Varieties of linguistic complexity in a standardized assessment of language performance

BACKGROUND

Impaired comprehension of sentence-level linguistic material (both listening and reading) is a common feature of language performance among persons with aphasia (PWA) (Kertesz, 2001) and is considered essential for aphasia diagnosis (McNeil & Pratt, 2001). The Computerized Revised Token Test (CRTT; McNeil, et al., 2010) is an assessment tool which targets sentence comprehension performance among a variety of populations. It presents readers or listeners with commands that ask them to touch and manipulate colored shapes (tokens) on a computer screen. The test employs a 15-point multidimensional scoring system to measure comprehension success, based on how quickly and accurately listeners/readers carry out the commands (McNeil & Prescott, 1978).

The CRTT manipulates the linguistic demands of sentence stimuli by systematically increasing the length and complexity of the sentences across subtests. It has been shown to be highly sensitive both to the presence of aphasia and to the effects of increasing complexity on sentence comprehension. For example, PWA exhibit poorer CRTT scores than unimpaired controls (Sung, et al., 2011), and commands involving greater syntactic complexity (such as commands with ditransitive verbs like “put” compared to commands with transitive verbs like “touch”) also elicit lower CRTT scores (Eberwein, et al., 2007). Furthermore, reading-based versions of the CRTT (CRTT-R) have shown on-line effects of increasing complexity: readers (both PWA and unimpaired adults) exhibit longer reading times for a head noun when the noun phrase containing it has two adjectives rather than one (“the black square” vs. “the little black square”: Sung, et al., 2011).

However, the linguistic-complexity manipulations employed to date in the CRTT-R – verb/command type, adjectival padding – may be insufficiently challenging to detect milder levels of language impairment. Furthermore, they are different from the structures which are assumed to be the locus of sentence-level language impairments in aphasia under many theories of aphasia (e.g., Grodzinsky, 1990; Mauner, et al., 1993). The CRTT-R could be made more theoretically powerful and diagnostically useful by supplementing its current linguistic-complexity manipulations with more challenging and theoretically targeted structural manipulations.

The current study adapted the CRTT-R by adding three different linguistic-complexity manipulations to the commands employed in the standard version of the test. Each of the manipulations was expected to increase the difficulty of the CRTT-R by increasing the complexity of the linguistic calculations required to successfully complete the test. The goal of the study was to determine which of the manipulations created greater demands on readers, and to determine which measures exhibited greatest sensitivity to these additional linguistic demands.

METHODS

Thirty unimpaired adults (Table 1) and 25 PWA (Table 2) completed a modified reading version of the CRTT-R (described below). The PWA met the definition and criteria for aphasia specified by McNeil and Pratt (2001), as evidenced by their performance on the *Porch Index of Communicative Ability* (*PICA*) (Porch, 2001) or the *Western Aphasia Battery (WAB)* (Kertesz, 2001). The unimpaired control group had no history of brain injury, a self-report of normal language development and/or PICA overall performance at or above the range established for normal adults (13.86) (Duffy & Keith, 1980). All participants were administered the Digit Span test from the Wechsler Memory Scale (Wechsler, 1981), and the Trail Making Test, Parts A and B (Reitan, 1958).

The basic CRTT-R was supplemented with three linguistic-complexity manipulations: an active-passive contrast (1a-b); a canonical versus non-canonical ordering of adverbial clauses, derived from Subtests IX and X of the RTT (2a-b); and a novel sentence type involving discontinuous adjective-noun dependencies (3a-b).

(1)	a. The black circle has touched the white square.	(active)
	b. The white square was touched by the black circle.	(passive)
(2)	a. Touch the black circle before you touch the white square.	(canonical order)
	b. Before you touch the black circle touch the white square.	(non-canonical order)
(3)	a. Touch the black circle and the white square.	(imperative)
	b. Touch the black and white circle and square.	(discontinuous)

Passive sentences (1b) are more syntactically complex than active sentences (Chomsky, 1967), and impaired performance on comprehension of passives is a hallmark of sentence-comprehension impairments in aphasia (viz. Kay, et al., 1993; Love & Oster, 2002). Sentences with non-canonical adverbial-clause ordering (2b) require readers to hold one clause/action in memory while processing another, and they are difficult for unimpaired adults (Mandler, 1986) and elicit poor performance among PWA on standardized tests like the RTT (McNeil & Prescott, 1978) and the WAB (Kertesz, 2001). Discontinuous-dependency sentences (3b) are also more syntactically complex than corresponding simple imperatives (3a), and connecting non-adjacent words which are linguistically related (like the adjectives and nouns in these sentences) imposes a significant processing cost for unimpaired adults (Gibson, 1998).

Participants read each sentence in a word-by-word, self-paced reading format. After each sentence, they carried out the action described in the sentence. Reading times for each word were collected and analyzed (reflecting on-line processing), as were CRTT-R scores for the whole sentence (reflecting off-line comprehension success).

RESULTS

Off-line measures: CRTT-R scores were lower for PWA than for controls, for all three linguistic-complexity manipulations. However, the three manipulations elicited qualitatively different patterns of results. For the active-passive manipulation (1a-b), passives elicited lower scores than actives (main effect of structure, $p<.05$) and the disadvantage for passives was larger for PWA than for controls (significant interaction of structure and group, $p<.05$). For the discontinuous-dependency manipulation (3a-b), discontinuous sentences elicited lower CRTT-R scores than corresponding imperatives (main effect of structure, $p<.05$), and the disadvantage for discontinuous sentences was larger for PWA than for controls (significant interaction of structure and group, $p<.05$). In contrast, there was no difference in CRTT-R scores between the canonical and non-canonical adverbial sentences (2a-b).

On-line measures: Reading times for the head NPs (the shape words, point at which significant on-line complexity effects appeared in previous studies: Sung, et al., 2011) were compared for each manipulation. For the active-passive manipulation, shape-word reading times were faster for passives than for actives (main effect of structure, $p<.05$). For the noncanonical adverbial sentences, the hypothetically more difficult noncanonical sentences also elicited faster shape-word reading times (main effect of structure, $p<.05$). For the discontinuous-dependency sentences, neither discontinuous nor imperative sentences elicited reliably faster shape-word reading times.

DISCUSSION

These results suggest that the CRTT-R can be augmented with manipulations that tax linguistic computations, increasing its potential sensitivity as a diagnostic instrument. The augmented version of the CRTT-R elicited poorer performance for PWA than for unimpaired controls, indicating that it remains sensitive to the presence of aphasia. Furthermore, among the linguistic-complexity manipulations tested here, those that involve complex syntax (passives, discontinuous dependencies) show greater promise than those which simply require participants to hold one clause in memory while another is processed (noncanonical adverbial sentences). While the CRTT-R and its multidimensional scoring system is clearly sensitive to the effects of linguistic complexity, including passive syntax which is especially challenging for PWA (e.g., Grodzinsky, 2000), current versions of the task do not yet permit us to localize when these manipulations have their effects during on-line processing. Further work is required to explain the current patterns of on-line reading times, which go in the opposite direction of the off-line effects of linguistic complexity found for passives and discontinuous dependencies.

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Table 1: Demographic and descriptive measures for unimpaired participants

Control Group	**Age (Years)**	**Education (Years)**	**Gender**	**PICA- %ile WAB – AQ****	**Digit Span - Forward**	**Digit Span - Backward**	**TMT - A**	**TMT - B**
1	50	16	M	35	10	6	16	43
2	58	13	F	45	11	10	19	36
3	69	12	M	50	11	12	21	51
4	41	12	M	25	10	9	12	40
5	55	14	F	25	7	7	19	49
6	80	14	M	10	11	12	52	100
7	55	16	M	30	8	6	37	97
8	56	16	F	30	9	6	33	87
9	83	16	M	15	10	8	33	69
10	85	18	F	25	8	8	33	81
11	76	12	M	10	6	4	47	108
12	77	18	M	60	11	8	34	85
13	80	12	M	35	8	7	61	81
14	78	12	F	15	8	6	19	54
15	54	16	M	35	7	6	24	59
16	25	14	M	----**	25**	**	21	48
17	42	16	M	----**	30**	**	19	84
18	60	16	F	----**	47**	**	25	66
19	63	16	F	----**	44**	**	19	46
20	69	18	M	----**	28**	**	19	56
21	73	16	F	----**	28**	**	32	80
22	69	16	F	----**	34**	**	33	67
23	54	7	M	----**	76**	**	28	90
24	57	18	F	----**	44**	**	24	70
25	60	18	F	----**	95**	**	34	55
26	61	16	F	----**	56**	**	27	59
27	50	18	F	----**	110**	**	17	30
28	62	18	M	----**	24**	**	18	47
29	64	15	F	----**	57**	**	38	59
Mean	62	15	F;14/ M;15	29.7	9/ 49.9**	7.7	28	65
SD	14	3		14.5	1.7/ 25.9**	2.3	11	21

PICA=Porch index of Communicative Ability (Porch, 2001); M=Male; F=Female; TMT=Trail Making Test (Reitan, 1958); Digit Span=maximum recalled items; *=WAB (Western Aphasia Battery Aphasia Quotient); **=WAIS-III digit span score -memory scale form 1.

Table 2: Demographic and descriptive measures for PWA

PWA Group	Age (Years)	Education (Years)	Gender	PICA-%ile / WAB –AQ*	MPO	Digit Span - Forward	Digit Span - Backward	TMT - A	TMT - B
1	55	16	F	81	362	7	4	33	114
2	75	14	F	79	369	8	5	56	143
3	47	14	F	72	36	2	4	26	103
4	50	18	F	90	19	4	4	64	128
5	58	17	M	71	57	7	4	52	144
6	42	18	M	66	37	4	2	27	157
7	63	16	M	69	48	4	2	40	247
8	71	10	F	71	48	2	2	99	257
9	67	13	F	74	492	6	4	142	468
10	64	15	M	75	73	5	5	34	193
11	54	18	F	30	22	8	4	41	55
12	37	16	M	38	76	2	2	233	>300
13	59	18	M	62	20	1	1	191	>300
14	54	14	M	60	154	1	2	85	282
15	57	14	M	52	24	0	2	120	>300
16	52	15	M	88*	-	7**	**	31	81
17	66	21	M	86.8*	-	0**	**	76	176
18	71	25	M	32.7*	-	0**	**	61	122
19	59	17	M	79.3*	-	6**	**	62	132
20	66	17	M	80.8*	-	27**	**	37	123
21	60	16	M	19.16*	-	0**	**	31	65
22	72	18	M	77.4*	-	0**	**	40	124
23	47	12	M	92.8*	-	31**	**	52	61
24	51	16	M	92.4*	-	70**	**	35	76
25	68	20+	M	91*	-	40**	**	43	137
Mean	59	16	F:7/M:18	PICA: 66 *WAB: 74	122	4.1 18.1**	3.1	68	172
SD	10	3			154	2.7 23.6**	1.3	52	100

PICA=Porch index of Communicative Ability (Porch, 2001); MPO=Months Post Onset; M=Male; F=Female; TMT=Trail Making Test (Reitan, 1958); Digit Span=maximum recalled items; *=WAB (Western Aphasia Battery Aphasia Quotient); **=WAIS-III digit span score - memory scale form 1.