# Word-Based or Morpheme-Based? Annotation Strategies for Modern Hebrew Clitics

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## Introduction

### Background
In morphologically rich languages a single word may carry different sorts of information and the different morphs may indicate a relation to other elements in the syntactic tree.

### The Question
Should we analyze a word as a sequence of morphological units or should we treat orthographic (space-delimited) words as the primitive units of our analyses?

### Our Investigation
We discuss and evaluate the adequacy of Morpheme-based and Word-based annotation strategies for the development of statistical parsers for Modern Hebrew.

**Morpheme-based (MB)** theories (Bloomfield, 1933; Hocket, 1954) assume that the atomic units of the language are morphs which are combined to create words through various processes (Matthews, 1991).

**Word-Based (WB)** theories consider words the atomic units of the language, and morphological considerations predict generalizations concerning the syntactic behavior of morphologically similar words (Blevins 2006).

## The Data

### Pronominal Clitics in Modern Hebrew

**(1) Prepositions** — *hwa ba ali* | הוא בא אלי

a. *hwa ba al ani*
he came to to I
He came to me

b. *hwa ba ali*
he came to.1p.sing
He came to me

**(2) Possessive Markers** — *hildim flnw* | הילדים שלנו

a. *hildim fl anxnw*
the-children of we
Our children

b. *hildim flnw*
the-children of.1p.masc.plural
Our children

**(3) Accusative Markers** — *hwa rah awth* | הוא ראה אותה

a. *hwa rah at hia*
he saw ACC she
He saw her

b. *hwa rah awth*
he saw ACC.3p.fem.sing
He saw her

**(4) The Dative Shift in Modern Hebrew**

a. *ntti lw mtnh* | נתתי לו מתנה
gave.1p.sing to.3p.masc.sing a-present
I gave him a present

b. **ntti mtnh lw* | *נתתי מתנה לו
*gave.1p.sing a-present to.3p.masc.sing
*I gave a present to him

c. *ntti lild mtnh* | נתתי לילד מתנה
gave.1p.sing to-the-child a-present
I gave the child a present

d. *ntti mtnh lild* | נתתי מתנה לילד
gave.1p.sing a-present to-the-child
I gave a present to the child

**(5) Coordinated Structures in Modern Hebrew**

a. *liwab wrewt* | ליואב ורעות
for-Yoav and-Reut
for Yoav and Reut

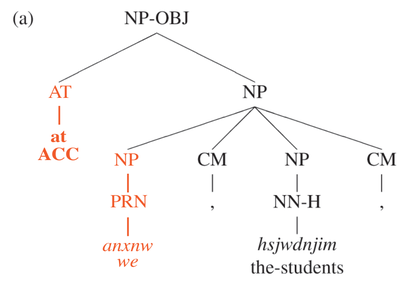
b. **li wrewt* | *לי ורעות
*for.1p.sing and-Reut
*for me and Reut

c. *li wliwab* | לי וליואב
for.1p.sing and-for-Yoav
for me and for Yoav

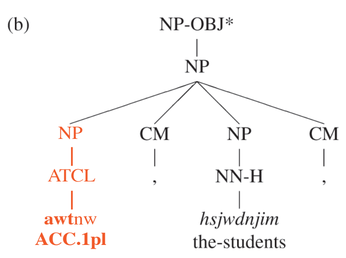
d. *li wlw* | *לי ולו
for.1p.sing and-for.3p.masc.sing
for me and for him

## Annotation Strategies

### A Morpheme-Based Strategy
The original annotation strategy in the Modern Hebrew Treebank.
**Advantage** | Capture correctly word- and constituent-boundaries discrepencies.
**Disadvantage** | Does not correspond deterministically to surface forms.

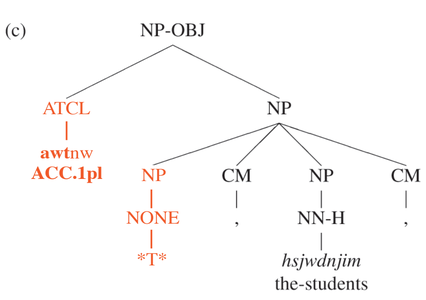



### A Naïve Word-Based Strategy
A naïve proposal for representing words as the yields of syntactic parse trees.
**Advantage** | Yields correspond directly to surface forms.
**Disadvantage** | grammatically incorrect.




### Our Word-Based Strategy
We propose an alternative Word-Based (WB) analysis as inflectional features on top of specialized categories of prepositions / markers. The special categories capture membership in distinct syntactic classes, and the features indicate agreement with a dropped pronoun marked as a trace of an empty element.

**Advantages** | recover correctly word- and constituent-boundaries discrepancies, represent yields directly as surface forms.




אותנו, הסטודנטים,
awtnw, hsjwdnjim,
ACC.1p.plural, the-students,
us, the students,

## Experimental Design

**Goal** | Compare and contrast the adequacy of the MB and WB annotation strategies for Modern Hebrew pronominal clitics

**Methodology** | Evaluate parsing performance of different treebank PCFGs corresponding to different annotation strategies.

**Data** | The Modern Hebrew Treebank version 1.0 (Sima'an et al., 2001), 5000 sentences from the daily newspaper `Ha'aretz'. The Test-Set constitutes the first 500 non-empty sentences.

**Grammar** | Extracted from tree-skeletons in which syntactic categories are extended with a handful of morphosyntactic features (marking infinitivals, definite phrases, Prepositional Possessive Phrases)

**Evaluation** | Problem: Different strategies result in different sentence length
Quantitative: compare PARSEVAL measures of sentences without clitics
Qualitative: analyze differences in the parse-trees that include clitics

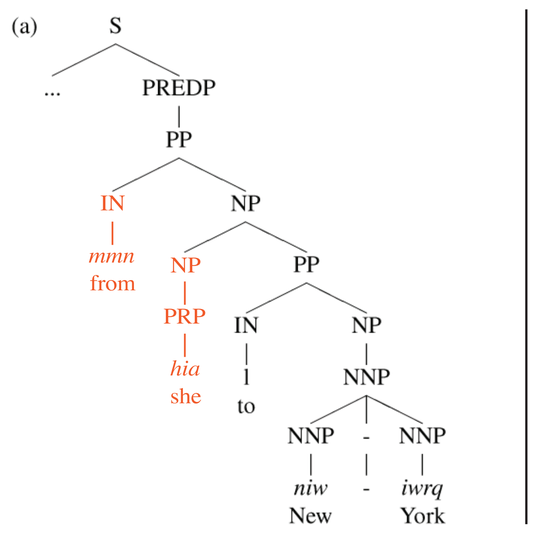
## Results and Analysis

### Quantitative Analysis
For sentences without pronominal clitics the conversion does not have a significant influence on the disambiguation capacity of the resulting grammars.

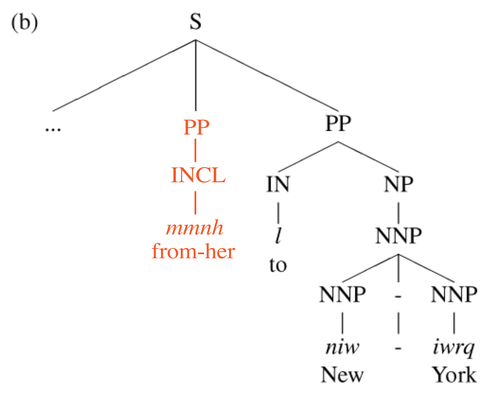
| | *No Clitics* before | *No Clitics* after | *Bare Prepositions* before | *Bare Prepositions* after |
|---|---|---|---|---|
| Prepositions (WP) | 79.15/80.94 (80.03) | 79.03/80.87 79.94 | 78.95/80.91 79.92 | 78.84/80.83 79.82 |
| Prepositions (WOP) | 80.57/82.42 (81.48) | 80.45/82.35 81.39 | 80.28/82.30 81.28 | 80.17/82.22 81.18 |
| Possessive Markers (WP) | 78.51/80.27 (79.38) | 78.52/80.28 (79.39) | 76.02/77.68 (76.84) | 76.02/77.73 (76.86) |
| Possessive Markers (WOP) | 79.89/81.72 (80.79) | 79.90/81.73 (80.80) | 77.51/79.26 (78.38) | 77.51/79.31 (78.40) |
| Accusatives Markers (WP) | 78.68/80.57 (79.61) | 78.63/80.55 (79.58) | 77.55/79.89 (78.70) | 77.39/79.83 (78.59) |
| Accusatives Markers (WOP) | 80.00/81.97 (80.97) | 79.97/81.96 (80.95) | 78.95/81.40 (80.16) | 78.83/81.37 (80.08) |

### Qualitative Analysis
For sentences with pronominal clitics the WB analysis is always as good or better than the original MB analysis.

| Parsing Result | Num of Sentences |
|---|---|
| Identical Parses | 116 |
| Only WB Correct | 5 |
| Only MB Correct | 0 |
| Both Wrong, WB Better | 8 |
| Both Wrong, MB Better | 0 |
| Both Wrong, None Better | 2 |




MB: Incorrect PP attachment




WB: correct PP attachment

The main source of errors for the MB strategy is its tendency to learn high attachment for prepositions that originate from cliticized elements.

## Conclusion

The WB analyses are more faithful to the surface forms thus avoiding the need for preceding segmentation.

The WB resulting treebank grammars provide better PP attachment disambiguation capacity.

The **Word-Based (WB)** annotation strategy is more adequate than the **Morpheme-Based (MB)** strategy for training statistical parsers on the Modern Hebrew Treebank.

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