be broadly supported by many languages. One of the major changes in USD is again related to the prepositions which are treated as case-marking elements and dependents of the nouns they attach, to draw a parallelism between the grammatical relations expressed by prepositions in some languages and by morphology in others. In USD scheme, the relation between *based* and *Angeles* (28) is labeled as *nmod* and *in* is a dependent of *Angeles* with the label of *case* (30).

(30) 

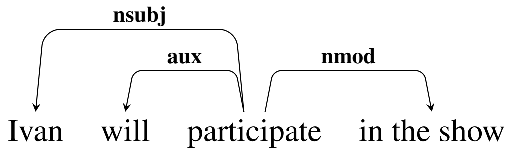
The Universal Dependencies (UD) project aims to develop cross-linguistically consistent dependency annotations for different languages to support comparative linguistic studies and cross-lingual learning by providing “a universal inventory of categories and guidelines to facilitate consistent annotation of similar constructions across languages, while allowing language specific extensions when necessary" (Nivre et al., 2016). It is a combination of several initiatives, one of which is the USD. The UD relations again hold between content words and target to distinguish nominals, clauses and modifiers and also distinguish core arguments (objects, subjects) and other dependents (all non-core dependents are labeled as modifiers), but does not distinguish complements and adjuncts. The relations are based on the three principles in below, which are quite similar to the SD design principles listed above.

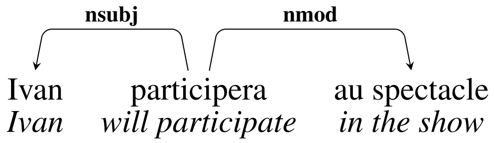
1. Content words are related by dependency relations.

2. Function words attach to the content word they further specify.

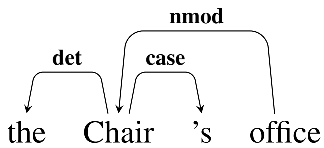
3. Punctuation attaches to the head of the phrase or clause in which it appears.

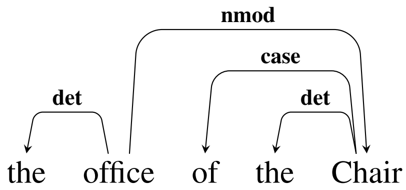
By having the relations between content words rather than function words, case-marking elements such as prepositions or postpositions, and copulas or auxiliaries are labeled as dependents (as in USD) and this leads higher probability of detecting parallelism between morphologically rich languages and the others. One such example (31), from Nivre et al. (2016), summarizes this parallelism.

(31) a. 

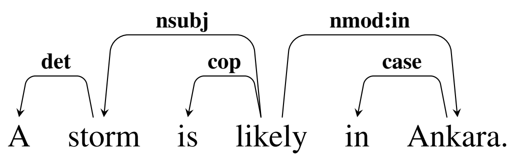
b. French: 

Taking content words as heads helps detecting the similarities also within languages. Again, the following example from Nivre et al. (2016) shows the situation.

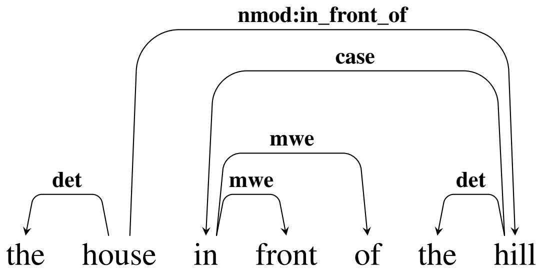
(32) a. 

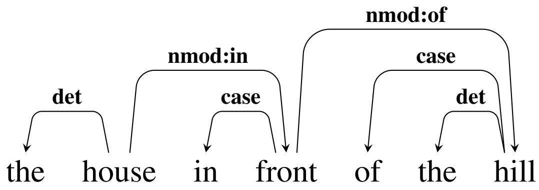
b. 

UD provides two more additional dependency graph representations, *enhanced* and *enhanced++*, to further specify the relations which are not explicitly stated due to the choice of relating the content words. For example, in enhanced UD representations, all nominal modifier relations also include the regarding preposition as in (33).

(33) 

For some problematic constructions, such as multiword prepositions, the *enhanced++* UD representations provide analyses where the enhanced representations are deficient. In the example below from Schuster & Manning (2016), *nmod:in_front_of* relation employs a direct connection between the content words *house* and *hill* to stress the connection between them explicitly (*enhanced++* representation, (34)) otherwise it will be implicit (*enhanced* representation, (35)).

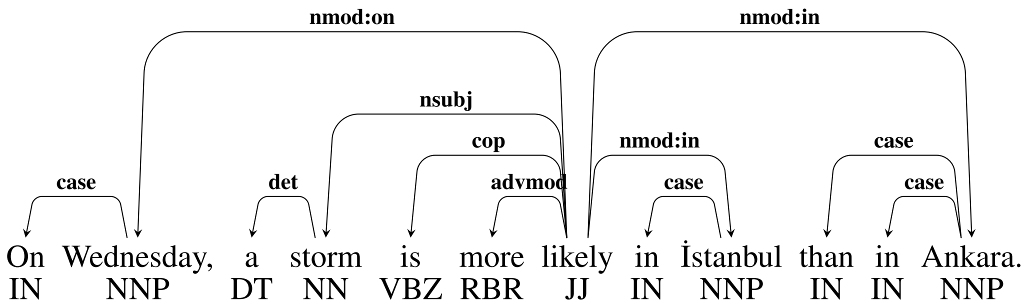
(34) 

(35) 

During the process of collecting the sentences for our dataset, we encountered a special comparative construction which compelled us for the extraction of comparees. These sentences contain prepositional comparees as in the sentence below.

(36) Baseline impedance levels are more critical in patients with gastroesophageal reflux disease than in healthy individuals.

Since Stanford parser connects content words and does not tend to make argument-adjunct distinction, it is not possible to extract one of the comparees in (37), because both *on Wednesday* and *in İstanbul* are headed by *likely* and there is no clue to separate which is the comparee and which is the adjunct. To overcome this problem, we propose a different dependency parse for comparative construction which is supported by semantic analysis in Chapter 5.

(37) 

CHAPTER 4

PREVIOUS APPROACHES TO COMPARATIVE DETECTION

In this section, we will discuss the literature that aims to detect or analyze comparatives (or both) in various kinds of texts. The chapter is split into three parts. The first and the second parts address the machine learning and rule-based methods for English comparatives, and the final one is for languages other than English.

4.1 Machine Learning Methods

Jindal & Liu (2006a) propose a method to identify comparative sentences in texts using class sequential rules and machine learning methods. They announce their study as the first reported one in the area of computational detection of comparative structures. Doran et al. (1994) mentioned two types of comparatives: (1) Metalinguistic Comparatives and (2) Propositional Comparatives. *I am more frustrated than sad* is a metalinguistic comparative sentence where one property (frustration) has a greater extent than the other (sadness). On the other hand, propositional comparatives make comparisons between two propositions and this type of comparatives are grouped in three subtypes, (1) Nominal Comparatives, (2) Adjectival Comparatives and (3)Adverbial Comparatives, depending on the part-of-speech tag of comparative word. Despite the fact that comparatives are categorized as nominal, adjectival or adverbial by linguists, the authors argue that this kind of categorization has limitations. One of the limitations is there are comparative sentences without any comparative words or phrases as categorized in above. For example:

(38) In market capital, Intel is way ahead of Amd. (Jindal & Liu, 2006a)

Also some sentences can have comparative words in them but they don't mean to compare.

(39) In the context of speed, faster means better. (Jindal & Liu, 2006a)

Because of the limitations mentioned above, they make their own definition and classification of comparative sentences. They classify a sentence as comparative if it “expresses a relation on similarities or differences of more than one object", where an object can be a person, a product, an action etc. with a set of features to be compared. Under this definition, they grouped comparatives into four types:

(i) Non-equal Gradables order objects with respect to some features and are based on relationships such as *greater* or *less*.

(ii) Equatives set equality between objects with respect to some features.

(iii) Superlatives rank one object over all the others.

(iv) Non-gradables compare objects without ordering them and reflect implicit comparisons.

Their approach to identify comparatives is a combination of class sequential rules and machine learning algorithms. Briefly, a class sequential rule states the probability of a sentence to be a comparison if it contains a particular pattern. Here a sentence is treated as a sequence and sequence mining aims to find all sequences which satisfy a predefined threshold. By replacing each word in a sentence with its part-of-speech tag, the patterns of comparatives become apparent and besides the patterns, Jindal & Liu (2006a) generated a set of keywords which occur frequently in comparisons. The set of keywords is manually identified and contains 83 words and phrases. It is defined as below.

K = {JJR, RBR, JJS, RBS} $\cup$ {words such as favor, prefer, win, beat, but, etc.} $\cup$ {phrases such as number one, up against, etc.}

They used news articles, consumer reviews on products, and Internet forum discussions to generate their dataset from and sentences that contain at least one of the keywords are extracted. This step filters out sentences which are unlikely to be comparisons and the words which are in the radius of 3 of the keyword are used as the sequence. Each word in the sequence is replaced with its part-of-speech tag.(Brill's tagger, (Brill, 1992)) Finally, the class labels are added manually to each sequence as *comparative* or *non-comparative*. The process is exemplified below.

(40) This camera has significantly more noise at iso 100 than the Nikon 4500. (Jindal & Liu, 2006a)

The keyword *more* is detected, POS tags are added:

(41) This/DT camera/NN has/VBZ significantly/RB more/JJR noise/NN at/IN iso/NN 100/CD than/IN the/DT Nikon/NN 4500/CD.

The sequence with its label:

(42) $< \{NN\}\{VBZ\}\{RB\}\{moreJJR\}\{NN\}\{IN\}\{NN\} >$ comparative

These labeled sequences are collected into a database to generate class sequential rules which meet a specified minimum confidence threshold. After class sequential rules are generated, each sentence is classified as *comparative* or *non-comparative* by the class sequential rule with the highest confidence. (Also some manually compiled rules are added) At the final step, they used the naïve Bayesian (SVM was tried too) model to build the classifier with class sequential rules as features of the classifier.

Several methods to identify comparatives are compared and the related results are as in Figure 4.1.

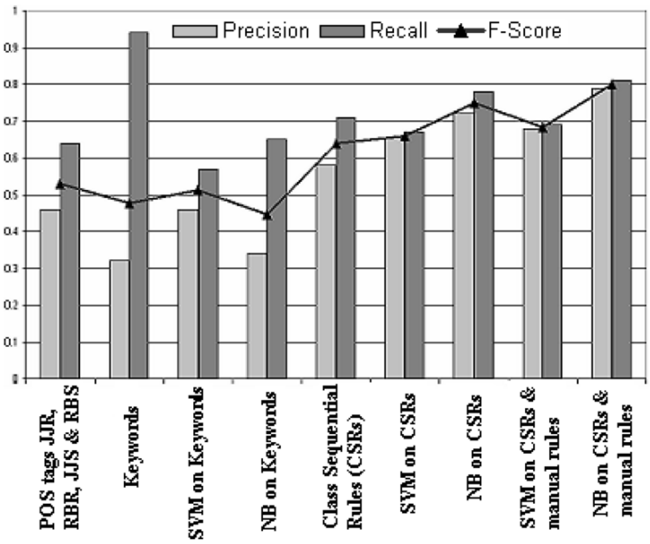


Figure 4.1: Results (Jindal & Liu, 2006a)

The following work of Jindal & Liu (2006b) focused on gradable comparatives (non-equal gradable, equative and superlative) and different from their preceding work, they also extract comparative relations which are expressed as below.

$$< relationWord, features, entityS1, entityS2, type >$$

In such a relation, relationWord refers to the keyword that reflects the comparison (i.e JJR or RBR tagged word), features refer to on what domains entities are being compared, 'entityS1', 'entityS2' are the entities compared and type is one of the non-equal gradable, equative or superlative type of gradable comparatives. For example:

(43) Canon has better optics than Nikon. (Jindal & Liu, 2006b)
$< better, optics, Canon, Nikon, non-equal\ gradable >$

They used label sequential rules, which are similar to class sequential rules, to extract relations and the results are as below. (CRF refers to conditional random fields)

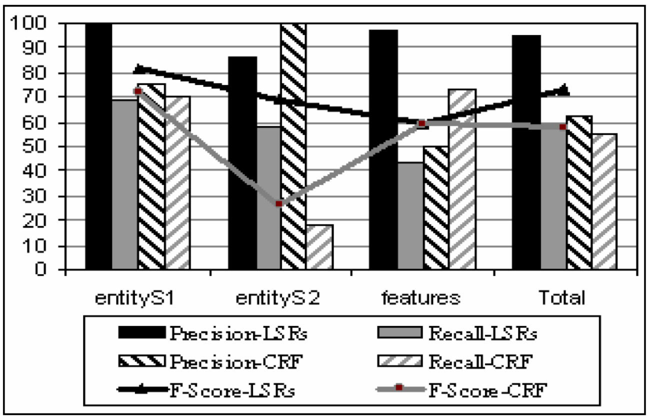


Figure 4.2: Results (Jindal & Liu, 2006b)

Ganapathibhotla & Liu (2008) proposed another technique to determine which entity is preferred in a comparative sentence. For example, in the following sentence, the preferred entity is *Camera X*.

(44) The picture quality of Camera X is better than that of Camera Y. (Ganapathibhotla & Liu, 2008)

However not all preferred entities can be easily determined as in the above example. In (45) *longer* has a positive meaning in the context of battery life so *Camera X* is preferred, on the contrary in (46) it has a negative meaning and *Program Y* is preferred.

(45) The battery life of Camera X is longer than Camera Y. (Ganapathibhotla & Liu, 2008)

(46) Program X's execution time is longer than Program Y. (Ganapathibhotla & Liu, 2008)

They defined this problem as context dependent and proposed that limiting the boundaries of the context with comparison word and the entity being compared works well for their purposes. To decide whether a comparison word in a particular context is positive or negative, they used customer reviews on the Web. If it is associated more with proponent comments, it is more likely to be positive, otherwise it would be negative.

Bakhshandeh & Allen (2015) also used machine learning methods to identify and analyze comparative constructions. According to their analysis, comparison structures are modeled as "inter-connected predicate-argument structures, where predicates are the main comparison operators (implicit and explicit comparison morphemes), and arguments are connected to the predicates via semantic roles (relations)". These three elements of comparison can be better understood by the following Figure 4.3.

Figure 4.3: Predicate-argument structure of comparatives (Bakhshandeh & Allen, 2015)

Here, *tall* and *taller* are the predicates and related arguments are connected to these predicates through semantic role edges. They used multi-class classifier to detect the predicates and two logistic regression classifiers for roles and arguments.

Kessler & Kuhn (2013) adapted Semantic Role Labeling (SRL) to detect comparative predicate, comparison aspect and compared entities for a given comparative sentence. As is evident from its name, SRL gives semantic labels to phrases as in the below sentence.

(47) [$_{AGENT}$ Sue] broke [$_{THEME}$ the window].

They retrained an existing SRL system with comparative predicates and their arguments; where comparative predicates refer to phrases like *more, bigger* or *beats* (no POS tag restriction) and arguments are comparison aspect and compared entities. So for any comparative sentence given, they expect to output a quadruple (predicate, entity+, entity-, aspect).

4.2 Rule-based Methods

In their article, Gupta et al. (2017) developed a rule-based method to identify comparative sentences in medical articles and extract components of them. They emphasize four components in comparative structures, which they named as compared entities (CE), comparison aspect (CA), scale indicator (SI) and entity separator (ES). These components may be better understood by the following example sentence (48), where scale indicator is a comparative adjective and entity separator can be a phrase or word such as *than, versus, compared to* etc.

(48) [Arteriolar sclerosis]$_{CA}$ was significantly higher$_{SI}$ in addicts$_{CE}$ than$_{ES}$ controls$_{CE}$. (Gupta et al., 2017)

They follow the categorization of Jindal & Liu (2006a), in which there exists four classes for comparative structures: (1) Non-Equal Gradable, (2) Equative, (3) Superlative and (4) Non- Gradable. They address only two classes in their work, non-equal gradables which set ordering relationships between compared entities and equative comparisons which indicate equality between the entities. Examples for the classes are mentioned as follows:

(49) a. Epidural morphine offers better pain control compared to intravenous morphine. (Gupta et al., 2017)

b. Botox is as effective as oral medication for overactive bladder. (Gupta et al., 2017)

Their approach includes different steps which are enumerated below.

(i) Tokenize and split the texts into sentences by Stanford coreNLP toolkit

(ii) Obtain constituency trees for sentences by Charniak-Johnson parser with McClosky's adaptation

(iii) Convert constituency trees into syntactic dependency graphs by Stanford conversion tool

(iv) Use Semgrex to match developed patterns with dependency parses of sentences

In the third step, they use collapsed dependencies which are useful to get direct dependencies between content words if the sentence includes prepositions, conjunctions or relative clauses. The same sentence is parsed with (Figure 4.4) and without (Figure 4.5) using collapsed dependencies to better show the difference in between.

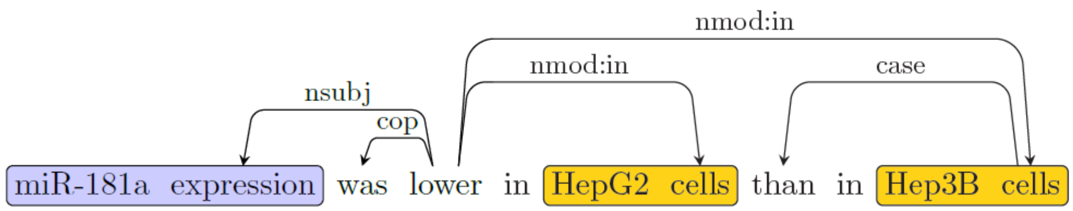


Figure 4.4: With collapsed dependencies (Gupta et al., 2017)

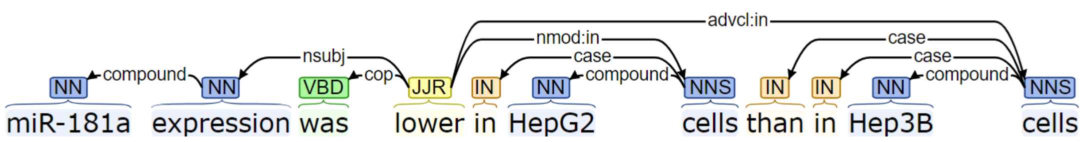


Figure 4.5: Without collapsed dependencies

Semgrex patterns work for matching node and edge configurations with a dependency graph. With the help of it, particular structures of comparative sentences can be formulated as patterns and then those patterns are searched for a match in dependency parses of the sentences.They developed 43 Semgrex patterns to identify non-equal gradable (35) and equative comparisons (8) and each of these patterns works for identifying both the comparative sentence and the components of it, namely the compared entities, comparison aspect, scale indicator and entity separator. Non-equal gradables are grouped into three categories based on the part-of-speech tag of the scale indicator in the sentence: (1) comparative adjectives, (2) comparative adverbs and (3) verbs. In comparative adjectives, scale indicator serves as an adjective and this category is mentioned to be the most frequent one. Also comparative adjectives are examined into two categories and the first one involves copular structure in which JJR (comparative adjective) acts as the predicate of the sentence. Figure 4.6 can be given as an example of this category. In this kind of copular sentences, comparison aspect can be found through the *nsubj* edge from JJR to subject of the comparison and to extract one of the compared entities, *nmod:than* edge from JJR is followed. The second compared entity is extracted by the following *nmod:in* edge from JJR.

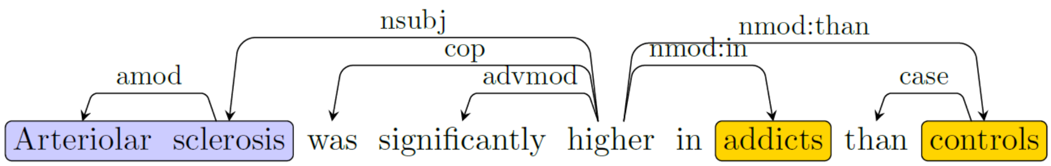


Figure 4.6: Comparative adjectives in copular structure (Gupta et al., 2017)

In the second category, there exist sentences with JJR that modifies a head noun, where modified noun gives the comparison aspect and JJR gives the scale indicator as usual. (Figure 4.7)

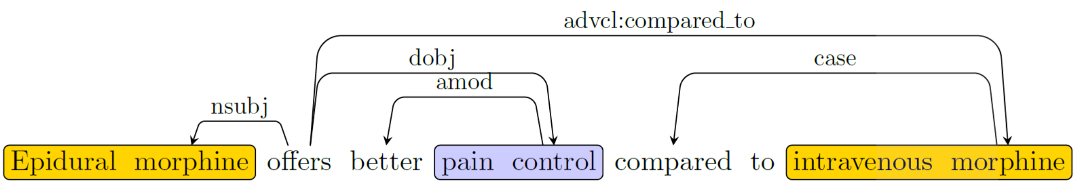


Figure 4.7: Comparative adjectives as noun modifier (Gupta et al., 2017)

The third category is comparative adverbs (RBR) and comparison scale has adverb part-of-speech tag in sentences with RBRs. A similar approach as in comparative adjectives is applied to all kind of comparative sentences. First JJR or RBR is found as scale indicator, then regarding the structure of the sentence, related edges are followed to extract entity separator, compared entities and comparison aspect and this process is the key for each different Semgrex pattern for each differently structured comparative sentence. One exception to this rule is the final category of non-equal gradables, namely the verbs. In this category, certain verbs such as *increased, improved, decreased* etc. play the role of scale indicator and JJR or RBR does not appear and in such sentences a list of verbs trigger the Semgrex patterns but the remaining is the same with the JJR/RBR cases.

Also the equative comparisons are grouped into 3 types. First type is the *X as adjective (JJ) as Y* structure. Here, JJ is the key of regarding Semgrex pattern, which serves as scale indicator and the edges from it are followed for the remaining components of comparison with a similar approach as in non-equal gradables. The second type involves the scalar indicator of *similar to* and the third type involves *no difference, no changes* etc..

They tested their system on 189 comparative sentences from 125 medical abstracts and each of the sentences contains the four components of comparison. (i.e a compared aspect, a scale indicator and two compared entities) The results can be seen in the following Table 4.1. They reported that most of the errors arised because of incorrect parses.

Type	**Precison**	**Recall**	**F-Score**
Sentence	0.91	0.83	0.87
Comparison Aspect	0.85	0.72	0.78
Scale Indicator	0.87	0.75	0.81
Compared Entities	0.84	0.72	0.77

Table 4.1: Results (Gupta et al., 2017)

Fiszman et al. (2007), extended the use of SemRep to make semantic interpretations about comparative structures but they concentrated only on structures where two drugs are compared with respect to an attribute. SemRep is a program, which is part of the Semantic Knowledge Representation project and it extracts semantic predications from texts. Process of semantic predication of Semrep begins with partial syntactic parse using SPECIALIST lexicon and part-of-speech tagger. After this step, MetaMap matches noun phrases with Metathesaurus concepts. These two steps are summed up by the following example.

(50) a. Lansoprazole for the treatment of gastroesophageal reflux disease (Fiszman et al., 2007)

b. [[head(noun(Lansoprazole), metaconc('lansoprazole':[phsu]))],
[prep(for), det(the), head(noun(treatment))],
[prep(of), mod(adj(gastroesophageal)), mod(noun(reflux)),
head(noun(disease), metaconc('Gastroesophageal reflux disease':[dsyn]))]]

As can be seen in the example, lansoprazole is matched to *phsu* (Pharmacologic Substance), gastroesophageal reflux disease matched to *dsyn* (Disease or Syndrome) and *treatment* matched to the UMLS Semantic Network relation "Pharmacologic Substance TREATS Disease or Syndrome." by an indicator rule that maps syntactic elements to relationships in the Semantic Network. As a result, the output below can be obtained.

(51) Lansoprazole TREATS gastroesophageal reflux disease

Two most frequently encountered patterns of comparative sentences in 10,000 MEDLINE citations that Fiszman et al. (2007) processed are mentioned as comp1 and comp2 in given in Figure 4.8.

comp1: Compared terms

C1: Term1 {BE} *compare with/to* Term2
C2: *compare* Term1 *with/to* Term2
C3: *compare* Term1 *and/versus* Term2
C4a: Term1 *comparison with/to* Term2
C4b: *comparison of* Term1 *with/to* Term2
C4c: *comparison of* Term1 *and/versus* Term2
C5 Term1 *versus* Term2

comp2: Scalar patterns

S1: Term1 BE *as* ADJ *as* {BE} Term2
S2a: Term1 BE *more* ADJ *than* {BE} Term2
S2b: Term1 BE ADJer *than* {BE}Term2
S2c: Term1 BE *less* ADJ *than* {BE} Term2
S4: Term1 BE *superior to* Term2
S5: Term1 BE *inferior to* Term2

Figure 4.8: Mostly encountered comparative patterns (Fiszman et al., 2007)

These patterns show minimum requirements, so modifiers can intervene. In the process of interpreting comp1 patterns, if SemRep encounters *compare* (or its forms), it looks to the right of *with, to, and* or *versus* to find a noun phrase. If this phrase's head can be matched to a concept with a semantic type in *Chemicals & Drugs*, then it is marked as Term2. After, their algorithm searches left of the Term2 for the second noun phrase. It also must have a semantic type in *Chemicals & Drugs* to be marked as Term1. This process is exemplified in (52) & (53).

(52) To compare the efficacy and tolerability of Hypericum perforatum with imipramine in patients with mild to moderate depression. (Fiszman et al., 2007)

(53) Hypericum perforatum COMPARED_WITH Imipramine

The process of interpreting comp2 patterns begins with finding *as, than* or *to*, then if the first noun phrase to the right is matched to a concept with a semantic type in *Chemicals & Drugs* as in the comp1 case, that noun phrase marked as Term1 and Term2 is found by a similar manner. Different from the comp1 patterns, here there is also a scale name which corresponds to the adjective located to the left of Term1 and the nominalization of this adjective is done with the help of SPECIALIST Lexicon. If the adjective is preceded by *as* Term1 and Term2 are equal otherwise it is an inequality case between two terms. If it is an inequality case and if the adjective is *less* or *inferior*, Term2 is higher than Term1 and for all other cases Term1 is higher. All these steps result as in (55), (57) and (59).

(54) Candesartan is as effective as lisinopril once daily in reducing blood pressure. (Fiszman et al., 2007)

(55) Candesartan COMPARED_WITH lisinopril
SCALE:Effectiveness
Candesartan SAME_AS lisinopril

(56) Losartan was more effective than atenolol in reducing cardiovascular morbidity and mortality in patients with hypertension, diabetes, and LVH. (Fiszman et al., 2007)

(57) Losartan COMPARED_WITH Atenolol
SCALE:Effectiveness
Losartan HIGHER_THAN Atenolol

(58) Morphine-6-glucoronide was significantly less potent than morphine in producing pupil constriction. (Fiszman et al., 2007)

(59) morphine-6-glucoronide COMPARED_WITH Morphine
SCALE:Potency
morphine-6-glucoronide LOWER_THAN Morphine

Their test set contains 287 sentences that contain 288 comparative structures from 3000 MEDLINE citations. (85 of them are comp2, 203 structures are comp1) Results are in below Table 4.2.

Task	**Recall**	**Precision**	**F-score**
Overall	0.70	0.96	0.81
Drug extraction	0.69	0.96	0.81
Comp1	0.74	0.98	0.84
Comp2	0.62	0.92	0.74
Scale	0.62	1.00	0.77
Position on scale	0.62	0.98	0.76

Table 4.2: Results (Fiszman et al., 2007)

4.3 Other Languages

Comparative extraction studies are conducted also in languages other than English. Yang & Ko (2009) used a set of comparative keywords, which they constructed, together with maximum entropy model and Naïve Bayes to detect comparative sentences in Korean text documents. They first identified candidate comparative sentences by using their comparative keywords set and then with the help of MEM or Naïve Bayes, they eliminated non-comparatives from the candidates. Comparative sentences are classified under six categories (*equality, similarity, difference, greater or lesser, superlative, predicative*) depending on the keywords in them. In their following study, Yang & Ko (2011) also extracted the components of comparison as *comparative predicate, subject entity* and *object entity*. In another study regarding Korean comparatives, Gu & Yoo (2010) collected restaurant comments as their dataset and they used particular sentence structure patterns to identify comparison and what are being compared with each other.

Park & Yuan (2015) compared two different techniques for comparative elements extraction in Chinese. They refer six elements of comparison as *subject entity, comparative marker, object entity, dimension, comparative result, comparative extent* and two proposed techniques as *part-of-speech chunking-based method* and *transformation-based error-driven learning*. First method makes use of POS tags and sequential patterns in comparative sentences. These patterns are caught by using manually constructed rules with regular expressions. Whereas in the second method, the pattern catching is done with the help of machine learning method, namely TBL. They concluded that TBL is more successful than manual rules in extraction of comparison elements. Also Liu et al. (2013) studied on Chinese comparatives and proposed a rule-based method and a CSR-based (class sequential rules) method. Similar to Park & Yuan (2015), they used regular expressions to manually compile rules that catch the syntactic regularities in comparative sentences. CSR-based method takes advantage of class sequential rules and machine learning methods. They compared these two methods with each other and found that the two have similar performances regarding comparative sentence identification. They also extracted *comparative subject, comparative object, comparative subject attribute* and *comparative object attribute* by using conditional random fields based classifier.

CHAPTER 5

THE PROPOSAL

We propose a different dependency parse for copular comparatives to reach a more syntactically and semantically motivated representation of them, as mentioned in Chapter 1. In the following sections of this chapter, we firstly explain the syntactic motivations of our proposal and the last two chapters are for semantic basis of the proposal.

5.1 Syntax

To decide which parses better explain the syntactic and semantic aspects of comparative sentences, we need to examine how the relations between words are specified and how the head and the dependents are determined. To identify the dependency relations between words and to determine the head (H) and the dependent (D) in a linguistic construction (C), a list of criteria have been proposed as below (Kübler et al., 2009).

1. H determines the syntactic category of C and can often replace C.
2. H determines the semantic category of C; D gives the semantic specification.
3. H is obligatory; D may be optional.
4. H selects D and determines whether D is obligatory or optional.
5. The form of D depends on H (agreement or government).
6. The linear position of D is specified with reference to H.

Not all syntactic constructions satisfy the whole criteria above, but two specific constructions are discussed in Kübler et al. (2009) to explain *head-complement* and *head-modifier* relations. de Marneffe & Nivre (2019) remark that "there is a core of syntactic construction on which all dependency grammar theories agre" and this core includes *exocentric* and *endocentric* constructions. *Head-modifier* relations are told to be endocentric constructions and they may satisfy all of the criteria mentioned above, for example the relation between a noun and an adjective. In (60), the phrase *financial markets* can be replaced with the head of the phrase, *markets*, and the sentence *Economic news had little effect on markets* will still have the same syntactic structure.

(60) Economic news had little effect on financial markets. (Kübler et al., 2009)

On the contrary, in exocentric constructions which are set between a *head* and a *complement*, the head cannot replace the whole phrase. The relation between *had* and *news* in the above sentence is told be an exocentric one and as mentioned, the head *had* cannot replace the whole phrase. So exocentric constructions fail to satisfy the criterion 1, but may satisfy the remaining. Clearly, the relation between a verb and its subject or object is exocentric, but de Marneffe & Nivre (2019) indicate that even though the relations between verbs and their arguments (subjects, objects) or the relations between adjectives and nouns are agreed universally by dependency theorists, other constructions besides those, are still controversial. One such construction includes function words like auxiliaries, case markers or prepositions which exist as morphological inflection in some languages. In some theories, function words are accepted as heads with the reason of linguistic fidelity, in others, as dependents to detect crosslinguistic similarities or to provide an easier interpretation of the relations even for non-linguists who work in the development of natural language understanding applications.

What about the relation between the comparative morpheme *more* and the following adjective or the comparative complement headed by *than*? In *She is more beautiful than her mother*, if we remove the phrase *more than her mother*, the remaining part of the sentence is still grammatical and meaningful (*She is beautiful*), so the relation between *beautiful* and *more than her mother* seems to be an endocentric construction and since *beautiful* can replace the whole phrase without disrupting the syntactic structure, it should be the head. Without contextual knowledge, *She is more beautiful* is not a complete sentence and it yields the question *than whom*. So the comparative clause is an inseparable part of the comparative phrase, whether it is explicit or implicit. Also, *She is beautiful than her mother* is not meaningful or grammatical and this makes us to conclude that there should be a dependency relation between *more* and *than*. By contrast with the relation between *more* and *beautiful*, the relation between *more* and *than* seems to be a exocentric construction, with the head being *more*, in the sense that neither of them can replace the whole phrase. Similarly, Pullum & Huddleston (2002) make a long discussion about comparative clause (*than* clause) and take *than* as the head of it and *more* as the main governor of the comparative phrase.

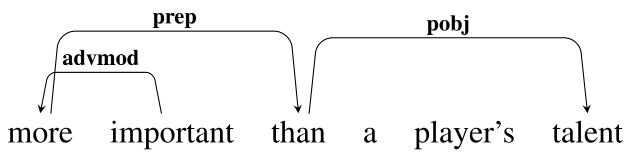
de Marneffe et al. (2013) remark that even though the Stanford dependency scheme "provides good coverage of core grammatical relations, such as subject, object, internal noun phrase relations, and adverbial and subordinate clauses, the standard remains underdeveloped and agnostic as to the treatment of many of the more difficult—albeit rarer—constructions that tend to dominate discussions of syntax in linguistics, such as tough adjectives, free relatives, comparative constructions, and small clauses" and in their paper, they propose dependency analyses for these more difficult constructions.

Stanford dependency parser does not have special relations to label comparative constructions but applies the existing modifier (to label *more,less*) and preposition (to label *than*) relations to comparatives. It takes the adjective as the head of the comparative structure. The reason for this is discussed in de Marneffe et al. (2013). For an expression like *more X than Y*, they take the head of the expression as the head of the *X* phrase, since keeping the head will result in a grammatical sentence which indicates that the head determines the syntactic type of the whole phrase and also *more ... than Y* acts as a modification of the *X* phrase. This reasoning is in accord with the endocentric construction explanation made above.

(61) Commitment is more important than a player's talent. (de Marneffe et al., 2013)

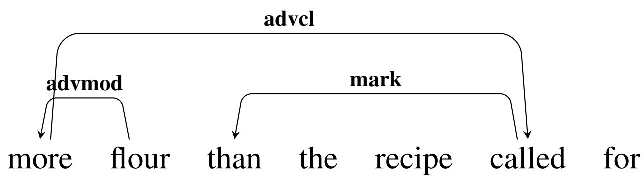
For the sentence (61), de Marneffe et al. (2013) argue that *Commitment is important* forms a grammatical sentence which shows that *important* determines the syntactic type of the whole phrase and it should be the head. They draw a parallelism between adverbial modifiers (i.e *Commitment is crucially important*) and *more ... than Y* phrase and to be consistent with other types of degree modification, they labeled the relation between *more* and *important* as *advmod* as in below.

(62)

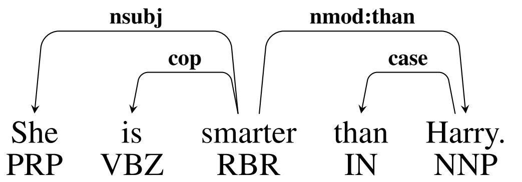


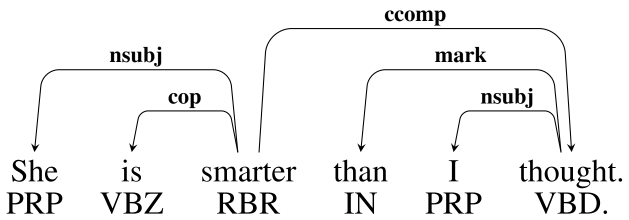
On the other hand, the relation between *more* and *than* depends on whether *Y* in *more X than Y* is a phrase or clause. If Y is a phrase, the label becomes *prep* (62), if it is a *clause*, the label becomes *mark* (63), with the reason of being consistent with Penn Treebank annotations (de Marneffe et al., 2013).

(63)



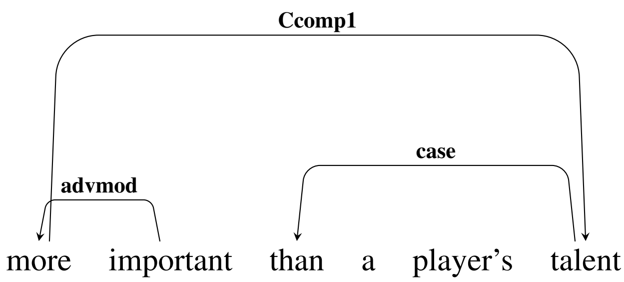
In Nivre et al. (2016), taking the content words as head and the function words as dependents has been discussed, by contrast with (62) in which *than* is taken as the head of the following comparative phrase. So, according to Nivre et al. (2016), *than* in (64) is a dependent of *Harry* and the relation is labeled with *case* or a dependent of *thought* with the relation *mark* as in (65). The reason is developing cross-linguistically consistent annotations to capture the similarities between different languages as part of the Universal Dependencies Project. In their article, they mention three principles; (i) content words are related by dependency relations, (ii) function words attach to the content word they further specify and (iii) punctuation attaches to the head of the phrase or clause in which it appears, which are the essentials of *head-dependent* relations in their framework as mentioned in Chapter 3. They say "Giving priority to dependency relations between content words increases the probability of finding parallel structures across languages, since function words in one language often correspond to morphological inflection (or nothing at all) in other languages".

(64) 

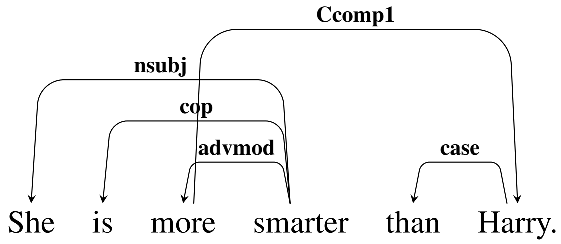
(65) 

We use Stanford CoreNLP toolkit (version 3.9.2) which provides the POS tagger and the dependency parser (among the other tools) to parse our dataset (Manning et al., 2014). The dependency parser outputs the relations in the UD representation and we preferred to use *enhanced++* dependencies, rather than *basic* dependencies, since they better match with our purposes.

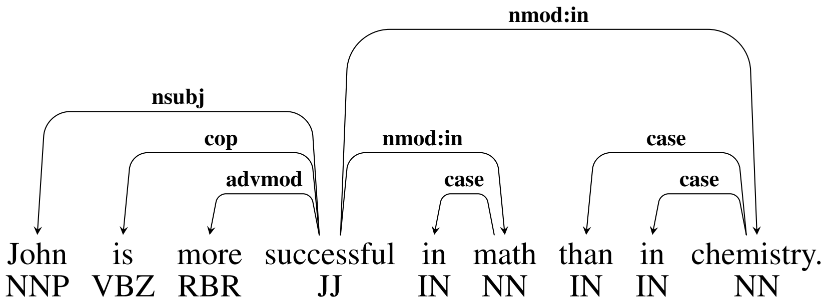
By following the above discussions, *than* can be taken as the head of the comparative clause as in (62) (based on the exocentric construction explanation and also de Marneffe et al. (2013)'s approach) or as a dependent of the following phrase as in (64) to give priority to content words rather than function words to find cross-linguistic parallelisms (based on UD representation). For our purpose of semantic extraction of comparees, taking *than* as head or dependent does not change the complexity of the problem, because one of the comparees will always follow *than*, so we decided to left it as it is, namely as dependent. However, for both easier extraction and more correct semantics, we connected the comparee following *than* to *more* rather than the adjective and we used the label *Ccomp1* referring to the *first comparative complement* (66).

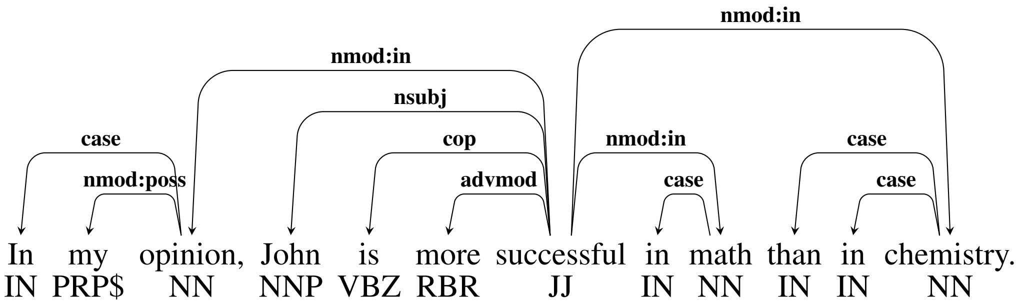
(66) 

For analytic comparatives, as can be seen in (66), we changed the head of the comparative clause from adjective to *more*. For synthetic comparatives, we add a *more* node and take it as the head of the comparative clause (67).

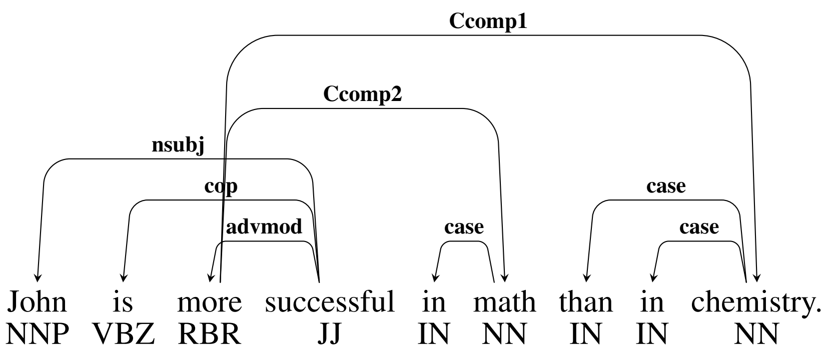
(67) 

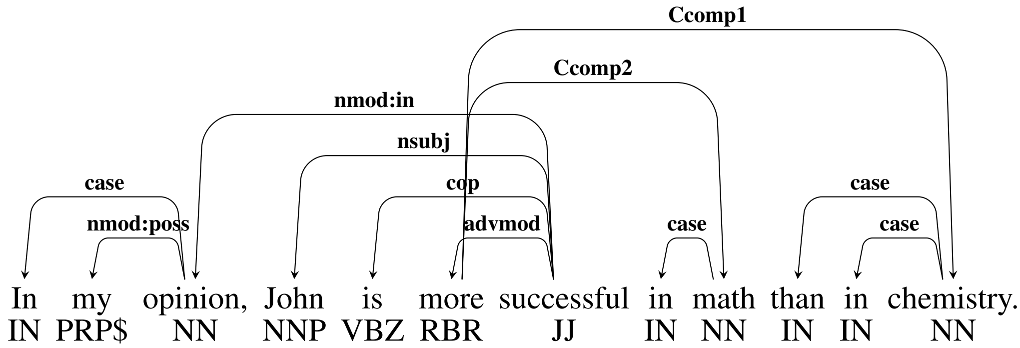
The problem of how to connect prepositional comparees is a critical one. Because even though we can extract the comparees for sentence (68a), it is not possible to differentiate whether *in my opinion* or *in math* is the comparee for sentence (68b) because both are headed by *successful* and both have the same labels (*nmod:in*).

(68) a. 

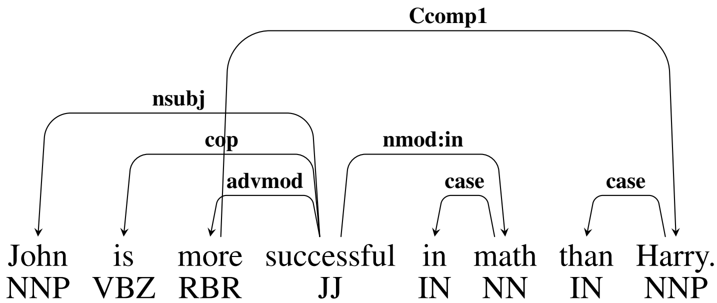
b. 

We left the prepositions as dependents by being faithful to UD, but as in the case with the comparee following *than*, we propose also to connect the second prepositional comparee to the comparative head, namely *more*, with the label *Ccomp2* referring to the *second comparative complement* and change the above parses as below.

(69) a. 

b. 

Also, an important distinction between the prepositional phrases *in math* and *in my opinion* in sentence (68b) can be demonstrated by removing them from the sentences, then checking if the remaining parts are still grammatical. Since *In my opinion, John is more successful than in chemistry* is not a grammatical sentence whereas *John is more successful in math than in chemistry* is, these two phrases must be syntactically different. The first can be regarded as an argument, on the contrary the second is an adjunct which can be dispensable. The same situation can be observed in the following sentence too. Again, *in math* is not a comparee in (70) and can be omitted without disrupting the sentence (*John is more successful than Harry*).

(70) 

5.2 Compositional Semantics

In this section we provide support from compositional semantics for the dependency structure we propose for copular comparatives.

Following Kennedy (2007), we take gradable adjectives to denote functions that map individuals to degrees on a dimension specified by the adjective. For instance, the adjective *successful* denotes a function that maps individuals to their level/degree of success.

(71) $[\![\text{successful}]\!] = \lambda x.success'(x)$ $\langle e, d\rangle$

With this adjectival semantics, the positive (i.e. non-comparative) form in (72) can be interpreted by having an abstract operator *pos*, as standard in the literature.

(72) Sally is successful.

The *pos* operator has the following interpretation:

(73) $[\![pos]\!] = \lambda a \lambda x \lambda s.ax > s$

Combining with the adjective, it gives,

(74) $[\![pos \text{ successful}]\!] = \lambda x \lambda s.success' x > s$

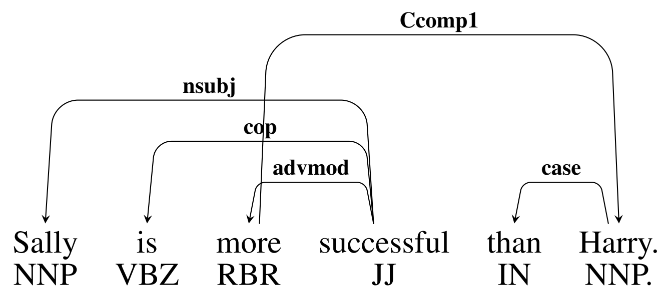
Then combining with the subject, the result is:

(75) $\lambda s.success'(sally') > s$

The argument s is saturated by the context with the standard of success, which is the contextually given level of success that a person has to pass to be considered successful. After this the meaning becomes,

(76) $success'(sally') > standard'$

Now we deal with the comparative form in (77).

(77) 

The comparative marker *than* is a type lifter, lifting a noun phrase interpretation to a function that takes an adjective interpretation and applies it to the noun phrase:

(78) $[\![\text{than}]\!] = \lambda x \lambda a.ax$ $\qquad \langle e, \langle \langle e, d \rangle, d \rangle \rangle$

With this interpretation for *than*, the expression *than Harry*, which we syntactically treat as the comparative complement (ccomp), gets the following interpretation:

(79) $[\![\text{than Harry}]\!] = \lambda a.a harry'$ $\qquad \langle \langle e, d \rangle, d \rangle$

This is a function from adjective meanings to degrees. The intuition behind this interpretation is that every individual can be treated as a function from adjectives to the degrees it possesses with regard to the input adjective. In other words, *than* turns *Harry* into a function that maps *intelligent* to Harry's degree of intelligence, *happy* to his degree of happiness, and so on.

The critical item in the present analysis is the adverbial modifier *more*, it is interpreted as follows:

(80) $[\![\text{more}]\!] = \lambda p \lambda a \lambda y . p\, a < a\, y \qquad \langle\langle\langle e,d\rangle,d\rangle,\langle\langle e,d\rangle,\langle e,t\rangle\rangle\rangle$

The idea here is that *more* first applies to a noun phrase lifted by *than*, then applies to an adjective, and then forms a predicate of type $\langle e,t\rangle$. With all these interpretations *more than Harry*, which is a discontinuous constituent in our treatment, is interpreted as:

(81) $[\![\text{more than Harry}]\!] = [\![\text{more}]\!]([\![\text{than Harry}]\!])$
$= (\lambda p \lambda a \lambda y . p\, a < a\, y)(\lambda a . a\, harry')$
$= \lambda a \lambda y . a\, harry' < a\, y$

Then this constituent, which is syntactically an adverbial modifier, applies to the adjective to give:

(82) $[\![\text{more successful than Harry}]\!] = [\![\text{more} \ldots \text{than Harry}]\!]([\![\text{successful}]\!])$
$= (\lambda a \lambda y . a\, harry' < a\, y)(\lambda x . success'(x))$
$= \lambda y . success'(harry') < success'(y)$

We get the final interpretation by applying this denotation to the subject. We omit the contribution of the copula, assuming it to be an identity function.

(83) $[\![\text{Sally is more successful than Harry}]\!] = [\![\text{is more successful than Harry}]\!]([\![\text{Sally}]\!])$
$= (\lambda y . success'(harry') < success'(y))(sally')$
$= (success'(harry') < success'(sally'))$

Now we show how the semantics of prepositional phrases can be integrated into the syntax proposed. Above we took the meaning of adjectives as simple functions mapping individuals to degrees.

(84) $[\![\text{successful}]\!] = \lambda x . success'(x) \qquad \langle e,d\rangle$

However, in this formulation the domain of success is left implicit. The sentence *Sally is successful* is meaningful only when we know the subject that Sally is successful in. Therefore we modify the meaning of the adjective as taking an extra domain argument.

(85) $[\![\text{successful}]\!] = \lambda s \lambda x . success'_s(x)$

With this meaning,

(86) Sally is successful in math.

is interpreted as follows. First, the meaning of *in math* is,

(87) $[\![\text{in math}]\!] = \lambda a.a math'$

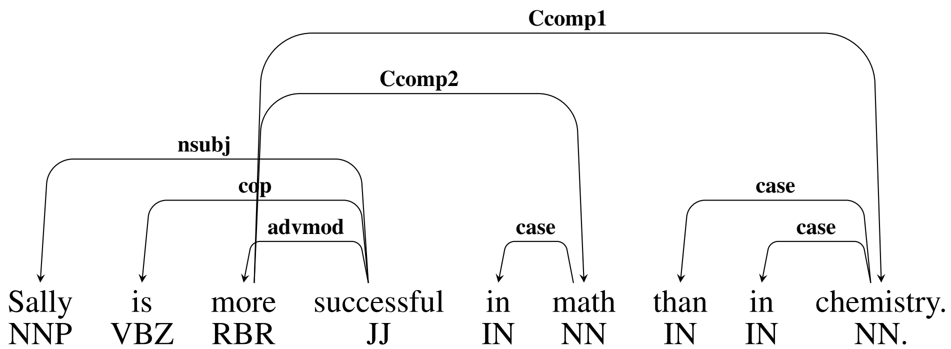
Therefore *successful in math* is interpreted as,

(88) $[\![\text{successful in math}]\!] = [\![\text{in math}]\!]([\![\text{successful}]\!])$
$= (\lambda a.a math')(\lambda s \lambda x.success'_s(x))$
$= \lambda x.success'_{math'}(x)$

In other words, we take prepositional phrases as modifiers that set the domain argument of adjectives.

Now we can take the comparative form,

(89)



We take *than* as the identity function. Therefore, *than in chemistry* is interpreted as

(90) $[\![\text{than in chemistry}]\!] = \lambda a.a chemistry'$

The comparative morpheme *more* gets the following interpretation:

(91) $[\![\text{more}]\!] = \lambda p \lambda q \lambda a \lambda x.pax > qax$

Now the task is to derive the meaning of the discontinuous constituent *more... in math than in chemistry*. First we derive *more... in math*:

(92) $[\![\text{more} \ldots \text{in math}]\!] = [\![\text{more}]\!]([\![\text{in math}]\!])$
$= (\lambda p \lambda q \lambda a \lambda x.pax > qax)(\lambda a.a math')$
$= \lambda q \lambda a \lambda x.a math' x > qax$

Now, *more* applies to its second argument, *than in chemistry*:

(93) $[\![\text{more}\ldots\text{in math than in chemistry}]\!]$
$= [\![\text{more}\ldots\text{in math}]\!]([\![\text{than in chemistry}]\!])$
$= (\lambda q \lambda a \lambda x. a\, math'\, x > q\, a\, x)(\lambda a. a\, chemistry')$
$= \lambda a \lambda x. a\, math'\, x > a\, chemistry'\, x$

This applies to the adjective *successful*:

(94) $[\![\text{more successful in math than in chemistry}]\!]$
$= [\![\text{more}\ldots\text{in math than in chemistry}]\!]([\![\text{successful}]\!])$
$= (\lambda a \lambda x. a\, math'\, x > a\, chemistry'\, x)(\lambda s \lambda x. success'_s(x))$
$= \lambda x. success'_{math'}(x) > success'_{chemistry'}(x)$

Finally, this interpretation applies to the subject to give:

(95) $[\![\text{Sally is more successful in math than in chemistry}]\!]$
$= [\![\text{is more successful in math than in chemistry}]\!]([\![\text{Sally}]\!])$
$= (\lambda x. success'_{math'}(x) > success'_{chemistry'}(x))(sally')$
$= success'_{math'}(sally') > success'_{chemistry'}(sally')$

In this section we showed that the dependency syntax proposed in the previous section can be given a compositional semantic interpretation. For this type of interpretation to be available one needs to know the lexical semantic interpretations of the nodes in the dependency tree. As these interpretations are not available, we will provide a more direct semantics where semantic interpretation is obtained directly from the dependency tree, without making a compositional semantic derivation.

5.3 Dependency Based Semantics

Analysis of comparatives involves detecting the comparees, comparative adjective, comparison frame (if any) and then assigning semantic roles to them. For the sentences which do not have prepositional phrases as comparees, we named the first comparee following *than* as 'standard' that refers to the standard of the comparison, since the comparative clause sets a standard point on the scale of dimension provided by the adjective that takes the comparative morpheme. Regarding the sentences with transitive verbs, if the auxiliary verb in the comparative clause is dropped, there are two possibilities for the second comparee: the subject or the object in the main clause. In such a sentence as (96), the standard (first comparee) is the noun phrase after *than* (*my husband*) but the second comparee might be the subject of the main clause (*I*) or the direct object of the main clause (*cockatiels*). So my love of cockatiels and my husband's love of cockatiels or my love of my husband and my love of cockatiels may be compared depending on the context. (Such an ambiguity would not be a matter, if the sentence was *I love cockatiels more than my husband does*)

(96) I love cockatiels more than my husband.

However, since we meant to only identify and analyze the copular comparatives (root *be*) and since intransitive verbs do not take direct objects, for the sentences in our dataset, there is only one possibility for the noun phrase after *than* to be compared with and it is the subject of the main clause. (Comparative sentences with prepositional comparees are discussed separately). Together with comparative adjective (the adjective with comparative morpheme), comparative clause creates a proposition which targets the subject (the second comparee), so we decided to call the second comparee as 'target'. Finally, comparative adjective reflects both a direction and dimension; for example *taller* has a dimensional feature of *tallness* and a directional feature of *more* on the scale of *tallness*. That is to say, on the scale of height, *taller* points in the direction of increasing height (superiority). If the comparative morpheme is attached to the adjective (*ADJ* + *er*, synthetic form), it always points in the increasing direction of the scale specified by the adjective (i.e *smaller* also points in the direction of increasing smallness), so the direction will always be *more*. If the comparative morpheme exists separately as *more* or *less* (*more/less* + *ADJ*, analytic form), then the direction will be that morpheme itself and the dimension will be designated by the adjective that takes the comparative morpheme. In below, some example sentences from our dataset and the regarding outputs are given to better express the discussion.

(97) a. These double-knockout mice are significantly smaller than their single-gene null parents and show much more severe muscle disease.

b.

standard:	their single-gene null parents
target:	These double-knockout mice
direction:	more
dimension:	smaller

(98) a. Our results have confirmed that global measures are better than local measures in capturing gene-gene relationships.

b.

standard:	global measures
target:	local measures
direction:	more
dimension:	better

(99) a. The results showed that our strategy was more advantageous than the hypergeometric distribution method.

b.

standard:	the hypergeometric distribution method
target:	our strategy
direction:	more
dimension:	adventageous

(100) a. Recently, it has been suggested that SC precursors may be more beneficial than SCS from newborn rodents.

b.

standard:	SCS from newborn rodents
target:	SC precursors
direction:	more
dimension:	beneficial

(101) a. Studies in rat models revealed that escitalopram was not less effective than fluoxetine in reducing withdrawal symptoms.

b.

standard:	fluoxetione
target:	escitalopram
direction:	NOT less
dimension:	effective

As can be seen in (97) and (98), if the comparative morpheme (*-er*) is attached to the adjective (synthetic form), we separately add the direction as *more* and the comparative adjective (*ADJ+er*) becomes the dimension, which should be converted to its noun form for every example (i.e *smallness* for (97)). However, as part of this thesis, we are not concerned with this job. In addition to *more*, also *NOT* is added if the verb in the main clause is in *negative* form (i.e (101)).

Regarding the prepositional comparatives, there is another element of comparison which does not exist in non-prepositional comparatives. In (102), *ERα-negative breast tumor cell lines* and *ERα-positive lines* are being compared with respect to *the expression of these genes* in them. We decided to name this element, which determines the boundaries of the comparison, as ‘frame’ and the frame of (102) is *the expression of these genes* and *hand reaction times* for (103).

(102) a. Interestingly, the expression of these genes was generally higher in ERα-negative breast tumor cell lines than in ERα-positive lines.

b.

standard:	in ERα-positive lines
target:	in ERα-negative breast tumor cell lines
frame:	the expression of these genes
direction:	more
dimension:	higher

(103) a. Hand reaction times were longer for the choice reaction time than for the simple reaction time .

b.

standard:	for the choice reaction time
target:	for the simple reaction time
frame:	Hand reaction times
direction:	more
dimension:	longer

CHAPTER 6

THE IMPLEMENTATION

6.1 Preprocessing

We randomly selected articles from PubMed Central (PMC) which is an archive of biomedical and life sciences journal literature at the U.S. National Institutes of Health's National Library of Medicine. The reason of this choice is the ease of access to numerous free full-text articles. Before we parsed sentences with Stanford dependency parser, we had identified the short forms of abbreviations in articles and turned them into their long forms by using Biotext Project Software (Schwartz & Hearst, 2002). For example, *DMD* was turned into *Duchenne muscular dystrophy* before parsing. Then, all images such as graphs or tables and all paragraphs with titles such as *Acknowledgments, Authors' contributions, Contributor Information, Corresponding Author, References, Bibliography* or *Supplementary Material* were removed from the articles since they do not contribute to the meaning of the texts.[1]

After preprocessing, we collected 300 comparative sentences from 200 articles as our dataset by dwelting on specific sentences that contains *than* clause, adjective or adverb with comparative inflection and *be* as comparative clause root (main verb).[2] We used this dataset to see what kind of structures copular comparative sentences can have and some examples from our dataset are given below to exemplify the structures that we deal with.

(104) The refluxate may *be more acidic than* the intragastric content.

(105) Results revealed that the center of pressure MV *was lower* in the frail group *than* in the control group .

(106) The time taken for the cell to arrive at the tumor must *be shorter than* the time taken for the virus to replicate in and lyse the cell.

(107) It seems counter intuitive that the protein-protein interaction *was more informative than* the pathway network.

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[1] For the code, see: https://github.com/atubakoksal/Thesis/blob/master/extracthtml.py

[2] For sentences, see: https://github.com/atubakoksal/Thesis/blob/master/pubmed300.txt

6.2 The Method

6.2.1 Syntactic Manipulation

We changed the parses outputted by Stanford CoreNLP as discussed in Section 5.1 by using a Python code.[3] The steps of the process are explained in detail below for example sentences.

(108) John is taller than Harry.

The Stanford CoreNLP's output for sentence (108) is as below (with Stanford CoreNLP toolkit annotators: tokenize, ssplit, pos, depparse).

```
Tokens:
[Text=John CharacterOffsetBegin=37 CharacterOffsetEnd=41 PartOfSpeech=NNP]
[Text=is CharacterOffsetBegin=42 CharacterOffsetEnd=44 PartOfSpeech=VBZ]
[Text=taller CharacterOffsetBegin=45 CharacterOffsetEnd=51 PartOfSpeech=JJR]
[Text=than CharacterOffsetBegin=52 CharacterOffsetEnd=56 PartOfSpeech=IN]
[Text=Harry CharacterOffsetBegin=57 CharacterOffsetEnd=62 PartOfSpeech=NNP]
[Text=. CharacterOffsetBegin=62 CharacterOffsetEnd=63 PartOfSpeech=.]

Dependency Parse (enhanced plus plus dependencies):
root(ROOT-0, taller-3)
nsubj(taller-3, John-1)
cop(taller-3, is-2)
case(Harry-5, than-4)
nmod:than(taller-3, Harry-5)
punct(taller-3, .-6)
```

Figure 6.1: Stanford CoreNLP Output for an Adjectival Comparative

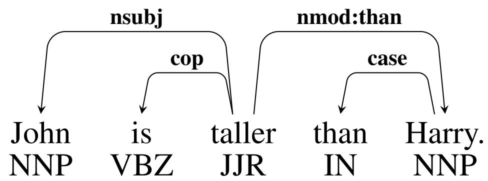
We turned this output into the following one to give it as an input to the code that will change the dependency relations in accord with our proposal.[4]

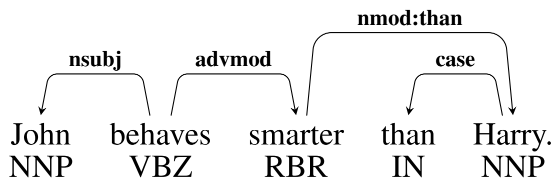
```
root(ROOT-0, taller/JJR-3)
nsubj(taller/JJR-3, John/NNP-1)
cop(taller/JJR-3, is/VBZ-2)
case(Harry/NNP-5, than/IN-4)
nmod:than(taller/JJR-3, Harry/NNP-5)
punct(taller/JJR-3, ./.-6)
```

Figure 6.2: Stanford CoreNLP Changed Output for an Adjectival Comparative

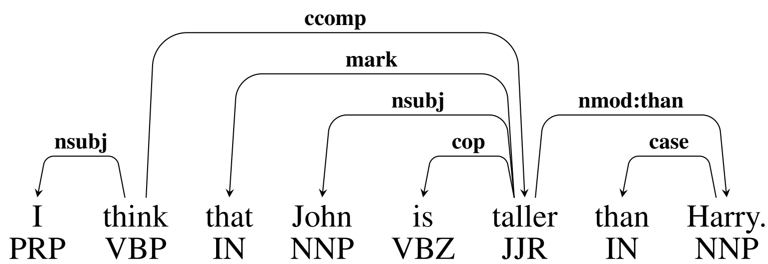
[3] For the code, see: https://github.com/atubakoksal/Thesis/blob/master/converter.py
[4] For the code, see: https://github.com/atubakoksal/Thesis/blob/master/depwithPOS.py

Before changing the parses, for each sentence we first check if it is a nominal or adjectival copular comparative. This step checks both if a sentence is comparative or not and if a sentence is nominal or adjectival comparative, at the same time. Since Stanford dependency scheme does not take copular verb (*be*) as the root of the sentence but as a dependent of the main content word in the sentence (it is the adjective or noun for our case) the copular and non-copular sentences have quite different parses regarding the verbs (aka the roots), as can be seen below. We differentiate the copular and non-copular sentences by checking if the comparison head is the root of the sentence or not.

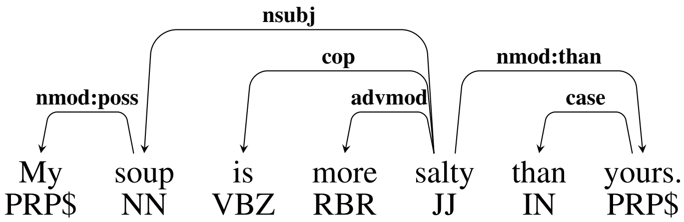
(109)


(110)


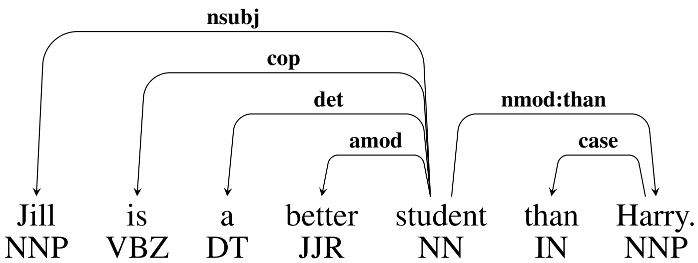
The comparison head may not be the root of the sentence as in (111), if the comparative sentence is in the complement clause. For this kind of sentences, we check if the comparison head's head is a verb and the comparison head's dependency label is *ccomp*.

(111)


To differentiate adjectival and nominal copulars, we took *than* as our anchor and after finding it, we checked if there is a token with *JJR* POS for synthetic comparatives or a *RBR* following a *JJ* for analytic comparatives above *than* node. For a synthetic case like (109), we first find *than*, then *taller* with POS *JJR* by following the head of *Harry* and conclude that it is an adjectival comparative. For an analytic case like (112), after finding *than* node, we find *salty* by *JJ* POS and finally search for *more* with *RBR* POS through the children of *salty*.

(112) 

The process is quite similar for nominal comparatives. Again, for sentence (113) we first find *than* node, then we search for a node with nominal POS tag (starting with *NN*) above it and if there is a node with POS *JJR* or *RBR* among the children of nominal node, we conclude that it is a nominal comparative.

(113) 

After deciding if an input sentence is adjectival or nominal comparative, we changed the parses according to our proposal given in Chapter 5. For each token in a sentence, we stored its children (if any) and its head while keeping all the regarding information, namely dependencies, POS tags and token ids. For example, the token *Harry* in (109) has *than* as child and *taller* as head with the regarding dependency labels and POS tags as attributes and all this information can be reached by the regarding methods. By this way, we can easily change the dependencies we aim to and also we can extract relations more easily. For sentence (109), we detach the connection between *taller* and *Harry*, add the node *more* and connect *Harry* to this newly created node. Since *than* is child of *Harry*, when we detach and connect *Harry* to a new node, *than* also comes with *Harry*. A similar approach is applied to nominal comparatives too and the resultant dependencies can be seen below.

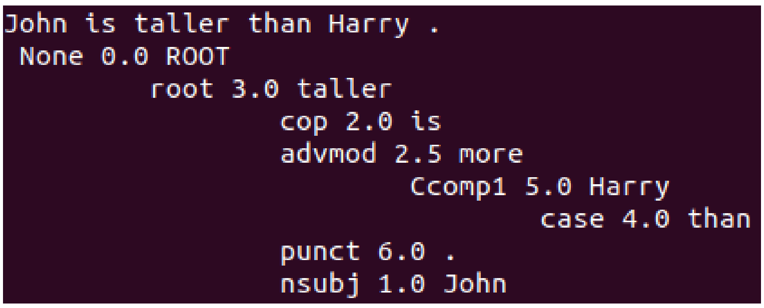
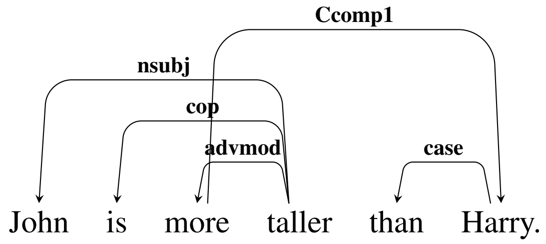

```
John is taller than Harry .
 None 0.0 ROOT
        root 3.0 taller
                cop 2.0 is
                advmod 2.5 more
                        Ccomp1 5.0 Harry
                                case 4.0 than
                punct 6.0 .
                nsubj 1.0 John
```

Figure 6.3: Our Output Parse for an Adjectival Comparative

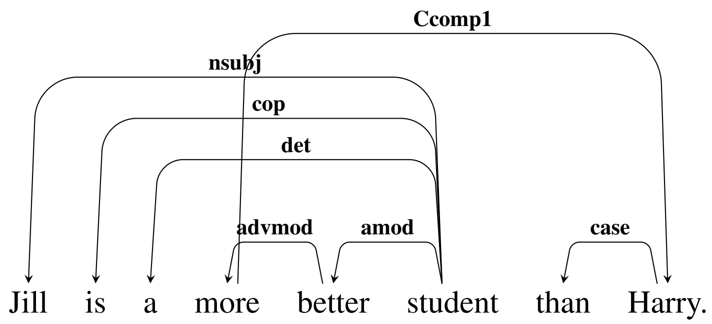
(114)




```
Jill is a better student than Harry .
 None 0.0 ROOT
         root 5.0 student
                 cop 2.0 is
                 det 3.0 a
                 amod 4.0 better
                         advmod 3.5 more
                                 Ccomp1 7.0 Harry
                                         case 6.0 than
                 punct 8.0 .
                 nsubj 1.0 Jill
```

Figure 6.4: Our Output Parse for a Nominal Comparative

(115)



A similar treatment is applied also to comparatives with prepositional comparees. Stanford CoreNLP output after merging POS tags and dependencies for sentence (116) is in below.

(116) A storm is more likely in Ankara than in İstanbul.

```
root(ROOT-0, likely/JJ-5)
det(storm/NN-2, A/DT-1)
nsubj(likely/JJ-5, storm/NN-2)
cop(likely/JJ-5, is/VBZ-3)
advmod(likely/JJ-5, more/RBR-4)
case(Ankara/NNP-7, in/IN-6)
nmod:in(likely/JJ-5, Ankara/NNP-7)
case(Istanbul/NNP-10, than/IN-8)
case(Istanbul/NNP-10, in/IN-9)
nmod:than(likely/JJ-5, Istanbul/NNP-10)
punct(likely/JJ-5, ./.-11)
```

Figure 6.5: Stanford CoreNLP Changed Output for an Adjectival Comparative with Prepositional Comparees

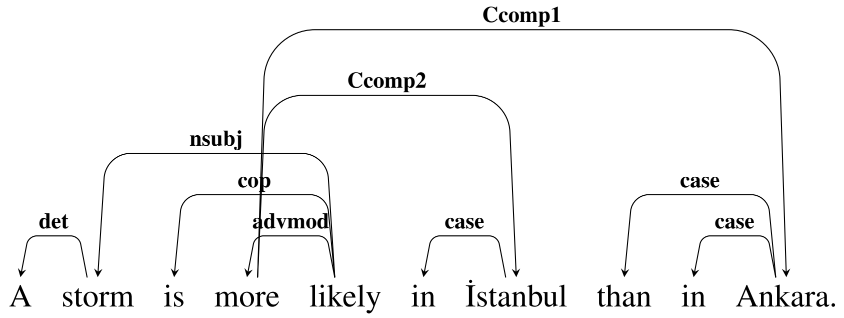
For prepositional comparees, we first check whether there is a preposition following *than* or not. If there is, then we expect a prepositional complement of the adjective, if it is an adjectival comparative, or the noun, if it is a nominal comparative. For the adjectival comparative sentence (116), after finding *than* and the following *in*, we check whether the adjective *likely* has prepositional complements other than *than*. In this case it has only one which is *in Ankara* and it is the second comparee we searched for. If there is more than one prepositional complement of the adjective as in (117), then we take the complement which is the closest antecedent of *than* as the second comparee.

(117) In my opinion, a storm is more likely in Ankara than in İstanbul.

After deciding that the sentence is a comparative sentence with prepositional comparees, we change the sentence as represented by the below figure. We connect *İstanbul* and *Ankara* to *more* node and meanwhile the prepositions headed by them are also connected to *more*.

```
A storm is more likely in Ankara than in Istanbul .
 None 0.0 ROOT
        root 5.0 likely
                cop 3.0 is
                advmod 4.0 more
                        Ccomp1 10.0 Istanbul
                                case 9.0 in
                                case 8.0 than
                        Ccomp2 7.0 Ankara
                                case 6.0 in
                punct 11.0 .
                nsubj 2.0 storm
                        det 1.0 A
```

Figure 6.6: Our Output Parse for an Adjectival Comparative with Prepositional Comparees

(118) 

The process is the same for the nominals with prepositional comparees. We again, first find *of* following *than* and check for an *of* preceding it in (119).

(119) She is a better player of chess than of bridge.

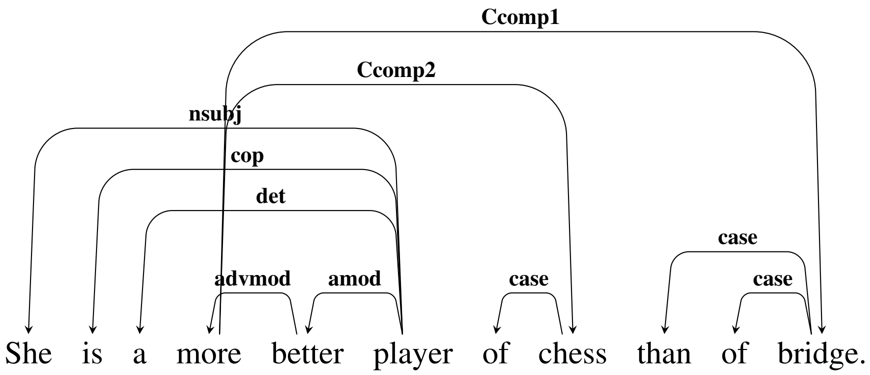
```
root(ROOT-0, player/NN-5)
nsubj(player/NN-5, She/PRP-1)
cop(player/NN-5, is/VBZ-2)
det(player/NN-5, a/DT-3)
amod(player/NN-5, better/JJR-4)
case(chess/NN-7, of/IN-6)
nmod:of(player/NN-5, chess/NN-7)
case(bridge/NN-10, than/IN-8)
case(bridge/NN-10, of/IN-9)
nmod:of(player/NN-5, bridge/NN-10)
punct(player/NN-5, ./.-11)
```

Figure 6.7: Stanford CoreNLP Changed Output for a Nominal Comparative Prepositional Comparees

When the sentence matches with the pattern we mentioned, we change the head of the comparative clause and the second comparee with newly added node *more* as below.

```
She is a better player of chess than of bridge .
 None 0.0 ROOT
        root 5.0 player
                cop 2.0 is
                det 3.0 a
                amod 4.0 better
                        advmod 3.5 more
                                Ccomp1 10.0 bridge
                                        case 9.0 of
                                        case 8.0 than
                                Ccomp2 7.0 chess
                                        case 6.0 of
                punct 11.0 .
                nsubj 1.0 She
```

Figure 6.8: Our Output Parse for a Nominal Comparative with Prepositional Comparees

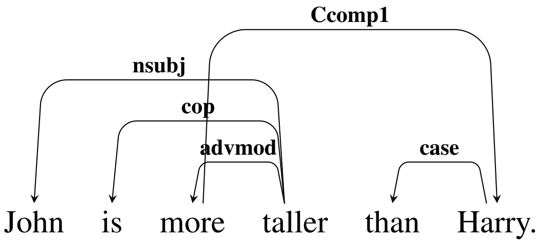
(120)


6.2.2 Semantic Interpretation

The final step of the implementation process is extracting the components of comparison and assigning semantic roles to them.[5] For an adjectival comparative sentence with nominal comparees like (121), we extract *Harry* as 'standard', *John* as 'target', *taller* as 'dimension' and *more* as 'direction'. We first find externally added *more* node for synthetic comparatives or already existing *more* node for analytic comparatives and label it as direction. By following *Ccomp1* edge from *more* node, we reach the standard of comparison. The head of *more* node is the dimension and the target is connected by *nsubj* relation to this head. The only difference in the extraction process for the nominal comparative sentences with non-prepositional comparees as (122) is the head of the head of *more* node is a nominal with adjectival modifier, and together they constitute the dimension (i.e *better student*). The final output of the code for nominal and adjectival comparatives with non-prepositional comparees can be seen in below.

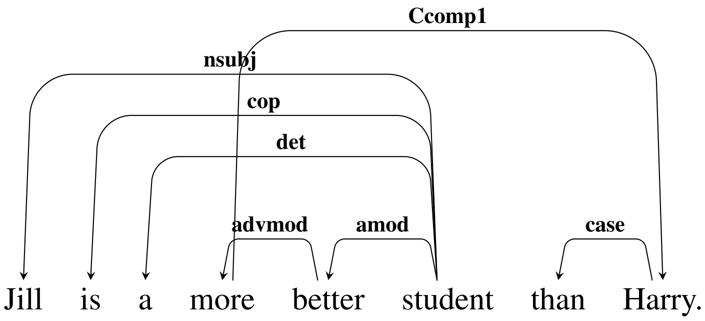
(121) a. John is more taller than Harry.

[5] For the code, see: https://github.com/atubakoksal/Thesis/blob/master/semantics.py

b. 

c.
standard: John
target: Harry
direction: more
dimension: taller

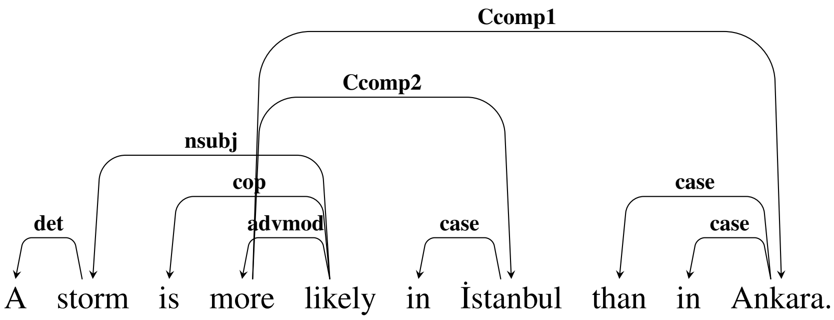
(122) a. John is a more better student than Harry.

b. 

c.
standard: Harry
target: Jill
direction: more
dimension: better student

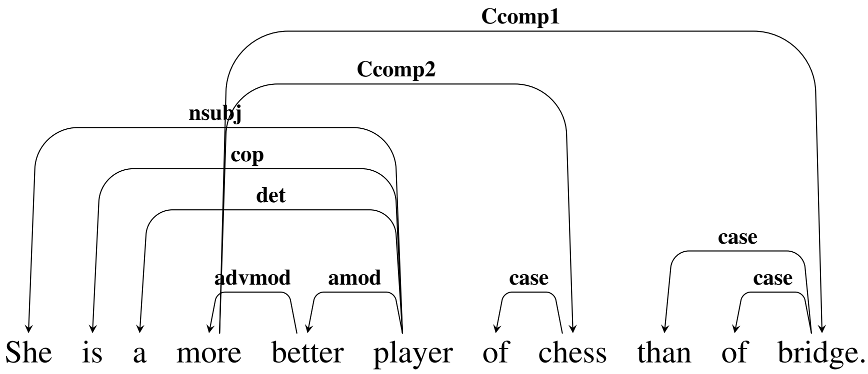
For the comparatives with prepositional comparees like (123) and (124), again we first find *more* node, then follow *Ccomp1* edge to find standard. The second comparee can be found by following the *Ccomp2* edge from *more*. This time *nsubj* edge directs us to the 'frame' of the comparison. The outputs for sentences (123) and (124) are in below.

(123) a. A storm is more likely in Ankara than in İstanbul.

b. 

standard: in Ankara
target: in Istanbul
c. frame: A storm
direction: more
dimension: likely

(124) a. She is a more better player of chess than of bridge.

b. 

standard: of bridge
target: of chess
c. frame: She
direction: more
dimension: better player

In Appendix A, we gave more example outputs of our code for both invented and PubMed sentences.

CHAPTER 7

CONCLUSION

As mentioned in Chapter 1, with the advances in the development of dependency-annotated corpora and dependency parsers, the dependency grammar became a formalism with wide practical application in natural language processing and computational linguistics. Also, since dependency representation provides direct connections between predicates and arguments, it is more suitable for semantic extraction purposes. The Stanford Dependencies and the following Universal Dependencies are good and widely used representatives of this formalism.

However, there are some constructions that the Stanford dependency scheme remains underdeveloped and one such construction is the comparative constructions (de Marneffe et al., 2013). We discussed and proposed a dependency representation for copular comparatives in their interaction with prepositional phrases.

We chose comparatives because they are widely used in language and rich in information content, so extracting the components of comparison will be useful in many applications of language. Sapir (1944) remarks that all languages have syntactic categories to express gradable concepts with designated comparative constructions. As a result, the importance of the study of the comparatives is not limited to English but is realized also across other languages.

In proposing a dependency syntax for comparatives we considered syntactic issues and we also wanted to have a dependency structure that will provide the right semantics. We supported our syntactic analysis by showing that it is suitable for a compositional semantic interpretation. Compositional semantics requires to know the semantic interpretations of lexical items. Since that information is not available at the current stage, we did not implement the compositional semantics on a wide scale. We instead proposed a semantics that is directly based on the dependency structure.

For implementation task, we wrote a program that transforms the dependency output of the Stanford Parser to our proposed syntax; and we wrote a program that interprets these dependency structures according to the semantics we proposed. We tested our program with invented sentences and also sample sentences from PubMed articles, both of which are given in Appendix A.

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Appendix A

SAMPLE SENTENCES AND REGARDING OUTPUTS

A.1 PubMed Sentences

The refluxate may be more acidic than the intragastric content.

```
None 0.0 ROOT
  root 6.0 acidic
    aux 3.0 may
    cop 4.0 be
    advmod 5.0 more
      Ccomp1 10.0 content
      det 8.0 the
      amod 9.0 intragastric
      case 7.0 than
    punct 11.0 .
    nsubj 2.0 refluxate
      det 1.0 The
```

{’standard’: ’the intragastric content’, ’target’: ’The refluxate’, ’dimension’: ’acidic’, ’direction’: ’more’}

Body mass index was significantly lower in the laparoscopic Nissen fundoplication group than in the PPI group.

```
None 0.0 ROOT
  root 6.0 lower
    cop 4.0 was
    advmod 5.0 significantly
    advmod 5.5 more
      Ccomp1 17.0 group
        case 14.0 in
        det 15.0 the
        compound 16.0 PPI
        case 13.0 than
      Ccomp2 12.0 group
        det 8.0 the
```

```
                amod 9.0 laparoscopic
                compound 10.0 Nissen
                compound 11.0 fundoplication
                case 7.0 in
    punct 18.0 .
    nsubj 3.0 index
            compound 2.0 mass
            compound 1.0 Body
```

{'standard': 'in the PPI group', 'target': 'in the laparoscopic Nissen fundoplication group', 'frame:': 'Body mass index', 'dimension': 'lower', 'direction': 'more'}

By doing so, the number of disease genes per family will be much greater than the number of genes per disease.

```
None 0.0 ROOT
    root 15.0 greater
        punct 4.0 ,
        nsubj 6.0 number
            nmod:of 9.0 genes
                compound 8.0 disease
                nmod:per 11.0 family
                    case 10.0 per
                case 7.0 of
            det 5.0 the
        aux 12.0 will
        cop 13.0 be
        advmod 14.0 much
        advmod 14.5 more
            Ccomp1 18.0 number
                det 17.0 the
                nmod:of 20.0 genes
                    nmod:per 22.0 disease
                        case 21.0 per
                    case 19.0 of
                case 16.0 than
        punct 23.0 .
        advcl:by 2.0 doing
            advmod 3.0 so
            mark 1.0 By
```

{'standard': 'the number of genes per disease', 'target': 'the number of disease genes per family', 'dimension': 'greater', 'direction': 'more'}

It seems counter intuitive that the protein-protein interaction was more informative than the pathway network.

```
None 0.0 ROOT
    root 2.0 seems
        xcomp 4.0 intuitive
            advmod 3.0 counter
        ccomp 11.0 informative
            nsubj 8.0 interaction
                amod 7.0 protein-protein
                det 6.0 the
            cop 9.0 was
            advmod 10.0 more
                Ccomp1 15.0 network
                    det 13.0 the
                    compound 14.0 pathway
                    case 12.0 than
             5.0 that
        punct 16.0 .
        nsubj 1.0 It
```

{’standard’: ’the pathway network’, ’target’: ’the protein-protein interaction’, ’dimension’: ’informative’, ’direction’: ’more’}

It was found that quality of protein interaction data was more important than its volume.

```
None 0.0 ROOT
    root 3.0 found
        auxpass 2.0 was
        ccomp 12.0 important
            nsubj 5.0 quality
                nmod:of 9.0 data
                    compound 7.0 protein
                    compound 8.0 interaction
                    case 6.0 of
            cop 10.0 was
            advmod 11.0 more
                Ccomp1 15.0 volume
                    nmod:poss 14.0 its
                    case 13.0 than
            mark 4.0 that
        punct 16.0 .
        nsubjpass 1.0 It
```

{’standard’: ’its volume’, ’target’: ’quality of protein interaction data’, ’dimension’: ’important’, ’direction’: ’more’}

The fatality of suicide attempts is also higher in bd than in the general population.

None 0.0 ROOT
    root 8.0 higher
        cop 6.0 is
        advmod 7.0 also
        advmod 7.5 more
            Ccomp1 15.0 population
                case 12.0 in
                det 13.0 the
                amod 14.0 general
                case 11.0 than
            Ccomp2 10.0 bd
                case 9.0 in
        punct 16.0 .
        nsubj 2.0 fatality
            nmod:of 5.0 attempts
                compound 4.0 suicide
                case 3.0 of
            det 1.0 The

{'standard': 'in the general population', 'target': 'in bd', 'frame:': 'The fatality of suicide attempts', 'dimension': 'higher', 'direction': 'more'}

The results showed that our strategy was more advantageous than the hypergeometric distribution method.

None 0.0 ROOT
    root 3.0 showed
        ccomp 9.0 advantageous
            nsubj 6.0 strategy
                nmod:poss 5.0 our
            cop 7.0 was
            advmod 8.0 more
                Ccomp1 14.0 method
                    det 11.0 the
                    amod 12.0 hypergeometric
                    compound 13.0 distribution
                    case 10.0 than
            mark 4.0 that
        punct 15.0 .
        nsubj 2.0 results
            det 1.0 The

{'standard': 'the hypergeometric distribution method', 'target': 'our strategy', 'dimension': 'advantageous', 'direction': 'more'}

Recently , it has been suggested that sc precursors may be more beneficial than scs from newborn rodents.

```
None 0.0 ROOT
    root 6.0 suggested
        punct 2.0 ,
        nsubjpass 3.0 it
        aux 4.0 has
        auxpass 5.0 been
        ccomp 13.0 beneficial
            nsubj 9.0 precursors
                compound 8.0 sc
            aux 10.0 may
            cop 11.0 be
            advmod 12.0 more
                Ccomp1 15.0 scs
                    nmod:from 18.0 rodents
                        amod 17.0 newborn
                        case 16.0 from
                    case 14.0 than
            mark 7.0 that
        punct 19.0 .
        advmod 1.0 Recently
```

{’standard’: ’scs from newborn rodents’, ’target’: ’sc precursors’, ’dimension’: ’beneficial’, ’direction’: ’more’}

These estimates of efficacy are more conservative than those reported in a previous review.

```
None 0.0 ROOT
    root 7.0 conservative
        cop 5.0 are
        advmod 6.0 more
            Ccomp1 9.0 those
                acl 10.0 reported
                    nmod:in 14.0 review
                    det 12.0 a
                    amod 13.0 previous
                    case 11.0 in
            case 8.0 than
        punct 15.0 .
        nsubj 2.0 estimates
            nmod:of 4.0 efficacy
                case 3.0 of
            det 1.0 These
```

{’standard’: ’those reported in a previous review’, ’target’: ’These estimates of efficacy’, ’dimension’: ’conservative’, ’direction’: ’more’}

The size of the gap in the cord is also larger at this stage than at all other stages.

```
None 0.0 ROOT
    root 11.0 larger
        cop 9.0 is
        advmod 10.0 also
        advmod 10.5 more
            Ccomp1 19.0 stages
                case 16.0 at
                det 17.0 all
                amod 18.0 other
                case 15.0 than
            Ccomp2 14.0 stage
                det 13.0 this
                case 12.0 at
        punct 20.0 .
        nsubj 2.0 size
            nmod:of 5.0 gap
                det 4.0 the
                nmod:in 8.0 cord
                    det 7.0 the
                    case 6.0 in
                case 3.0 of
            det 1.0 The
```

{’standard’: ’at all other stages’, ’target’: ’at this stage’, ’frame:’: ’The size of the gap in the cord’, ’dimension’: ’larger’, ’direction’: ’more’}

Studies in rat models revealed that escitalopram was less effective than fluoxetine in reducing withdrawal symptoms.

```
None 0.0 ROOT
    root 5.0 revealed
        ccomp 10.0 effective
            nsubj 7.0 escitalopram
            cop 8.0 was
            advmod 9.0 less
                Ccomp1 12.0 fluoxetine
                    case 11.0 than
            advcl:in 14.0 reducing
                dobj 16.0 symptoms
                    compound 15.0 withdrawal
                mark 13.0 in
            mark 6.0 that
        punct 17.0 .
        nsubj 1.0 Studies
            nmod:in 4.0 models
                compound 3.0 rat
```

        case 2.0 in

{’standard’: ’fluoxetine’, ’target’: ’escitalopram’, ’dimension’: ’effective’, ’direction’: ’less’}

The 325 distal reflux episodes were significantly more frequent than the 58 proximal ones.

None 0.0 ROOT
  root 9.0 frequent
    cop 6.0 were
    advmod 7.0 significantly
    advmod 8.0 more
      Ccomp1 14.0 ones
        det 11.0 the
        nummod 12.0 58
        amod 13.0 proximal
        case 10.0 than
    punct 15.0 .
    nsubj 5.0 episodes
      nummod 2.0 325
      amod 3.0 distal
      compound 4.0 reflux
      det 1.0 The

{’standard’: ’the 58 proximal ones’, ’target’: ’The 325 distal reflux episodes’, ’dimension’: ’frequent’, ’direction’: ’more’}

No Web site was statistically better than the condition average for childhood asthma and obesity obesity.

None 0.0 ROOT
  root 6.0 better
    cop 4.0 was
      advmod 5.0 statistically
      advmod 5.5 more
        Ccomp1 10.0 average
          det 8.0 the
          compound 9.0 condition
          nmod:for 13.0 asthma
            compound 12.0 childhood
            cc 14.0 and
            conj:and 15.0 obesity
            case 11.0 for
          conj:and 15.0 obesity
          case 7.0 than
    punct 16.0 .

```
        nsubj 3.0 site
            compound 2.0 Web
            neg 1.0 No
```

{’standard’: ’the condition average for childhood asthma and obesity obesity’, ’target’: ’No Web site’, ’dimension’: ’better’, ’direction’: ’more’}

Overall , exacerbations were more prevalent than community-acquired pneumonia.

```
None 0.0 ROOT
    root 6.0 prevalent
        punct 2.0 ,
        nsubj 3.0 exacerbations
        cop 4.0 were
        advmod 5.0 more
            Ccomp1 9.0 pneumonia
            amod 8.0 community-acquired
            case 7.0 than
        punct 10.0 .
        advmod 1.0 Overall
```

{’standard’: ’community-acquired pneumonia’, ’target’: ’exacerbations’, ’dimension’: ’prevalent’, ’direction’: ’more’}

However , the percentage of women having non-erosive reflux disease was higher than that of men having non-erosive reflux disease.

```
None 0.0 ROOT
    root 12.0 higher
        punct 2.0 ,
        nsubj 4.0 percentage
            nmod:of 6.0 women
                acl 7.0 having
                    dobj 10.0 disease
                        compound 9.0 reflux
                        amod 8.0 non-erosive
                case 5.0 of
            det 3.0 the
        cop 11.0 was
        advmod 11.5 more
            Ccomp1 14.0 that
                nmod:of 16.0 men
                    acl 17.0 having
                        dobj 20.0 disease
                            compound 19.0 reflux
                            amod 18.0 non-erosive
                    case 15.0 of
                case 13.0 than
        punct 21.0 .
```

```
    advmod 1.0 However
```

{’standard’: ’that of men having non-erosive reflux disease’, ’target’: ’the percentage of women having non-erosive reflux disease’, ’dimension’: ’higher’, ’direction’: ’more’}

A.2 Invented Sentences

Jill is more competent in badminton than Harry.

```
None 0.0 ROOT
  root 4.0 competent
    cop 2.0 is
    advmod 3.0 more
      Ccomp1 8.0 Harry
        case 7.0 than
    nmod:in 6.0 badminton
      case 5.0 in
    punct 9.0 .
    nsubj 1.0 Jill
```

{’standard’: ’Harry’, ’target’: ’Jill’, ’dimension’: ’competent’, ’direction’: ’more’}

Who can imagine that I think John is more intelligent than Harry?

```
None 0.0 ROOT
  root 3.0 imagine
    aux 2.0 can
    ccomp 6.0 think
      nsubj 5.0 I
      ccomp 10.0 intelligent
        cop 8.0 is
        advmod 9.0 more
          Ccomp1 12.0 Harry
            case 11.0 than
        nsubj 7.0 John
      mark 4.0 that
    punct 13.0 ?
    nsubj 1.0 Who
```

{’standard’: ’Harry’, ’target’: ’John’, ’dimension’: ’intelligent’, ’direction’: ’more’}

John is more intelligent than Harry.

```
None 0.0 ROOT
    root 4.0 intelligent
        cop 2.0 is
        advmod 3.0 more
            Ccomp1 6.0 Harry
                case 5.0 than
        punct 7.0 .
        nsubj 1.0 John
```

{’standard’: ’Harry’, ’target’: ’John’, ’dimension’: ’intelligent’, ’direction’: ’more’}

John is taller than Harry.

```
None 0.0 ROOT
    root 3.0 taller
        cop 2.0 is
        advmod 2.5 more
            Ccomp1 5.0 Harry
                case 4.0 than
        punct 6.0 .
        nsubj 1.0 John
```

{’standard’: ’Harry’, ’target’: ’John’, ’dimension’: ’taller’, ’direction’: ’more’}

John was wiser in chess than in mess.

```
None 0.0 ROOT
    root 3.0 wiser
        cop 2.0 was
        advmod 2.5 more
            Ccomp1 8.0 mess
                case 7.0 in
                case 6.0 than
            Ccomp2 5.0 chess
                case 4.0 in
        punct 9.0 .
        nsubj 1.0 John
```

{’standard’: ’in mess’, ’target’: ’in chess’, ’frame:’: ’John’, ’dimension’: ’wiser’, ’direction’: ’more’}

John had been quicker in chess than in mess.

```
None 0.0 ROOT
    root 4.0 quicker
```

aux 2.0 had
cop 3.0 been
advmod 3.5 more
Ccomp1 9.0 mess
case 8.0 in
case 7.0 than
Ccomp2 6.0 chess
case 5.0 in
punct 10.0 .
nsubj 1.0 John

{'standard': 'in mess', 'target': 'in chess', 'frame:': 'John', 'dimension': 'quicker', 'direction': 'more'}

John is more skillful in chess than in mess.

None 0.0 ROOT
root 4.0 skillful
cop 2.0 is
advmod 3.0 more
Ccomp1 9.0 mess
case 8.0 in
case 7.0 than
Ccomp2 6.0 chess
case 5.0 in
punct 10.0 .
nsubj 1.0 John

{'standard': 'in mess', 'target': 'in chess', 'frame:': 'John', 'dimension': 'skillful', 'direction': 'more'}

Smoking is more dangerous in cancer patients than in flu patients.

None 0.0 ROOT
root 4.0 dangerous
cop 2.0 is
advmod 3.0 more
Ccomp1 11.0 patients
case 9.0 in
compound 10.0 flu
case 8.0 than
Ccomp2 7.0 patients
compound 6.0 cancer
case 5.0 in
punct 12.0 .
nsubj 1.0 Smoking

{'standard': 'in flu patients', 'target': 'in cancer patients', 'frame:': 'Smoking', 'dimension': 'dangerous', 'direction': 'more'}

Jill is taller than her twin sister.

```
None 0.0 ROOT
    root 3.0 taller
        cop 2.0 is
        advmod 2.5 more
            Ccomp1 7.0 sister
                nmod:poss 5.0 her
                compound 6.0 twin
                case 4.0 than
        punct 8.0 .
        nsubj 1.0 Jill
```

{'standard': 'her twin sister', 'target': 'Jill', 'dimension': 'taller', 'direction': 'more'}

Serious adverse events were more common with Gabapentin than with placebo.

```
None 0.0 ROOT
    root 6.0 common
        cop 4.0 were
        advmod 5.0 more
            Ccomp1 11.0 placebo
                case 10.0 with
                case 9.0 than
            Ccomp2 8.0 Gabapentin
                case 7.0 with
        punct 12.0 .
        nsubj 3.0 events
            amod 2.0 adverse
            amod 1.0 Serious
```

{'standard': 'with placebo', 'target': 'with Gabapentin', 'frame:': 'Serious adverse events', 'dimension': 'common', 'direction': 'more'}

Positive effects were more common with Gabapentin than side effects.

```
None 0.0 ROOT
    root 5.0 common
        cop 3.0 were
        advmod 4.0 more
            Ccomp1 10.0 effects
                amod 9.0 side
                case 8.0 than
```

```
        nmod:with 7.0 Gabapentin
            case 6.0 with
        punct 11.0 .
        nsubj 2.0 effects
            amod 1.0 Positive
```

{’standard’: ’side effects’, ’target’: ’Positive effects’, ’dimension’: ’common’, ’direction’: ’more’}

In New York , thunderstorm is more likely than in Boston.

```
None 0.0 ROOT
    root 8.0 likely
        punct 4.0 ,
        nsubj 5.0 thunderstorm
        cop 6.0 is
        advmod 7.0 more
            Ccomp1 11.0 Boston
                case 10.0 in
                case 9.0 than
            Ccomp2 3.0 York
                compound 2.0 New
                case 1.0 In
        punct 12.0 .
```

{’standard’: ’in Boston’, ’target’: ’In New York’, ’frame:’: ’thunderstorm’, ’dimension’: ’likely’, ’direction’: ’more’}

In New York , thunderstorm is more likely in winter than in summer.

```
None 0.0 ROOT
    root 8.0 likely
        punct 4.0 ,
        nsubj 5.0 thunderstorm
        cop 6.0 is
        advmod 7.0 more
            Ccomp1 13.0 summer
                case 12.0 in
                case 11.0 than
            Ccomp2 10.0 winter
                case 9.0 in
        punct 14.0 .
        nmod:in 3.0 York
            compound 2.0 New
            case 1.0 In
```

{’standard’: ’in summer’, ’target’: ’in winter’, ’frame:’: ’thunderstorm’, ’dimension’:

'likely', 'direction': 'more'}

She is more talented in this field than him.

```
None 0.0 ROOT
    root 4.0 talented
        cop 2.0 is
        advmod 3.0 more
            Ccomp1 9.0 him
                case 8.0 than
        nmod:in 7.0 field
            det 6.0 this
            case 5.0 in
        punct 10.0 .
        nsubj 1.0 She
```

{'standard': 'him', 'target': 'She', 'dimension': 'talented', 'direction': 'more'}

In summer , thunderstorm is more likely than in winter.

```
None 0.0 ROOT
    root 7.0 likely
        punct 3.0 ,
        nsubj 4.0 thunderstorm
        cop 5.0 is
        advmod 6.0 more
            Ccomp1 10.0 winter
                case 9.0 in
                case 8.0 than
            Ccomp2 2.0 summer
                case 1.0 In
        punct 11.0 .
```

{'standard': 'in winter', 'target': 'In summer', 'frame:': 'thunderstorm', 'dimension': 'likely', 'direction': 'more'}

In chess , John was wiser than in mess.

```
None 0.0 ROOT
    root 6.0 wiser
        punct 3.0 ,
        nsubj 4.0 John
        cop 5.0 was
        advmod 5.5 more
            Ccomp1 9.0 mess
                case 8.0 in
```

```
            case 7.0 than
        Ccomp2 2.0 chess
            case 1.0 In
    punct 10.0 .
```

{'standard': 'in mess', 'target': 'In chess', 'frame:': 'John', 'dimension': 'wiser', 'direction': 'more'}

John is not much taller than Harry.

```
None 0.0 ROOT
  root 5.0 taller
    cop 2.0 is
    neg 3.0 not
    advmod 4.0 much
    advmod 4.5 more
        Ccomp1 7.0 Harry
            case 6.0 than
    punct 8.0 .
    nsubj 1.0 John
```

{'standard': 'Harry', 'target': 'John', 'dimension': 'taller', 'direction': 'NOT more'}

A storm is not much more likely in Ankara than in Istanbul.

```
None 0.0 ROOT
  root 7.0 likely
    cop 3.0 is
    neg 4.0 not
    advmod 6.0 more
        Ccomp2 9.0 Ankara
            case 8.0 in
        Ccomp1 12.0 Istanbul
            case 11.0 in
            case 10.0 than
        advmod 5.0 much
    punct 13.0 .
    nsubj 2.0 storm
        det 1.0 A
```

{'standard': 'in Istanbul', 'target': 'in Ankara', 'frame:': 'A storm', 'dimension': 'likely', 'direction': 'NOT more'}

John is less tall than Harry.

```
None 0.0 ROOT
```

```
    root 4.0 tall
        cop 2.0 is
        advmod 3.0 less
            Ccomp1 6.0 Harry
                case 5.0 than
        punct 7.0 .
        nsubj 1.0 John
```

{’standard’: ’Harry’, ’target’: ’John’, ’dimension’: ’tall’, ’direction’: ’less’}

John is not less tall than Harry.

```
None 0.0 ROOT
    root 5.0 tall
        cop 2.0 is
        neg 3.0 not
        advmod 4.0 less
            Ccomp1 7.0 Harry
                case 6.0 than
        punct 8.0 .
        nsubj 1.0 John
```

{’standard’: ’Harry’, ’target’: ’John’, ’dimension’: ’tall’, ’direction’: ’NOT less’}

I think that John is taller than Harry.

```
None 0.0 ROOT
    root 2.0 think
        ccomp 6.0 taller
            nsubj 4.0 John
            cop 5.0 is
            advmod 5.5 more
                Ccomp1 8.0 Harry
                    case 7.0 than
            mark 3.0 that
        punct 9.0 .
        nsubj 1.0 I
```

{’standard’: ’Harry’, ’target’: ’John’, ’dimension’: ’taller’, ’direction’: ’more’}

I think that John is more intelligent in chess than in bridge.

```
None 0.0 ROOT
    root 2.0 think
        ccomp 7.0 intelligent
            nsubj 4.0 John
```

cop 5.0 is
advmod 6.0 more
Ccomp1 12.0 bridge
case 11.0 in
case 10.0 than
Ccomp2 9.0 chess
case 8.0 in
mark 3.0 that
punct 13.0 .
nsubj 1.0 I

{'standard': 'in bridge', 'target': 'in chess', 'frame:': 'John', 'dimension': 'intelligent', 'direction': 'more'}

I think that John is not much more intelligent in chess than in bridge.

None 0.0 ROOT
root 2.0 think
ccomp 9.0 intelligent
nsubj 4.0 John
cop 5.0 is
neg 6.0 not
advmod 8.0 more
Ccomp2 11.0 chess
case 10.0 in
Ccomp1 14.0 bridge
case 13.0 in
case 12.0 than
advmod 7.0 much
mark 3.0 that
punct 15.0 .
nsubj 1.0 I

{'standard': 'in bridge', 'target': 'in chess', 'frame:': 'John', 'dimension': 'intelligent', 'direction': 'NOT more'}

Jill is a better student in chess than in bridge.

None 0.0 ROOT

root 5.0 student
cop 2.0 is
det 3.0 a
amod 4.0 better
advmod 3.5 more
Ccomp1 10.0 bridge
case 9.0 in
case 8.0 than
Ccomp2 7.0 chess

```
            case 6.0 in
    punct 11.0 .
    nsubj 1.0 Jill
```

{'standard': 'in bridge', 'target': 'in chess', 'frame:': 'Jill', 'dimension': 'better student', 'direction': 'more'}

Jill is a better student than Harry.

```
None 0.0 ROOT
  root 5.0 student
    cop 2.0 is
    det 3.0 a
    amod 4.0 better
      advmod 3.5 more
        Ccomp1 7.0 Harry
          case 6.0 than
    punct 8.0 .
    nsubj 1.0 Jill
```

{'standard': 'Harry', 'target': 'Jill', 'dimension': 'better student', 'direction': 'more'}

Jill is not a much better student than Harry.

```
None 0.0 ROOT
  root 7.0 student
    cop 2.0 is
    neg 3.0 not
    det 4.0 a
    amod 6.0 better
      advmod 5.5 more
        Ccomp1 9.0 Harry
          case 8.0 than
      advmod 5.0 much
    punct 10.0 .
    nsubj 1.0 Jill
```

{'standard': 'Harry', 'target': 'Jill', 'dimension': 'better student', 'direction': 'NOT more'}

Jill is a more intelligent student than Harry.

```
None 0.0 ROOT
  root 6.0 student
    cop 2.0 is
    det 3.0 a
```

```
        amod 5.0 intelligent
            advmod 4.0 more
                Ccomp1 8.0 Harry
                    case 7.0 than
        punct 9.0 .
        nsubj 1.0 Jill
```

{'standard': 'Harry', 'target': 'Jill', 'dimension': 'intelligent student', 'direction': 'more'}

Jill is a more intelligent student in chess than Harry.

```
None 0.0 ROOT
    root 6.0 student
        cop 2.0 is
        det 3.0 a
        amod 5.0 intelligent
            advmod 4.0 more
                Ccomp1 10.0 Harry
                    case 9.0 than
        nmod:in 8.0 chess
            case 7.0 in
        punct 11.0 .
        nsubj 1.0 Jill
```

{'standard': 'Harry', 'target': 'Jill', 'dimension': 'intelligent student', 'direction': 'more'}

Jill is not a much more intelligent student in chess than Harry.

```
None 0.0 ROOT
    root 8.0 student
        cop 2.0 is
        neg 3.0 not
        det 4.0 a
        amod 7.0 intelligent
            advmod 6.0 more
                Ccomp1 12.0 Harry
                    case 11.0 than
                advmod 5.0 much
        nmod:in 10.0 chess
            case 9.0 in
        punct 13.0 .
        nsubj 1.0 Jill
```

{'standard': 'Harry', 'target': 'Jill', 'dimension': 'intelligent student', 'direction': 'NOT more'}

She is a better player of chess than of bridge.

```
None 0.0 ROOT
    root 5.0 player
        cop 2.0 is
        det 3.0 a
        amod 4.0 better
            advmod 3.5 more
                Ccomp1 10.0 bridge
                    case 9.0 of
                    case 8.0 than
            Ccomp2 7.0 chess
                case 6.0 of
        punct 11.0 .
        nsubj 1.0 She
```

{’standard’: ’of bridge’, ’target’: ’of chess’, ’frame:’: ’She’, ’dimension’: ’better player’, ’direction’: ’more’}

In my opinion , John is a better player of tennis than of badminton.

```
None 0.0 ROOT
    root 9.0 player
        punct 4.0 ,
        nsubj 5.0 John
        cop 6.0 is
        det 7.0 a
        amod 8.0 better
            advmod 7.5 more
                Ccomp1 14.0 badminton
                    case 13.0 of
                    case 12.0 than
                Ccomp2 11.0 tennis
                    case 10.0 of
        punct 15.0 .
        nmod:in 3.0 opinion
            nmod:poss 2.0 my
        case 1.0 In
```

{’standard’: ’of badminton’, ’target’: ’of tennis’, ’frame:’: ’John’, ’dimension’: ’better player’, ’direction’: ’more’}

In my opinion , John is a better player of tennis than Harry.

```
None 0.0 ROOT
```

root 9.0 player
    punct 4.0 ,
    nsubj 5.0 John
    cop 6.0 is
    det 7.0 a
    amod 8.0 better
        advmod 7.5 more
            Ccomp1 13.0 Harry
                case 12.0 than
    nmod:of 11.0 tennis
        case 10.0 of
    punct 14.0 .
    nmod:in 3.0 opinion
        nmod:poss 2.0 my
        case 1.0 In

{'standard': 'Harry', 'target': 'John', 'dimension': 'better player', 'direction': 'more'}

John is not much better at tennis than at badminton.

None 0.0 ROOT
    root 5.0 better
        cop 2.0 is
        neg 3.0 not
        advmod 4.0 much
        advmod 4.5 more
            Ccomp1 10.0 badminton
                case 9.0 at
                case 8.0 than
            Ccomp2 7.0 tennis
                case 6.0 at
        punct 11.0 .
        nsubj 1.0 John

{'standard': 'at badminton', 'target': 'at tennis', 'frame:': 'John', 'dimension': 'better', 'direction': 'NOT more'}

He says that John is not much better at tennis than at badminton.

None 0.0 ROOT
    root 2.0 says
        ccomp 8.0 better
            nsubj 4.0 John
            cop 5.0 is
        neg 6.0 not
            advmod 7.0 much
            advmod 7.5 more

```
            Ccomp1 13.0 badminton
                case 12.0 at
                case 11.0 than
            Ccomp2 10.0 tennis
                case 9.0 at
        mark 3.0 that
    punct 14.0 .
    nsubj 1.0 He
```

{'standard': 'at badminton', 'target': 'at tennis', 'frame:': 'John', 'dimension': 'better', 'direction': 'NOT more'}

They think John is not much better at tennis than at badminton.

```
None 0.0 ROOT
    root 2.0 think
        ccomp 7.0 better
            cop 4.0 is
            neg 5.0 not
            advmod 6.0 much
            advmod 6.5 more
                Ccomp1 12.0 badminton
                    case 11.0 at
                    case 10.0 than
                Ccomp2 9.0 tennis
                    case 8.0 at
            nsubj 3.0 John
        punct 13.0 .
        nsubj 1.0 They
```

{'standard': 'at badminton', 'target': 'at tennis', 'frame:': 'John', 'dimension': 'better', 'direction': 'NOT more'}

They think John is not much better at tennis than Harry.

```
None 0.0 ROOT
    root 2.0 think
        ccomp 7.0 better
            cop 4.0 is
            neg 5.0 not
            advmod 6.0 much
            advmod 6.5 more
                Ccomp1 11.0 Harry
                    case 10.0 than
            nmod:at 9.0 tennis
                case 8.0 at
            nsubj 3.0 John
```

punct 12.0 .
nsubj 1.0 They

{'standard': 'Harry', 'target': 'John', 'dimension': 'better', 'direction': 'NOT more'}

Appendix B

STANFORD POS TAGS

TAG	DESCRIPTION
CC	Coordinating conjunction
CD	Cardinal number
DT	Determiner
EX	Existential there
FW	Foreign word
IN	Preposition or subordinating conjunction
JJ	Adjective
JJR	Adjective, comparative
JJS	Adjective, superlative
LS	List item marker
MD	Modal
NN	Noun, singular or mass
NNS	Noun, plural
NNP	Proper noun, singular
NNPS	Proper noun, plural
PDT	Predeterminer
POS	Possessive ending
PRP	Personal pronoun
PRP$	Possessive pronoun
RB	Adverb
RBR	Adverb, comparative
RBS	Adverb, superlative
RP	Particle
SYM	Symbol
TO	to
UH	Interjection
VB	Verb, base form
VBD	Verb, past tense
VBG	Verb, gerund or present participle
VBN	Verb, past participle
VBP	Verb, non-3rd person singular present
VBZ	Verb, 3rd person singular present
WDT	Wh-determiner
WP	Wh-pronoun
WP$	Possessive wh-pronoun
WRB	Wh-adverb

Table B.1: Stanford POS Tags (P. Webpage (n.d.))

Appendix C

STANFORD DEPENDENCY LABELS

LABEL	DESCRIPTION
acl	clausal modifier of noun (adjectival clause)
advcl	adverbial clause modifier
advmod	adverbial modifier
amod	adjectival modifier
appos	appositional modifier
aux	auxiliary
case	case marking
cc	coordinating conjunction
ccomp	clausal complement
clf	classifier
compound	compound
conj	conjunct
cop	copula
csubj	clausal subject
dep	unspecified dependency
det	determiner
discourse	discourse element
dislocated	dislocated elements
expl	expletive
fixed	fixed multiword expression
flat	flat multiword expression
goeswith	goes with
iobj	indirect object
list	list
mark	marker
nmod	nominal modifier
nsubj	nominal subject
nummod	numeric modifier
obj	object
obl	oblique nominal
orphan	orphan
parataxis	parataxis
punct	punctuation
reparandum	overridden disfluency
root	root
vocative	vocative

xcomp	open clausal complement

Table C.1: Stanford Dependency Labels (U. Webpage (n.d.))