The Role of the Head in the Interpretation of English Deverbal Compounds

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Deverbal (DCs) vs. Root Compounds (RCs)

- N-N compounds that are interpreted on the basis of a relationship between the head and the non-head;
- RCs are headed by lexical nouns (usually non-derived); the relationship is determined by world knowledge or context:

1. fireman, train station vs. book chair, chocolate box

- DCs are headed by deverbal Ns; the relationship is often identified to the one between the base verb and the non-head:

2. snow remov**al** < to remove (the) snow (OBJ)
   police question**ing** < the police questions somebody (SUBJ)
   safety instruct**ion** < to instruct somebody on safety (OTHER)

- Even DCs are often hard to interpret, in spite of the verbal base and especially due to the ambiguity of the deverbal noun head:

3. marketing approval, committee assignment, security assistance

Argument Structure Nominals (ASNs) vs. Result Nominals (RNs)

- Grimshaw (1990): Deverbal Ns are ambiguous between compositional V-like ASN-readings and more lexicalized RN-readings:

4. a. The examination/exam was on the table. (RN)
   b. The examination of the patients took a long time/*was on the table. (ASN).

- ASNs vs. RNs (presence/absence of event structure):

Property	**ASN-reading**	**RN-reading**
Obligatory internal arguments	Yes	No
Agent-oriented modifiers (*careful*, *deliberate*, *intentional*)	Yes	No
By-phrases are arguments	Yes	No
Aspectual *in/for-X-time* adverbials	Yes	No
Frequent, *constant* appear with the singular form	Yes	No
Must appear in the singular	Yes	No

(adapted from Alexiadou & Grimshaw 2008: 3, citing Grimshaw 1990; see Appendix-1 for details)

The Linguistic Debate on DCs

- **Grimshaw (1990)**: **DCs ~ ASNs**: DCs obey AS-constraints; only lowest argument (Theme/OBJ) is possible (Agent<Goal<Theme):

5. gift-giving to children - *child-giving of gifts (*to give gifts to children*)
   book-reading by students - *student-reading of books (*Students read books)*

- Cf. RCs (e.g., compounds headed by zero-derived nominals):

6. bee sting; dog bite (vs. *bee-stinging, *dog-biting)

- **Borer (2013)**: **DCs = RCs**; DCs have no AS or event structure:

7. a. the house demolition (*by the army) (*in two hours) (DC)
   b. the demolition of the house by the army in two hours (ASN)

- As in RCs, non-heads are context-dependent: Agent/SUBJ is OK:

8. teacher recommendation; court investigation; government decision

Contribution of this Talk

- Hypothesis: If a noun is used more like an ASN or a RN, this should be preserved in compounds => ASN-like nouns head DCs with OBJ/int. argument, RN-like nouns form RCs with context-dependent readings:

9. $snow_{OBJ}$/$waste_{OBJ}$ removal vs. $health_{OBJ}$/$flood_{OTHER}$ insurance
   $drug_{OBJ}$/$child_{OBJ}$ trafficking $body_{OBJ}$/$protest_{OTHER}$/$student_{SUBJ}$ movement

- Our study: a balanced collection of DCs automatically extracted from the Annotated Gigaword Corpus (Napoles et al. 2012)
- Use machine learning techniques to check which morphosyntactic properties of DC heads are relevant for the (OBJ-NOBJ) interpretation of DCs and what correlations we find between the two
- Our results provide support for Grimshaw's analysis and our hypothesis that DCs headed by ASN-like nouns receive OBJ readings

Outline

1) Our Methodology: Data Extraction and Annotation
2) Verification by Machine Learning Techniques
3) Discussion of Results
4) Conclusion and Future Plans

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Our Plan

- Test if heads of DCs are more like ASNs or RNs in the corpus
- Hypothesis: DCs ≠ RCs

  Two types of *compounds headed by ASN/RN-like deverbal Ns*:
  - **True DCs**: non-head = only internal argument (OBJ)
  - **RCs**: non-head = ext. arg. (SUBJ); OTHER; int. arg. (OBJ)
- Expectation to test:
  - Correlation between ASN-properties in heads of DCs and an OBJ interpretation of the DC
- Corpus and Tools: see details in Appendix-2

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3) Annotate each compound's interpretation: OBJ, SUBJ, OTHER

3) Annotation of Compounds

- Two trained annotators (native speakers of American English)
- **Annotate** the relation between head and non-head:
  - SUBJ: ext. Arg. (police questioning, designer creation)
  - OBJ: int. Arg. (book writing, crop destruction, hair removal)
  - OTHER (contract killing, safety instruction)
  - ERROR (PoS tag errors or uninterpretable compounds: e.g. *face*$_V$ *abandonment*, *fond*$_A$ *remembrance*, *percent assurance*)
- Allow for ambiguity & preference order: SUBJ – OBJ, SUBJ > OBJ
- Post-processing (Appendix-4) => binary classification OBJ-NOBJ
- Simple interannotator agreement after post-processing: 81.5%
- **Result**: 2399 DCs: 1502 OBJ - 897 NOBJ

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3) Annotate each compound's interpretation: OBJ, SUBJ, OTHER
4) Determine ASN vs. RN properties of heads based on some of Grimshaw's (1990) tests by extracting contexts from the Gigaword

4) Morphosyntactic Features to Test

- 2. - 4. are Grimshaw's ASN-properties; 3. is the crucial one!
- 5. & 6. - comparable properties when the head is part of DCs

Feature label	**Description and illustration**
1. *suffix*	The suffix of the head noun: AL (rental), ANCE (insurance), ING (killing), ION (destruction), MENT (treatment)
2. *sg_head_outside_DC*	Percentage of the head's occurrences as singular outside compounds.
3. *sg_head*+of*_outside_DC*	Percentage of the head's occurrences as singular outside compounds which realize a syntactic relation with an *of*-phrase. (e.g., *assignment* **of** *problems*).
4. *sum_adjectives*	Percentage of the head's occurrences in a modifier relation with one of the adjectives *frequent*, *constant*, *intentional*, *deliberate*, or *careful*.
5. *sg_head_inside_DC*	Percentage of the head's occurrences as singular inside compounds.
6. *sg_head*+by *_inside_DC*	Percentage of the head's occurrences as singular inside compounds which realize a syntactic relation with a *by*-phrase. (e.g., task assignment **by** teachers)
7. *head_in_DC*	Percentage of the head's occurrences within a compound out of its total occurrences in the corpus.

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Logistic Regression for Data Analysis

- Questions for the experiments:
  1) Can the head's ASN-properties help in predicting the meaning of DCs (OBJ or NOBJ)?
  2) Which properties are the strongest predictors?
- 7 independent variables (one categorical: suffix)
- Categorical dependent variable (OBJ-NOBJ)
- Split up data so that no head in test data is seen in training
- Balanced data set for two classes (by removing OBJ instances)
- **Data used**: 1614 training, 180 test compounds

Results in Ablation Experiments

Features	Accuracy
All features	66.7%
All features, except *sg_head_outside_DC*	66.7%
All features, except *sum_adjectives*	66.7%
All features, except *sg_head_inside_DC*	66.7%
All features, except *head_in_DC*	46.7%†
All features, except *sg_head*+of_*outside_DC*	56.1%†
All features, except *suffix*	61.7%†
All features, except *sg_head*+by_*inside*	71.1%†
Head_in_DC, *sg_head*+of_*outside_DC*, and *suffix* combined	**76.1%**†

† indicates a statistically significant difference from the performance when all features are included

Answers to our Questions

1) Are the features predictive? YES – cf. random baseline: 66.7% vs. 50%; best performance: 76.1% vs. 50% (see Appendix-5 & 6)

2) Which features are strongest?

- ***Head_in_DC***: how often a head noun appears within a compound out of its total occurrences in the corpus
- ***Sg_head+of_outside_DC***: how often a head noun (in the singular) realizes an *of*-phrase outside compounds

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Head_in_DC (46.7% vs. 66.7%)

- ➔ High percentage of occurrences of a head inside compounds
- ➔ It indicates an OBJ interpretation (see Appendix-6)
- • Not related to ASN-hood and not mentioned in previous literature
- • High compoundhood of a head noun indicates its specialization for compounds
- • The fact that it correlates with an OBJ reading shows us that if a deverbal noun typically forms a compound with one of its arguments, then this argument will be the object
- ➔ This supports Grimshaw's claim that DCs embed event structure with internal arguments

Head_in_DC: Examples

Head noun	Head_in_DC	OBJ-reading
laundering	94.80%	95.45%
mongering	91.77%	100%
growing	68.68%	95.23%
trafficking	61.99%	100%
enforcement	53.68%	66.66%
insurance	43.73%	**46.15%**
chasing	44.74%	90%
rental	42.95%	87.5%
acquittal	1.80%	12.5%
ignorance	0.85%	0%
refusal	0.77%	43.75%
anticipation	0.70%	37.5%
defiance	0.64%	35.29%

Heads with most/least frequent occurrence in compounds; outliers in bold

Sg_head+of_*outside_DC* (56.1% vs. 66.7%)

- ➔ The presence of an *of*-phrase realizing the internal argument of the head/verb (cf. *the examination **of** the patient*)
- ➔ It predicts an OBJ reading (see Appendix-6)
- In Grimshaw (1990), the realization of the internal argument is most indicative of the ASN status of a deverbal noun.
- ➔ This proves our hypothesis to be right: high ASN-hood of the head => OBJ reading in compound
- Precision & recall in the extraction of *of*-phrases is pretty good:
  - **Precision**: 90.96
  - **Recall**: 90.08

Sg_head+of_*outside_DC*: Examples

Head noun	*Of*-phrases	OBJ-reading
creation	80.51%	72.72%
avoidance	70.40%	100%
obstruction	65.25%	90.47%
removal	63.53%	92%
breaking	58.83%	94.11%
abandonment	55.90%	90%
assassination	52.27%	**11.76%**
preservation	52.14%	100%
education	1.81%	30%
proposal	1.08%	**76.19%**
counseling	0.53%	10%
insurance	0.42%	46.15%
mongering	0%	**100%**

Heads with (in)frequent *of*-phrases outside compounds; outliers in bold

Sg_head+by_*inside_DC* (71.1% vs. 66.7%)

- Frequency of a *by*-phrase (i.e., ext. argument) with a compound
- It is noisy – results improve when feature is dismissed
- Grimshaw (1990): *book-reading by students*
- Borer (2013): *the house demolition (*by the army)*
- Possible interferences:
  - *by* is ambiguous between ext. arg. and 'author'-*by*: e.g., *a book by Chomsky* => in principle, both ASNs and RNs should be OK
  - Precision **85.02** & recall **72.78** in our *by*-phrase extractions
- Further investigation is needed

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Conclusions

- Heads of DCs are ambiguous between ASNs and RNs and this influences the interpretation of DCs
- We find two correlations:
  - realization of internal arguments as *of*-phrases and OBJ readings
  - high compoundhood and OBJ readings
- These support Grimshaw's claim that DCs include event structure with internal arguments
- The *by*-phrase in compounds is a noisy feature – this may be due to its ambiguity
- Suffixes: see Appendix-7

Future Plans

- Add third annotator (majority vote)
- Add annotation feature *result* (RN) vs. *process* (ASN) (1 to 5)
- We extracted the base verbs and their objects/subjects – check whether:
  - the high frequency of a direct object with a verb correlates with an OBJ reading of the DCs
  - the non-heads that appear in DCs correlate with the objects/ subjects of the verb – close to Borer's (2013) suggestions
- Would descriptive statistics be able to explain the correlations in our data better than ML techniques?

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Appendix

Appendix-1: ASNs vs. RNs (Grimshaw 1990)

- Arguments are introduced by verbs via their event structure (aspectual properties, argument licensing, verbal properties)
- ASNs preserve event structure & AS from verbs; RNs do not
- ASN: obligatory internal arguments (vs. RNs) (Grimshaw 1990: 50-52)

(7) a. The assignment is to be avoided. (RN)

b. *The constant assignment is to be avoided. (ASN-RN)

c. The constant assignment of unsolvable problems is to be avoided. (ASN)

- *Constant* and *frequent* are aspectual modifiers when they appear with a singular noun => they require event structure (7b, c); if the noun is plural, it can be a RN:

(9) The constant assignments were avoided by the students. (RN)

Appendix-1: ASNs vs. RNs (Grimshaw 1990)

- *Intentional*, *deliberate*, *careful* are agent-oriented modifiers and only appear with event structure => ASNs but not RNs

(11) a. *The instructor's intentional examination took a long time.

b. The instructor's intentional examination of the papers took a long time.

- ASNs reject plural (not nominal enough) vs. RNs (Grimshaw 1990: 54)

(18) a. The assignments were long. (RN)

b. *The assignments of the problems took a long time. (ASN)

Appendix-2: Corpus and Tools

- The Annotated Gigaword Corpus (Napoles et al. 2012) – LDC Catalog No. LDC2012T21
- 10-million documents from seven news outlets
- Total of more than 4-billion words
- Automatic processing and annotation we use:

  1. Segmentation (using Splitta - Gillick, 2009) and tokenization (using Stanford‘s CoreNLP pipeline)

  2. Lemmatization and POS tags (Stanford‘s CoreNLP pipeline)

  3. Treebank-style constituent parse trees (Huang et al. 2010, Avg. F score = 91.4 on WSJ sec 22)

  4. Syntactic dependency trees (Using Stanford‘s CoreNLP pipeline for the conversion from constituency to dependency trees)

- We removed within-file (1010 files) duplicate sentences (170 >143 GB)

Appendix-3: Selection of Target Head Nouns

- For each suffix, we selected 25 nouns derived from transitive verbs, which head NN compounds (no N before or after) in Gigaword;
- *Arrival* – the only unaccusative verb

Frequency	ING	ION	MENT	AL	ANCE
High	spending	production	enforcement	proposal	insurance
	building	protection	development	approval	performance
	training	reduction	movement	withdrawal	assistance
	bombing	construction	treatment	arrival	clearance
	trafficking	consumption	punishment	rental	surveillance
Medium	killing	supervision	deployment	renewal	assurance
	writing	destruction	replacement	burial	disturbance
	counseling	cultivation	placement	survival	dominance
	firing	deprivation	assignment	denial	acceptance
	teaching	instruction	adjustment	upheaval	tolerance
Low	weighting	demolition	reinforcement	retrieval	defiance
	baking	anticipation	realignment	acquittal	reassurance
	chasing	expulsion	empowerment	disapproval	endurance
	measuring	obstruction	mistreatment	rebuttal	remembrance
	mongering	deportation	abandonment	dispersal	ignorance

Appendix-4: Post-processing of Annotations

- Initial database of 3111 compounds
- Conflate OTHER and SUBJ to NOBJ (=> binary classification)
- Remove errors (163)
- Remove disagreements (547)
- Remove true ambiguous cases (for both annotators) (2)
- DCs headed by *arrival*: SUBJ > OBJ (but we didn‘t check alternating verbs – on our to do list)
- For ambiguous vs. unambiguous annotations, take overall preference (e.g., A1: NOBJ-OBJ; A2: NOBJ => NOBJ)

Appendix-5: Comparison to NLP Studies

- Our best performance: 76.1% vs. 50% => 26.1% improvement
- Previous work in the NLP literature targets state-of-the-art performance in prediction with methods different from ours
- Our purpose was to start from linguistic theory and test linguistic hypotheses
- These studies include more suffixes (**-er**, **-ee**) and zero-derived nouns; **-er** and **-ee** are biased, so they are more predictive;
- We had only 'event'-denoting suffixes, where SUBJ/OBJ are similarly conceivable
- Lapata (2002): 86.1% vs. 61.5% => 24.6% above the baseline

Appendix-6: Predicted Interpretation

Variable	Class OBJ
suffix=nt	-0.1518
suffix=ce	-0.5366
suffix=on	0.3439
suffix=al	0.2855
suffix=ng	-0.0636
head_in_DC	0.0328
sg_head+of_outside_DC	0.0202

- The two most predictive features correlate with an OBJ-reading (see ***head_in_DC, sg_head+of_outside_DC***
- For the suffix feature we get some variation:

Suffix: *-ion*, *-al* : OBJ

-ance, *-ment, -ing* : NOBJ

Appendix-7: Suffixes (61.7% vs. 66.7%)

- It is the weakest predictive feature
- **Grimshaw (1990)**: *ing*-nominals are always ASNs => **OBJ**
- **Borer (2013)**: *ing* introduces the Originator (ext. arg.) itself and biases the DC towards an **OBJ reading**

➔ Both theories predict a correlation between *ing* and OBJ, which we did not find

- Latinate suffixes (-*ion*, -*ment*, -*al*, -*ance*) are taken to behave similarly in theory, but we find a bias for OBJ in -*ion* and -*al*, and for NOBJ in -*ance* and -*ment*
- Further research is needed: both cleaner data on our side and linguistic research on the selectional preferences of suffixes