Analyzing agrammatic narrative production using Northwestern Narrative Language Analysis (NNLA) and Computerized Language Analysis (CLAN): A qualitative and quantitative comparison

Abstract

Spontaneous language sample analysis is often used to characterize production deficit patterns in aphasia. Methods for accomplishing this, however, are labor-intensive. The Computerized Language Analysis (CLAN) system, developed for analyzing children's language production, has recently been adopted for analysis of aphasic speech samples through AphasiaBank. However, the extent to which this automated system accurately quantifies lexical and morophosyntactic deficits, commonly seen in agrammatism, has not been explored. This study compared the CLAN with the Northwestern Narrative Language Analysis (NNLA) system, developed to evaluate linguistic deficits in aphasia. Results indicate that the CLAN does not identify important characteristics of agrammatic production. (100)

Background and Rationale

Individuals with agrammatic aphasia show marked language production deficits at different micro-structural levels: the utterance, sentence, lexical, bound morpheme, and verb argument structure (VAS) level. Such difficulties are reflected in agrammatic speakers' spontaneous speech and impact their daily communication. Research has emphasized that spontaneous speech analysis systems are important clinical and research tools to classify syndromes, characterize language breakdown patterns, document language changes during recovery, and evaluate treatment effects (Prins & Bastiaanse, 2004; Rochon et al., 2000; Saffran et al., 1989; Thompson et al., 1995a, b).

One quantitative analysis system that has been shown to provide reliable measures for the above purposes is the Northwestern Narrative Language Analysis (NNLA), the application of which has been extended to study other language impairments (Ballard & Thompson, 1999; Faroqi-Shah and Thompson, 2007; Kim and Thompson, 2004; Thompson et al., 1995a, b; Thompson et al., 2012). The NNLA is a comprehensive system for quantifying various aspects of aphasic language production at micro-structural levels, providing codes for several important linguistic variables that are not included in other systems, for example, sentence and embedded clause types, as well as verb argument structure (Thompson, 1995a). However, like other traditional systems, the NNLA is labor-intensive, and requires thorough linguistic knowledge to manually code each linguistic variable.

Recently, AphasiaBank, the world's largest database of aphasic language samples, has provided a set of predominately automated analysis tools: the Codes for the Human Analysis of Transcripts (CHAT) system, the Computerized Language Analysis (CLAN) system and additional utterance-level and lexical-level error codes for typical aphasic language characteristics (MacWhinney et al., 2011). Therefore, these tools have made aphasic language analysis much easier (Forbes et al., 2012; MacWhinney et al., 2010). However, only a few studies of aphasia have used these as analysis tools, and those studies mostly focused on lexical level analyses (Johnson et al., 2012; MacWhinney et al., 2010). No study has compared these tools with other traditional analysis systems. In addition, CLAN only supports analyses roughly

equivalent to the utterance, lexical and bound morpheme levels in the NNLA, and AphasiaBank's error codes are limited to these levels. Sentence and VAS-level deficits are primary agrammatic characteristics (Thompson et al., 1995a, b; Thompson, 2003; Webster et al., 2007). Without these levels, the CLAN may not detect important characteristics of agrammatic speech production.

This study aims to compare the AphasiaBank analysis tools with the NNLA to investigate whether the CLAN system is able to detect error patterns as revealed by NNLA in agrammatic aphasic speakers. Both analysis systems were used to code the same language samples in both healthy and impaired speakers. The results of the study can be used to improve the existing aphasic language analysis systems that serve both clinical and theoretical purposes.

Methods

Participants

Eight individuals with agrammatic aphasia (Age: 45-80; WAB AQ: 65.9-85.4) and nine age-matched controls participated (Age: 37-78) in the study. All participants were native English speakers, and their vision and hearing were within normal range. There was no reported history of neurological or psychological disorders. Table 1 lists the participants' clinical and demographic information.

Procedures

Participants were asked to view a wordless storybook of Cinderella and were then asked to tell the story without the book. All language samples were obtained in a quiet room at the Northwestern University Aphasia and Neurolinguistics Research Laboratory.

All samples were then transcribed and coded following the NNLA (Thompson et al., 2012) and CLAN (MacWhinney, 2000) protocols. For the NNLA, each transcribed utterance was manually coded at five levels: the utterance, sentence, lexical, bound morpheme, and VAS level. On the other hand, the CLAN required manual coding on errors only; analyses of utterance, lexical and bound morpheme levels were automatically performed when given appropriate commands.

Data inclusion criteria were different in the two analysis systems. Exact repetitions, revisions and interjections (e.g., uh, um) were excluded in both protocols, but the NNLA also excluded direct comments, revisional phrases, and filler conjunctions at the beginning of sentences. Therefore, the samples for different analysis systems were slightly different in size. See below for an example.

> NNLA: ~~and uh slipper I mean~~ glass slipper ~~I think so~~.
> CLAN: and ~~uh slipper~~ I mean glass slipper I think so.

Results

NNLA: between-group comparison

The NNLA indicated that the agrammatic individuals exhibit deficits at all five micro-structural levels. Overall, the agrammatic individuals showed significantly lower MLU and lower speech rate. At the utterance and sentence levels, the agrammatic speakers produced almost as many

utterances as control participants, but the patients produced significantly fewer utterances with verbs, only 44.5% of which were grammatical with neither syntactic nor semantic flaws. The patients' sentence production was also significantly less complex. They exhibited lexical impairments, especially in verb production. Specifically, they produced significantly higher noun-to-verb ratios, and marginally significant higher open-to-close class word ratios. At the bound morpheme level, agrammatic speakers' accuracy scores on the production of regular and irregular inflectional morphemes were significantly lower. Finally, the patients showed a significant VAS deficit. All results in this section are detailed in Table 2-5.

CLAN: between-group comparisons

The CLAN automatically documents the frequency counts of linguistic variables at the lexical and bound morpheme levels. The output of the analyses showed production deficits in agrammatism at utterance, lexical and bound morpheme levels. The results of this set of analyses are shown in Table 6-7. Different from the NNLA results, the CLAN was not able to detect between-group statistical differences for noun-to-verb ratios and open-to-close class word ratios. In addition, although the CLAN showed an overall lower frequency counts of all linguistic variables, this may reflect the difference in sample size. Finally, different from the NNLA, the CLAN did not provide accuracy data.

The NNLA vs. CLAN

Table 8 is a direct comparison between the overlapping output measures from the two different systems. The NNLA significantly differs from the CLAN only in the total numbers of ungrammatical sentences, conjunctions, modals and particles. The NNLA identified a significantly greater number of ungrammatical sentences in the same speech samples. The difference stems from different criteria for syntactic errors in the two systems. In addition, the differences in the frequency counts of the lexical items were predicted, because the two systems had different data inclusion criteria, and analyzed some lexical items differently. For example, the NNLA does not include filler conjunctions into analyses, but the CLAN does. In addition, NNLA codes phrases like 'be going to' as a modal, while the CLAN codes the same modal phrase as separate lexical items.

Discussion

The results suggest that while both coding systems have advantages, the NNLA is more sensitive to agrammatic characteristics, and is able to identify all possible micro-structural deficits in agrammatic aphasia. The CLAN is a highly customizable set of tools; with some modifications and addition of new codes, the CLAN has potential to be as sensitive as the NNLA, and could become a useful tool for researchers and clinicians. (1146)

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Tables

Table 1

Clinical and demographic data of the individual agrammatic participants

*Months

Participant		**P01**	**P02**	**P03**	**P04**	**P05**	**P06**	**P07**	**P08**	**Patients mean**	**Controls mean**
Age at testing		45	47	68	80	54	70	57	45	58	57
Gender		M	F	M	F	M	M	M	F	M=5; F=3	M=6; F=4
Handness		R	R	R	R	R	R	R	R		
Education		17	16	18	16	21	18	14	16	17	17.11
Post onset*		3;0	1;7	14;3	3;0	2;6	9;11	18;0	2;3		
WAB	Fluency	5	4	4	4	5	5	4	5	4.5	
	Auditory Comprehension	9.2	6.75	7.65	9.7	8.95	10	7.4	7.8	8.46.353	
	Repetition	6.8	8.1	7.6	7.6	9.8	9.2	8.9	9.4	3.6	
	Naming	10	5.1	8.8	8.5	9.6	9.5	8.6	7.6	6.3	
	AQ	80	65.9	73	77.6	82.7	85.4	75.8	77.6	77.25	
SPPT	Canonical	20%	47%	47%	53%	100%	100%	67%	53%	61%	
	Non Canonical	0%	0%	40%	47%	73%	53%	60%	20%	37%	
ASPT	arguments	80%	88%	94%	98%	97%	100%	96%	88%	93%	
	words	98%	92%	97%	100%	100%	100%	86%	94%	96%	
NAVS	VNT	38%	29%	86%	91%	100%	100%	88%	82%	77%	
	VCT	100%	97%	100%	100%	100%	100%	100%	100%	100%	

Table 2

The NNLA General measures

	Agrammatic		**Normal Control**			
	Mean	**SD**	**Mean**	**SD**	**Z**	**P**
Mean Length of utterance (MLU)	6.66	.79	12.15	2.53	-3.55	.00
Word per minute (WPM)	58.75	20.61	121.40	19.25	-3.10	.00
Type token ratio (TTR)	.48	.08	.41	.06	-1.87	.06

Table 3

The NNLA Utterance and sentence level measures

	Agrammatic		**Normal Control**			
	Mean	**SD**	**Mean**	**SD**	**Z**	**P**
Utterance level						
Total number of utterances	41.63	25.96	45.30	21.67	-.76	0.45
Total number of utterances with verbs	33.50	21.22	44.30	20.76	-1.38	0.17*

Proportion of complete sentences with correct syntax and semantics	44.61	17.72	97.21	3.25	-3.57	0.00*
Proportion of ungrammatical sentences with syntactic flaw	49.73	17.76	2.18	3.29	-3.62	0.00*
Proportion of ungrammatical sentences with semantic flaw	11.90	8.47	.23	.72	-3.14	0.00*
Proportion of abandoned sentences	4.79	5.51	.23	.72	-2.49	0.01*
Sentence Level						
Sentence complexity ratio	.24	.11	.82	.26	-3.55	0.00*
Number of embedded clauses per sentence	.19	.09	.71	.20	-3.55	0.00*

Table 4
The NNLA Lexical-level and bound Morpheme- level measures

	Non-fluent		**Normal**			
	Mean	**SD**	**Mean**	**SD**	**Z**	**P**
Lexical level						
Total # of words	235.13	168.17	469.30	197.60	-2.22	.03*
Total # of open class words	124.63	85.88	230.20	106.18	-2.22	.03*
Total # of close class words	110.50	84.91	239.10	92.37	-2.49	.01*
Total # of nouns	56.38	36.54	88.20	33.99	-1.60	.11
Total # verbs	44.00	29.57	84.00	36.41	-2.22	.03*
Open-to-close class word ratio	1.25	.48	.95	.12	-1.87	.06+
N-to-V ratio	1.29	.30	1.07	.13	-1.95	.05*
Morphological Level						
Proportion of correct regular inflection	86.74	10.94	99.23	2.43	-2.93	.00*
Proportion of correct irregular inflection	73.78	33.63	86.74	10.94	-3.37	.00*

Table 5
The NNLA VAS-Level Measures

	Non-fluent		**Normal**			
	Mean	**SD**	**Mean**	**SD**	**Z**	**P**
Total # of 1-place verbs	11.25	7.13	25.20	8.51	-2.94	0.00*
Total # of 2-place verbs	25.75	20.81	53.70	27.97	-2.18	0.03*

Total # of 3-place verbs	1.50	1.77	4.30	2.16	-2.47	0.01*
Proportion of 1-place verbs with correct AS	89.31	11.27	100.00	.00	-2.81	0.00*
Proportion of 2-place verbs with correct AS	89.78	5.19	100.00	.00	-3.54	0.00*
Proportion of 3-place verbs with correct AS	88.28	7.42	99.00	3.16	-3.14	0.00*

Table 6
The CLAN General and utterance level measures

	Non-fluent		**Normal**			
	Mean	**SD**	**Mean**	**SD**	**Z**	**P**
General measures						
Mean Length of utterance	6.63	1.00	13.33	2.49	-3.55	0.00*
Type token ratio	.40	.05	.40	.05	0.00	1.00
Utterance level measures						
Total # of utterances	50.13	28.44	45.70	21.39	-0.27	0.79
Total # of flawed sentences	17.50	7.95	.10	.32	-3.80	0.00*
Total # of clauses per sentence	.70	.12	1.62	.35	-3.55	0.00*

Table 7 The CLAN lexical level measures

	Non-fluent		**Normal**			
	Mean	**SD**	**Mean**	**SD**	**Z**	**P**
Lexical level						
Total # of words	298.75	191.04	515.80	210.25	-2.22	0.03*
Total # of open class words	139.75	86.86	234.20	97.73	-2.09	0.04*
Total # of close class words	132.38	83.09	239.70	78.08	-2.31	0.02*
Total # of nouns	67.13	39.24	102.60	42.95	-1.42	0.15
Total # verbs	41.75	27.77	74.40	27.46	-2.22	0.03*
N-to-V ratio	1.73	.55	1.39	.23	-1.78	0.08
Open-to-close class word ratio	1.10	.36	.96	.13	-1.24	0.21
Morphological Level						

Total # of regular inflection	9.88	6.60	20.60	14.48	-1.65	0.10
Total # of irregular forms	16.75	18.65	26.90	13.76	-1.20	0.23
Total # of regular plural markers	13.13	10.16	13.20	7.36	-0.18	0.86
Total # of irregular plural forms	1.75	1.91	3.00	1.63	-1.45	0.15
Total # of regular aspect markers	8.75	5.70	10.50	6.04	-0.76	0.45
Total # of irregular aspect forms	1.00	1.07	1.90	1.45	-1.33	0.18

Table 8 Quantitative Comparisons between NNLA and CLAN

	NNLA		**CLAN**			
	Mean	**SD**	**Mean**	**SD**	**Z**	**P**
General measures						
Mean Length of utterance	41.63	25.96	6.63	1.00	-0.11	0.92
Type token ratio	.48	.08	.40	.05	-1.89	0.06
Utterance level measures						
Number of utterances	34.70	19.88	39.1	21.91	-1.16	0.25
Number of ungrammatical sentences	55.38	17.78	17.50	7.95	-3.37	0.00*
Lexical level measures						
Total # of words	235.13	168.17	298.75	191.04	-1.16	0.25
Total # of nouns	55.75	35.54	67.13	39.24	-0.74	0.46
Total # of verbs	43.88	29.36	41.75	27.77	-0.32	0.75
Total # of adjectives	9.75	9.25	8.75	9.11	-0.53	0.60
Total # of adverbs	14.38	14.56	22.13	16.00	-1.26	0.21
Total # of open class words	124.63	85.88	139.75	86.86	-0.53	0.60
Total # of determiners	31.38	22.87	40.25	23.46	-1.37	0.17
Total # of pronouns	24.75	26.36	26.00	24.32	-0.47	0.64
Total # of auxiliaries	7.88	7.08	5.88	5.44	-0.63	0.53
Total # of conjunctions	8.25	7.85	27.38	22.44	-2.42	0.02*
Total # of modals	2.63	3.16	.13	.35	-2.94	0.00*

Total # of prepositions	16.13	13.41	21.25	14.83	-0.79	0.43
Total # of negation markers	1.75	1.49	1.75	1.49	-0.05	0.96
Total # of infinitival markers	2.75	3.49	3.25	3.24	-0.65	0.52
Total # of quantifiers	5.13	2.53	5.38	2.33	-0.32	0.75
Total # of WH-words	.75	.89	1.13	1.36	-0.45	0.65
Total # of prt	1.88	1.25	.00	.00	-3.25	0.00*
Total # of closed class words	110.50	84.91	132.38	83.09	-0.74	0.46
Bound morpheme measures						
Comparative suffixes	.13	.35	.13	.35	0.00	1.00
Superlative suffixes	.00	.00	.00	.00	0.00	1.00
Possessive markers	.75	1.49	1.13	1.36	-1.05	0.30
Regular plural markers	9.88	10.23	13.13	10.16	-0.79	0.43
Irregular plural forms	1.13	1.13	1.75	1.91	-0.49	0.62
3rd person present tense markers	3.75	3.73	4.88	7.20	-0.21	.83
Regular past tense markers	5.13	4.76	5.00	5.10	-0.11	0.92
Irregular past tense markers	14.13	15.57	16.75	18.65	-0.16	0.87
Regular perfect aspect markers	6.25	5.06	7.13	5.28	-0.42	0.67
Irregular perfect participles	1.00	1.41	2.63	2.33	-1.72	0.08
Progressive aspect markers	.25	.46	1.00	1.07	-1.65	0.10