Disentangling Noun & Verb Production in Aphasia: Evidence from Item Response Theory

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Introduction

Word production is a rapid and integrative system

- Associative concepts (semantic processing) are mapped to word forms (lexical processing), their associated grammatical markers (morphosyntactic processing), and their sound representations (phonological processing).[1]
- Deficits in word production have been studied extensively in aphasia as a means of understanding this underlying architecture.

Whether the cognitive processes involved in word production differ across word classes remains contested

- Prior studies have shown noun-verb dissociations,[2] yet recent literature suggests these dissociations may be the byproduct of measurement issues related to the tests used.[3]
- Item response theory (IRT) is a modern measurement framework that has previously been used to obtain precise scores for both noun and verb production tests in aphasia.[4,5]

Purpose

- We extended our prior work[3] using IRT to evaluate the dimensionality of two common noun and verb production tests in a large and diverse sample of individuals with aphasia.
- Our aims were to (1) test whether item response probabilities on both tests simultaneously are best modeled as varying along one or two dimensions, and (2) explore the effect of relevant covariates on person-level IRT scores.

Method

Participants

- Binary item responses on the short form of the Boston Naming Test (BNT), a test of noun production, and the Verb Naming Test (VNT), a test of verb production, were extracted from an archival dataset of 107 participants with chronic aphasia[6] (see our prior work for more details).

Characteristic	Value
Age (years)	
Mean (SD), range	60 (10.4), 39.5–85.7
Education (years)	
Mean (SD), range	14.7 (2.3), 11–20
Missing (%)	3.7
Ethnicity (%)	
African American	14
Asian	0.9
White	84.1
Gender (%)	
Female	39.8
Male	40.2
Post-stroke onset (years)	
Mean (SD), range	5.1 (4.1), 0.3–24.7
WAB-R Aphasia Quotient (1–100)	70 (17.1), 20.5–97.9
BNT, Short Form (% correct)	
Mean (SD), range	46.5 (29.2), 0–100
VNT (% correct)	
Mean (SD), range	65.6 (29.4), 0–100

Person covariates

- **Aphasia severity**, given it is an overall measure of language performance. This was indexed as the Aphasia Quotient of the Western Aphasia Battery—Revised (WAB-R AQ).
- **Connected speech**, given that language produced in context is sensitive to a range of deficit patterns.[7] This was indexed as four transcription metrics, averaged across five tasks[6]: % of nouns produced, % of verbs produced, % of word errors, and % of utterance errors.

IRT modeling framework

- To address our first aim, we specified two Rasch IRT models in a generalized linear mixed effects framework: (1) a random-item unidimensional model, where verb and noun production are treated as requiring the same underlying cognitive processes; and (2) a random-item two-dimensional model, where verb and noun production are treated as requiring two distinct yet correlated combinations of underlying cognitive processes.
- To address our second aim, we used the best-fitting model to explore the effect of first aphasia severity and then connected speech on person-level IRT scores.

Results

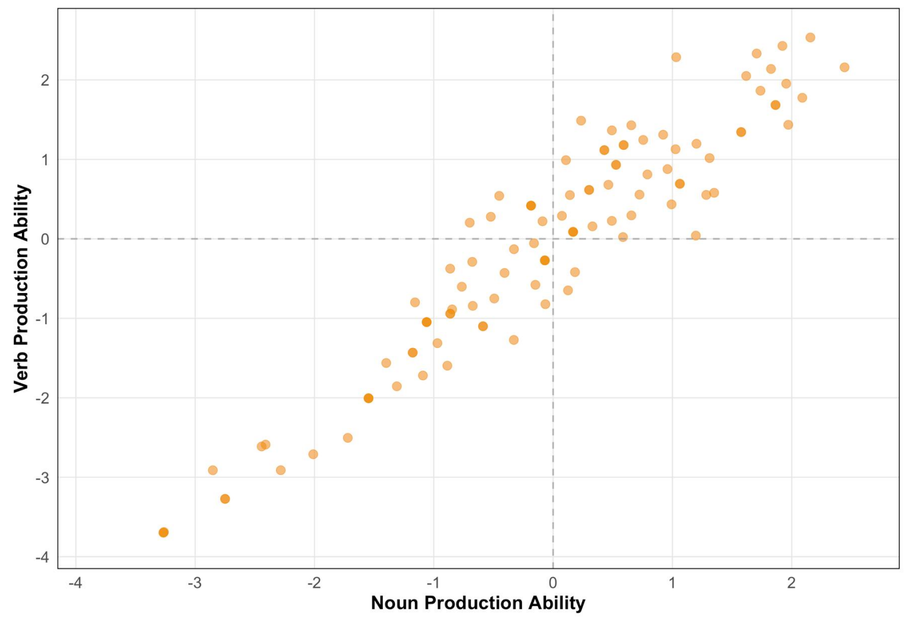
Model fit

						LRT		
Model	**# Par.**	**AIC**	**BIC**	**LL**	**Dev.**	**χ^2**	**df**	**p**
1D	3	4067.0	4085.8	-2030.5	4061.0	–	–	–
2D	5	4050.6	4082.0	-2020.3	4040.6	20.366	2	<.001
2D with WAB-R AQ	6	3917.7	3955.3	-1952.8	3905.7	134.92	1	<.001
2D with WAB-R AQ and connected speech	10	3899.1	3961.9	-1939.6	3879.1	26.56	4	<.001

Model results

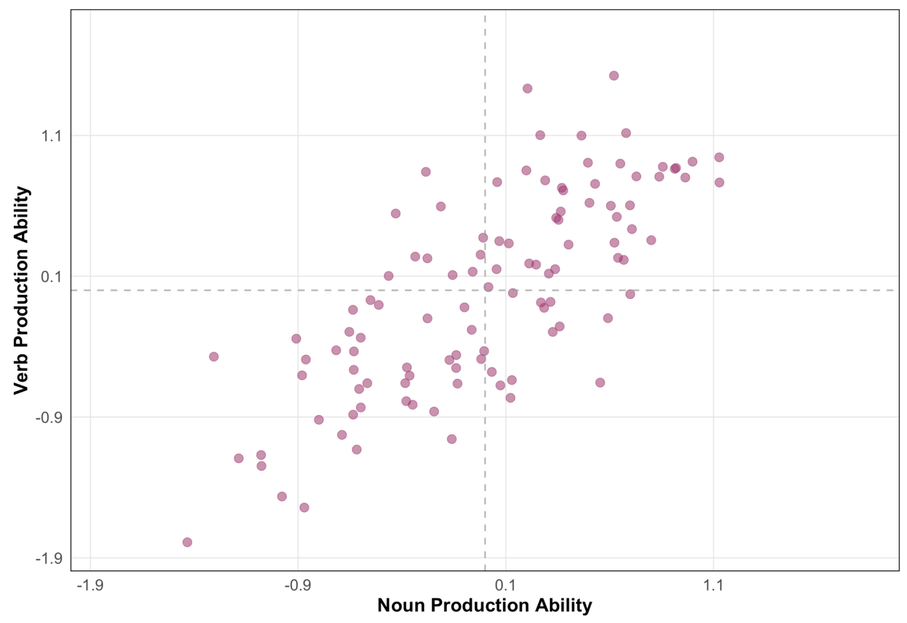
2D

Fixed Effects	**Estimate**	**SE**	**z**	**p**
Intercept	-0.505	0.267	-1.89	.059
Random Effects	**Variance**	**R^2**		
Person: BNT	3.092			
Person: VNT	2.267	.81		
Item	1.716			



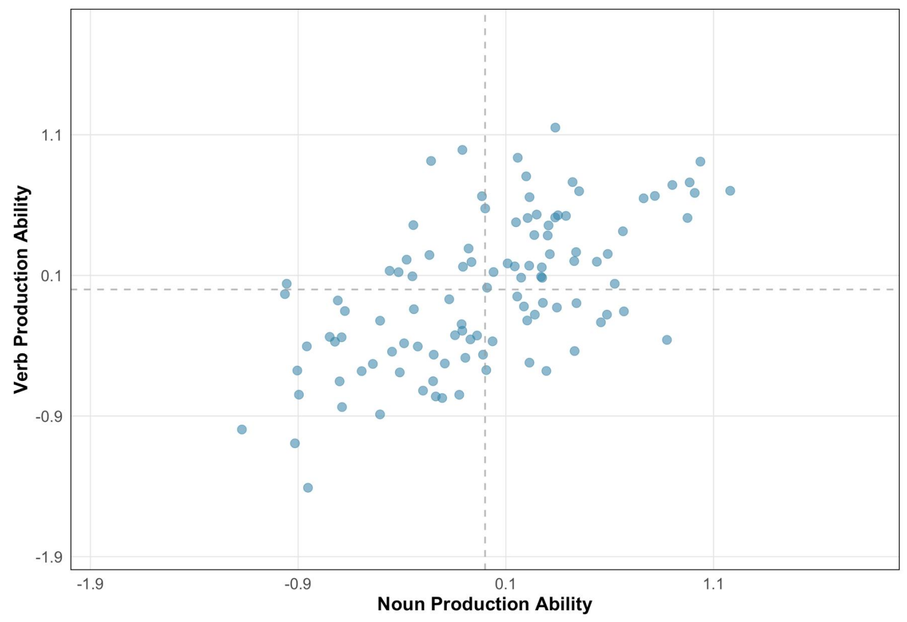
2D with WAB-R AQ

Fixed Effects	**Estimate**	**SE**	**z**	**p**
Intercept	-0.502	0.227	-2.205	.027
WAB-R AQ	1.354	0.091	14.855	<.001
Random Effects	**Variance**	**R^2**		
Person: BNT	0.818			
Person: VNT	0.534	.36		
Item	1.661			



2D with WAB-R AQ and Connected Speech

Fixed Effects	**Estimate**	**SE**	**z**	**p**
Intercept	-0.500	0.223	-2.240	.027
WAB-R AQ	1.042	0.106	9.816	<.001
% Nouns	0.470	0.102	4.621	<.001
% Verbs	0.126	0.097	1.305	.192
% Word errors	-0.301	0.085	-3.550	<.001
% Utterance errors	-0.226	0.096	-2.346	.019
Random Effects	**Variance**	**R^2**		
Person: BNT	0.535			
Person: VNT	0.441	.19		
Item	1.649			



Discussion

In summary, we found that:

- Noun and verb production in aphasia can be treated as two distinct yet highly correlated dimensions.
- Shared covariance between noun and verb production was explained by aphasia severity and connected speech, reducing the covariance between person-level IRT scores by more than half.
  - Controlling for these and using a sophisticated modeling framework such as IRT may be useful for future research.