# Automatic Grammatical Complexity Analysis in Aphasia

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## Objective and Rationale

Treatment evaluation and research requires discourse measures that are: VALID, RELIABLE, and RELEVANT but also PRACTICAL in terms of labor and training.

Primary limiting factors for linguistic discourse analysis are:
TIME and CLINICAL KNOWLEDGE[1].

This project describes an **automatic system for measuring grammatical complexity in discourse** using CLAN[2].

The system uses a grammatical relations (GR) parser[1] that has recently been trained on adult language samples and tested for computation of a syntactic complexity index.

By identifying the GRs that mark embedding, a Grammatical Relations-Complex (GR-C) measure can be calculated.

This GR-C measure adds important and relevant linguistic data that can be computed on multiple samples with accuracy, replicability, speed, and flexibility.

## Background

Linguistic analyses in aphasia often focus on grammatical aspects[3,4] because syntax is a key component of aphasia diagnosis and treatment.

Many measures can be computed automatically – e.g., total utterances, total words, total unique words, TTR, MLU, words per minute, frequencies of parts-of-speech, morphological affixes, proposition density, repetitions, revisions. However, grammatical complexity has been less amenable to automatic computation.

Embedding, or recursion, is a structural indicator considered to be a good indicator of syntactic complexity. Systems used more commonly for child language, such as LARSP[5], use embeddings to compute grammatical complexity.

GRASP (Grammatical Relations Analyzer for Spontaneous Protocols) is a parser developed to accurately and automatically measure syntactic complexity by producing a tier for grammatical relations (GRs) in CHAT files[6].

Recent training of the GRASP parser on adult language samples allows us to compute grammatical complexity from the GR codes.

All of the GRs (n=45) are explained in detail in the CLAN Manual (http://talkbank.org/manuals/MOR.pdf) .

Running the MOR command in CLAN automatically produces a %mor tier with morphosyntactic analysis and a %gra tier with pairwise GRs words in a matter of seconds. For example:

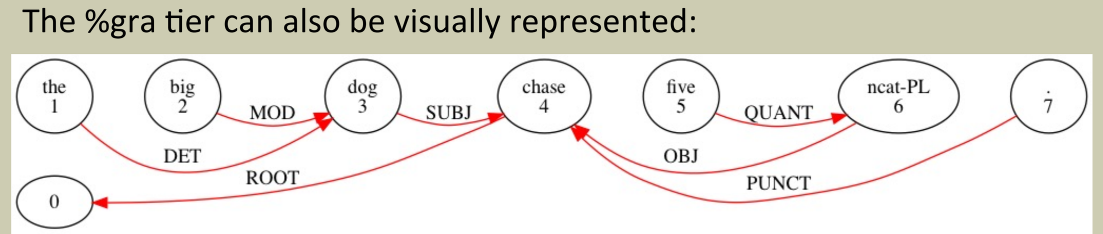
***PAR: the big dog chased five cats.**
**%mor: det|the adj|big n|dog v|chase-PAST quant|five n|cat-PL**
**%gra: 1|3|DET 2|3|MOD 3|4|SUBJ 4|0|ROOT 5|6|QUANT 6|4|OBJ 7|4|PUNCT**

In this sentence:

- the DETerminer (the) and MODifier (big) attach to the SUBJect (dog) which attaches to the verb (chased), the ROOT of the clause
- the QUANTifier (five) attaches to OBJect (cats) which attaches to the verb.

The numbers indicate the pairwise grammatical relations, where the first number is the word's order in the sentence and the second number indicates its attachment.

The %gra tier can also be visually represented:




Testing this automated GRASP system with human coding of embeddings in adult discourse samples yielded an overall accuracy of 95% (of the 74 embeddings spotted by the automated system, two were false alarms and one was missed).

## Research Questions

Will the Grammatical Relations-Complex (GR-C) measure reveal differences between Cinderella narratives produces by people with nonfluent aphasia (Broca's), fluent aphasia (Anomic), and people without aphasia?

Does the GR-C index correlate with other measures used as indicators of grammatical complexity – MLU and # of verbs/utterance?

## Methods

### Participants

Using the AphasiaBank database[7], inclusion criteria were:

- native English speakers
- aphasia as a result of stroke
- ≥ 20 words on the Cinderella task
- first session only, if participant was seen multiple times

**Demographic characteristics** – means and standard deviations

| | Anomic (n=87) | Broca (n=50) | Controls (n=191) |
|---|---|---|---|
| Age (yrs.) | 62.3 (12.2) | 56.8 (11.3) | 62.0 (19.2) |
| Education (yrs.) | 15.8 (2.8) | 14.5 (2.4) | 15.4 (2.4) |
| Sex (% males) | 59.8% | 54% | 45% |
| WAB-R AQ | 85.0 (6.5) | 57.0 (9.7) | NA |

No significant group differences on age, sex, education.

### Procedure

**Transcriptions** were completed by trained and experienced transcribers. Utterances were segmented using the QPA hierarchy[8]: syntax, intonation, pause, semantics. Two transcribers reviewed each transcription and reached forced choice agreement on any discrepancies. Complete transcripts and videos are available at http://aphasia.talkbank.org/.

1. Run MOR on all transcripts → %mor and %gra tiers
2. Run freq +t%gra +t*PAR +sg|* +d2 *.cha → spreadsheet of GRs

**% GR-Complex = (embedding GRs ÷ total number of GRs) x 100**

Of the 41 possible grammatical relations (excluding 4 cosmetic punctuation markers), the 10 that mark syntactic embeddings are:

COMP the finite clausal complement of a verb
*I think that **was** Fraser.*

XCOMP the non-finite clausal complement of a verb
*The cat wants to **eat** a can of tuna.*

CPRED a full clause that serves as the predicate nominal of verbs
*My goal is to **win** the competition.*

CPOBJ a full clause that serves as the object of a preposition
*I'm not clear on why she **did** that.*

COBJ a full clause that serves as the direct object
*I remember what you **said**.*

CSUBJ the finite clausal subject of another clause
*That Eric **cried** moved Bush.*

XJCT a non-finite clause that attaches to a verb, adjective, or adverb
*We spent the day **visiting** museums and galleries.*

NJCT the head of a complex noun phrase with a prepositional phrase attached as an adjunct of a noun.
*The policeman saw the spy **with** a revolver.*

CMOD a finite clause that is a nominal modifier or complement
*He was happy he **found** the girl.*

XMOD a non-finite clause that is a nominal modifier or complement
*It's time to **take** a nap.*

Examples of other non-embedding GRs are: SUBJ (subject), OBJ (object), PRED (predicate nominal or predicate adjective), POBJ (prepositional object), JCT (adjunct), MOD (modifier), DET (determiner), QUANT (quantifier), POSS (possessive), AUX (auxiliary), NEG (negation), INF (infinitive), COM (communicator).

## Results

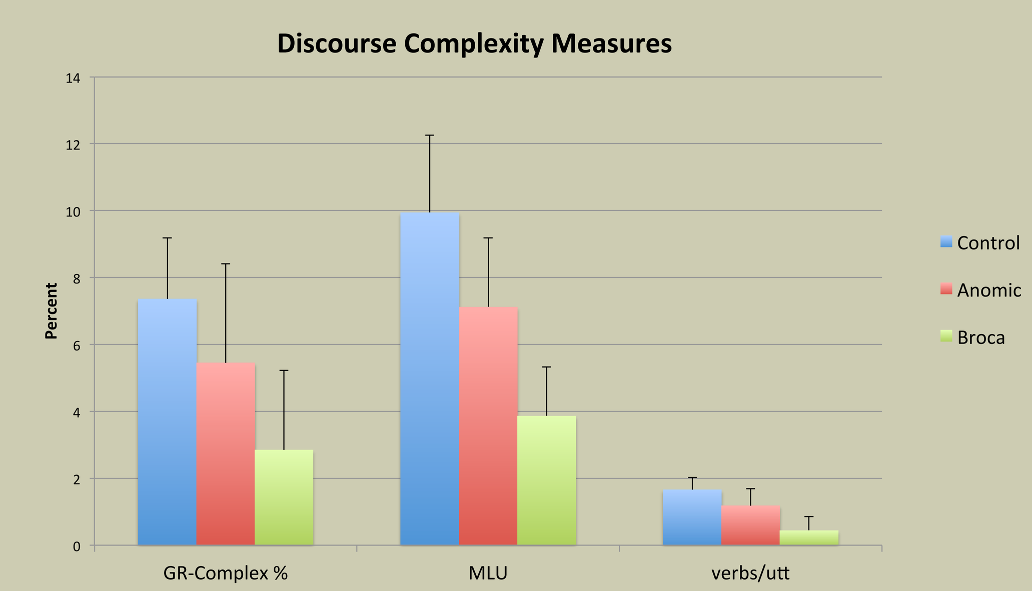
- All three groups were significantly different on GR-Complex [F(2, 325) = 85.1, p = .000)].
- Post-hoc testing (Bonferroni multiple comparison test) revealed significant GR-Complex differences between all groups with the Broca's group having the lowest GR-Complex score (2.85%) and the non-aphasic group having the highest (7.36%).
- Similar results were found for verbs per utterance [F(2, 325) = 173.5, p = .000)] and MLU [F(2, 325) = 177.0, p = .000)].
- Correlations between GR-Complex and # of verbs per utterance and MLU were strong, positive, and significant (p < .01).

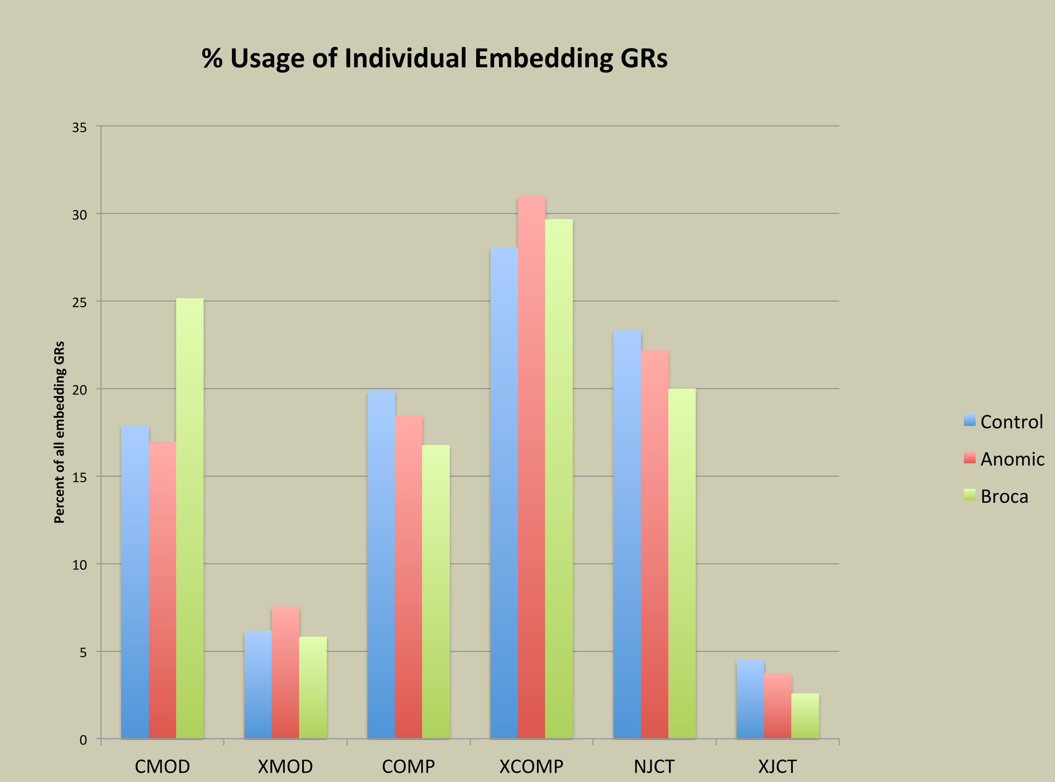
**Discourse data** – means and standard deviations

| | Anomic (n=87) | Broca (n=50) | Controls (n=160) |
|---|---|---|---|
| GR-Complex** | 5.45 % (2.96) | 2.85 % (2.38) | 7.36 % (1.82) |
| MLU** | 7.1 (2.1) | 3.9 (1.5) | 9.9 (2.3) |
| # verbs/utterance** | 1.2 (0.5) | 0.5 (0.4) | 1.7 (0.4) |
| total words** | 226.3 (174.6) | 97.3 (69.6) | 473.3 (282.3) |
| total utterances* | 31.1 (21.6) | 25.54 (17.2) | 48.7 (34.1) |

** significant differences among all groups (p<.01), according to Bonferroni test for multiple comparisons

- significant difference between both aphasia groups and control group (p<.01) but not between Anomic and Broca groups, according to Bonferroni test for multiple comparisons




## Results, cont.

**Pearson product moment correlations**

| | GR-Complex | MLU |
|---|---|---|
| MLU | .65* | -- |
| # verbs/utterance | .67* | .93* |

* significant correlation coefficients (p <. 01)

## Conclusions and Future Directions

- The GR-complex measure is a promising and practical tool for automatic analysis of syntax in clinical and research discourse analyses.
- Once a discourse sample is transcribed in CHAT format, this complexity index can be automatically calculated with no further coding or annotation.
- These results are consistent with the literature, showing more embeddings in language samples of non-aphasic participants than PWA[9] and more general findings of reduced syntactic complexity in Broca's aphasia[10].
- Use the GR-complex measure:
  1. to evaluate the effect of syntax treatment programs on discourse;
  2. with other populations such as Primary Progressive Aphasia, where recent neuroimaging results showed that reduced frequency of embeddings was associated with atrophy in the left frontal lobe (posterior inferior frontal gyrus, superior frontal sulcus and adjacent prefrontal regions and the supplementary motor area) [11]; and
  3. to learn more about the types of embeddings used in different discourse genres and in participants with different types and severities of aphasia.

Ideas for improving the GR measure include the following:

- Address the fact that CSUBJ and COBJ were not coded properly and CPRED and COBJ were coded too infrequently on the %gra tier;
- Consider the new Google Universal Dependency Relations initiative and consider using the relativizer as the head of the subordinate clause and simplifying the %gra tier coding (use SUBJ and OBJ instead of CSUBJ and COBJ) and do cross-tier searches (for example, for relativizers on the %mor tier linked to the verb as SUBJ on the %gra tier);
- Do additional training of the %gra tier with more discourse genres and more samples.

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