Relationships between Working Memory Capacity and Listening and Reading Sentence Comprehension in Normal Elderly Individuals and Persons with Aphasia

Abstract

The purposes of the study are to investigate whether working memory (WM) capacity significantly predicts performance on auditory and reading comprehension tasks for aphasic individuals, and to examine whether WM-group differences between low and high WM groups emerge in demanding comprehension tasks. The results revealed that WM capacity significantly predicted performance on an auditory comprehension task and on a reading comprehension task presented with a self-paced moving window method. WM group effects emerged especially under the subtests with more linguistic elements and these findings are consistent with the WM capacity model (Just & Carpenter, 1992).

Introduction

Regardless of whether language is written or spoken, the input to the comprehender unfolds over time, and incoming material must be related to previously-encountered material for successful comprehension. Language comprehension must therefore involve a temporary storage and processing system for assembling and computing inputs (Waters & Caplan, 2005). Working memory (WM) has received considerable attention as a possible cognitive construct underlying language processing and comprehension since Baddeley and Hitch (1974) proposed that WM consisted of temporary storage and processing components responsible for various cognitive tasks. Just and Carpenter (1992) proposed a WM capacity model, which suggested that WM capacity effects emerge only when the capacity available either for storage or processing is exceeded. WM capacity may be measured by WM span tasks such as a reading/listening span task (Daneman and Carpenter, 1980). A series of studies has found that WM span measures are correlated with reading and auditory comprehension tasks in normal adults (e.g., Daneman and Merikle, 1996) as well as in persons with aphasia (PWA) (e.g., Caspari Parkinson, LaPointe, & Katz, 1998).

WM demands have been manipulated in several ways, such as by adding concurrent memory load to sentence processing and/or by manipulating syntactic complexity. Another way of manipulating WM loads is to add extra verbal material such as padding adjectives, prepositional or adverbial phrases like that used in the *Revised Token Test* (*RTT*; McNeil & Prescott, 1978), which varies the number of linguistic units across ten subtests (Haarmann et al., 1997). Recently, the *RTT* has been computerized (*CRTT*) which allows for increased control over stimulus presentation, response scoring and quantification (Eberwein et al., 2007). The purposes of the current study are:

1) To examine which of the following factors significantly predict performance on listening and reading comprehension on the CRTT in PWA:
   - a. WM, as assessed by a listening WM span task (Tompkins, Bloise, Timko, & Baumgaertner, 1994)
   - b. Overall aphasia severity, as measured by *Porch Index of Communicative Ability* (*PICA*) (Porch, 1981)
   - c. Overall reading ability, as measured by *Reading Comprehension Battery for Aphasia* (*RCBA*; LaPointe & Horner, 1979)

2) To investigate whether WM-group differences between low and high span groups emerge more clearly on more complex subtests of the CRTT, with more verbal material, than for less complex subtests.

Method

Twenty individuals with aphasia who were defined by their performance on the *PICA*, the *CRTT* and on an immediate and delayed language recall task of the *Assessment Battery of Communication in Dementia* (Bayles & Tomoeda, 1993) completed a listening version of the WM span task (Tompkins et al., 1994), *PICA, RCBA* and four different conditions of the *CRTT*. Biographical and selection data are summarized for PWA in **Table 1**.

All the participants completed the *CRTT* in four different conditions: one listening version, with commands presented acoustically, and three reading versions (*CRTT*-reading; *CRTT*-R), with the commands presented visually. In the auditory condition, commands were pre-recorded and presented acoustically via loudspeakers at 75dB SPL as measured at the level of each participant's ear. In the reading conditions, commands were presented in a textbox at the bottom of a touch-screen with three different stimulus presentation methods: 1) full-sentence presentation (*CRTT-R-FS*); 2) participant-paced word-by-word moving window reading with cumulative presentation, with all words remaining on the screen (word constant; *CRTT-R-WC*); and 3) participant-paced word-by-word moving window presentation, with each previous word disappearing with the onset of the following word (word fade; *CRTT-R-WF*).

Four different methods were employed based on the assumption that the auditory and *CRTT-R-WF* conditions employ different modalities (auditory vs. visual) but are similar in making information only temporarily available. The *CRTT-R-FS* condition is the most analogous to natural reading, and both *CRTT-R-FS* and *CRTT-R-WC* conditions are assumed to be less memory demanding compared to the auditory and *CRTT-R-WF* conditions, since participants may re-read previous material as needed.

Results

In order to investigate which WM, overall aphasic severity, and reading ability factors significantly predicted the performance on the *CRTT* conditions, a stepwise multiple regression analysis was performed. Performance on the WM task best predicted overall *CRTT* scores in the auditory and *CRTT-R-WF* conditions, whereas, *RCBA* scores best predicted performance in the FS condition and *PICA* overall scores best predicted performance in the *CRTT-R-WC* condition ($p<.05$) (Table 2). In addition, WM significantly correlated with *PICA* and *RCBA* overall scores ($r=.70$ and $r=.69$, respectively). More detailed information on the correlation coefficients among the predictor variables and each *CRTT* condition is summarized in **Table 3**.

To further examine the impact of working memory, the 20 PWA were classified into low (n=10) and high (n=10) WM groups based on a median split because the distribution of WM scores (a total number of items recalled) was bimodal. The descriptive data for the two groups are presented in **Table 4**. Two-way mixed ANOVAs with WM group as a between-subject factor and the *CRTT*-subtest score as a within-subject factor were performed only for the auditory and *CRTT-R-WF* conditions, because only the overall scores from these two conditions were significantly predicted by WM in the regression analysis. In both auditory and *CRTT-R-WF* conditions, significant main effects of subtest and WM-group were found, as well as significant interactions of subtest and WM-group (all *p*s<.05). The low WM-group performed significantly more poorly on both the *CRTT* and *CRTT-R-WF* conditions than the high WM-group. This was most evident on more complex subtests that contained either prepositional phrases or adverbial clauses. Post-hoc comparisons with Bonferroni adjusted alpha levels revealed that the WM-group differences emerged in subtest 5 and 6 of the auditory-*CRTT* condition and in subtest 9 of the *CRTT-R-WF* condition ($p<0.005$). Despite the fact that WM-group differences in subtest 5 and 6 of the *CRTT-R-WF* were of greater magnitude than the significant difference for subtest 9, they were not significant ($p=0.006$ and $p=0.008$, respectively), because performance was more variable on subtests 5 and 6, compared to 9. (**Figure 1 and 2**).

Discussion

A listening WM span task significantly predicted overall performance both on the auditory *CRTT* and reading *CRTT-R-WF* conditions. Despite using different modalities, these conditions are similar in making information only temporarily available and therefore require greater WM involvement. In contrast, overall reading ability and aphasic severity better predicted performance on *CRTT-R-FS* and *CRTT-R-WC* conditions than WM. These conditions are closer to naturalistic reading and less memory demanding than *CRTT-R-WF* or auditory *CRTT* since people can go back and re-read sentences as needed. These findings are consistent with the broad class of WM theories (e.g., Baddeley, 1986), which argue that WM construct underlies the ability to maintain and process temporarily available information. The findings of a significant interaction between WM-group and CRTT-subtest are consistent with the WM capacity theory (Just & Carpenter, 1992), which predicts that WM effects manifest themselves only when WM capacity is taxed enough to be exceeded.

References

Baddeley, A., & Hitch, G. (1974). Working memory. In G.A. Bower (Ed.), *Recent advances in learning and motivation* (Vol. 8, pp. 47-90). New York: Academic Press.

Baddeley, A.D. (1986). *Working memory*. New York: Oxford University Press.

Bayles, K.A. & Tomoeda, C.K. (1993). *Arizona Battery for Communication Disorders of Dementia*. Tucson, AZ: Canyonlands Publishing, Inc.

Caspari, I., Parkinson, S. R., LaPointe, L. L., & Katz, R. C. (1998). Working Memory and Aphasia. *Brain and Cognition,* 37, 205-223.

Daneman, M. & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, 19, 450-466.

Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin and Review,* 3, 422-433.

Eberwein, C.A., Pratt, S.R. McNeil, M.R., Fossett, T.R.D., Szuminsky, N.J., & Doyle, P.J. Auditory Performance Characteristics of the Computerized Revised Token Test (CRTT). *Journal of Speech, Language, and Hearing Research, 50*, 865-877.

Haarmann, H. J., Just, M. A., & Carpenter, P. A. (1997). Aphasic sentence comprehension as a resource deficit: a computational approach. *Brain and Language, 59,* 76-120.

Just, M. A. & Carpenter, P. A. (1992). A Capacity Theory of Comprehension: Individual Differences in Working Memory. *Psychological Review, 99*, 122-149.
LaPointe, L. & Horner, J. (1978). *Reading Comprehension Battery for Aphasia*-RCBA.
McNeil, M.R. & Prescott, T.E. (1978). *Revised Token Test*. Austin, Pro-Ed.
Porch, B.E. (1967). *The Porch Index of Communicative Ability*. Palo Alto, CA: Consulting Psychologists Press.
Tompkins, C. A., Bloise, C. G. R., Timko, M. L., & Baumgaertner, A. (1994). Working memory and inference revision in brain-damaged and normally aging adults. *Journal of Speech and Hearing Research*, 37, 896-912.
Waters, G. S. & Caplan, D. (2005). The relationship between age, processing speed, working memory capacity, and language comprehension. *Memory, 13*, 403-413.

Tables

Table 1. Descriptive information of individuals with aphasia

ID	PICA (%ile)	RCBA (OA)	Age	Education	MPO	Gender
A1	73	178	63	14	456	F
A2	76	172	66	12	192	M
A3	66	181	72	14	444	F
A4	72	178	60	16	24	M
A5	86	185	66	13	25	F
A6	84	184	49	16	71	F
A7	66	186	61	16	15	F
A8	76	179	65	12	201	M
A9	57	166	76	12	564	F
A10	88	187	43	14	91	M
A11	69	174	62	16	60	M
A12	89	190	53	18	88	F
A13	71	176	69	10	453	F
A14	88	182	56	18	31	M
A15	69	166	40	18	12	M
A16	89	190	51	18	139	F
A17	83	189	90	12	58	M
A18	59	184	63	18	46	M
A19	70	157	70	12	29	F
A20	76	179	82	16	106	M
Mean	75.35	179.15	62.85	14.75	155.25	(F;10 / M;10)
SD	9.91	8.77	12.31	2.57	175.87	

MPO: Months Post Onset

Table 2. Summary of the results from stepwise multiple regression

CRTT condition	Significant predictor	R-square	Significance
CRTT Auditory	WM	0.357**	0.005
CRTT-R-FS	RCBA	0.325*	0.011
CRTT-R-WC	PICA_OA	0.412**	0.002
CRTT-R-WF	WM	0.361**	0.006

*: significant at $p<.05$
**: significant at $p<.01$

Table 3. Correlation coefficients among the predictors and *CRTT* conditions

	WM	*PICA*_OA	*RCBA*	*CRTT*-Auditory	*CRTT-R-FS*	*CRTT-R-WC*	*CRTT-R-WF*
WM	1.00						
*PICA*_OA	0.70**	1.00					
RCBA	0.69**	0.54*	1.00				
CRTT-Auditory_OA	0.60*	0.35	0.55*	1.00			
CRTT-R-FS_OA	0.45*	0.36	0.57**	0.65**	1.00		
CRTT-R-WC_OA	0.58**	0.64**	0.51**	0.67**	0.65**	1.00	
CRTT-R-WF_OA	0.60**	0.53*	0.52*	0.66**	0.70**	0.88**	1.00

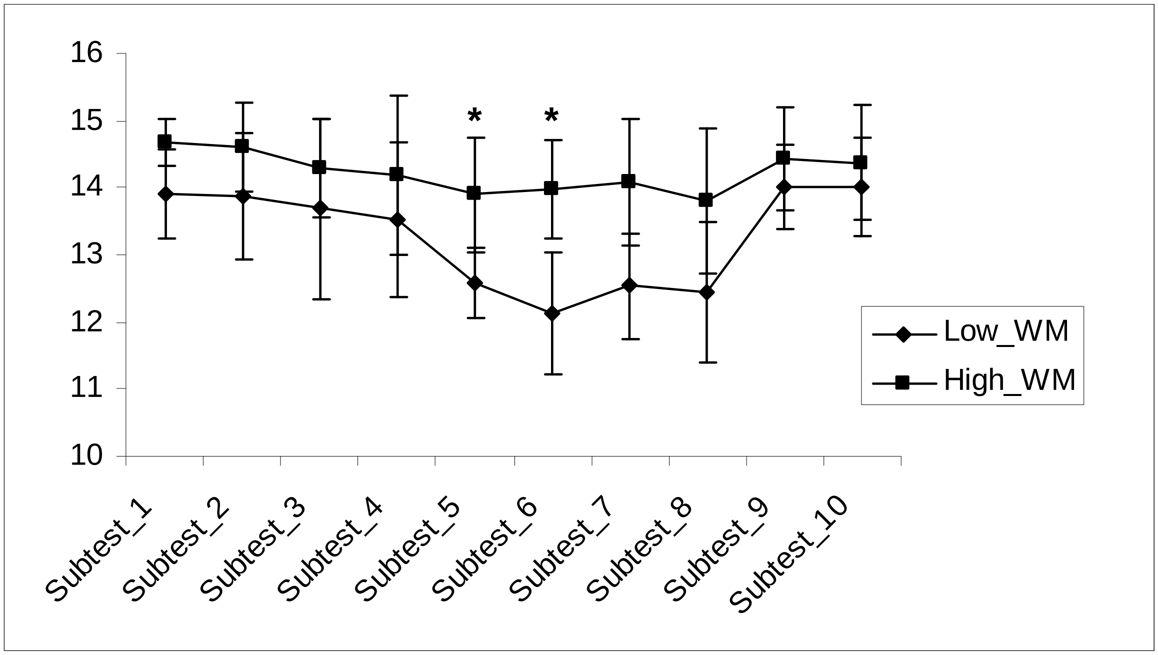
OA means "overall scores"
*significant at $p=.05$,
**significant at $p=.01$

Table 4. Descriptive data with means and standard deviations for each WM-group in both auditory and *CRTT-R-WF* conditions

	CRTT-Auditory	*CRTT-R-WF*
Low WM-group	13.27 (0.23)	12.79 (0.32)
High WM-group	14.23 (0.23)	13.78 (0.30)
Both groups	13.64 (0.75)	13.26 (0.97)

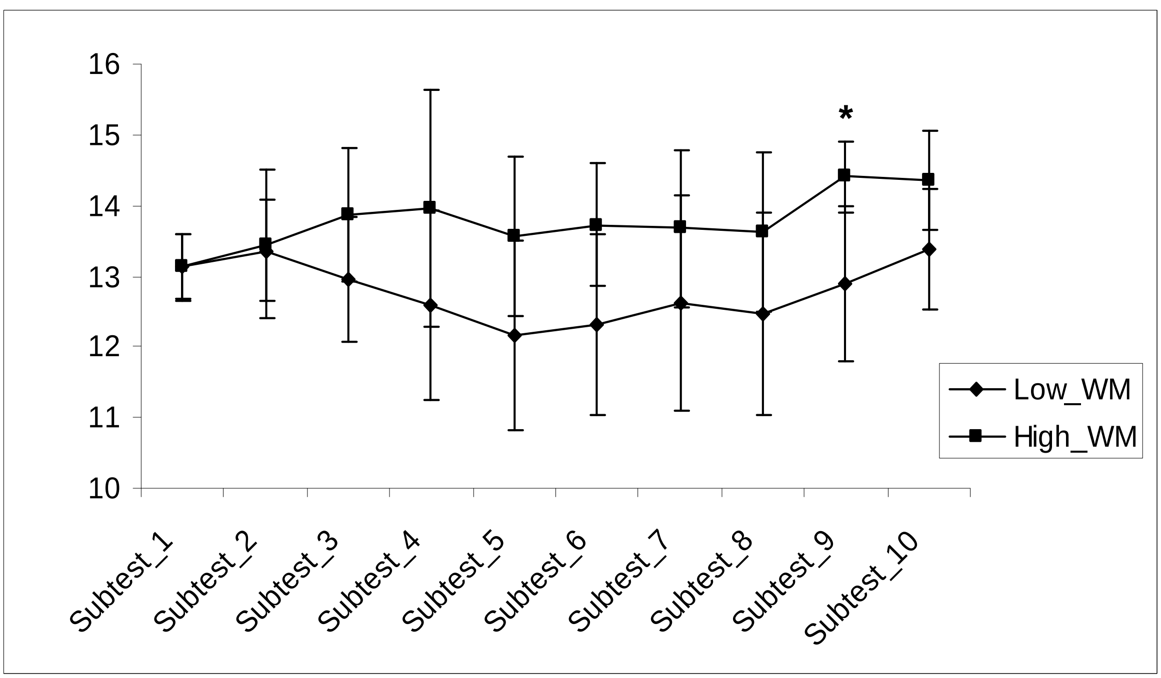
Numbers in parenthesis are standard deviations.

Figure 1. Differences of the scores from each subtest in the auditory *CRTT* between low and high working memory groups



*significant at *p=0.005*,

Figure 2. Differences of the scores from each subtest in the reading *CRTT-R-WF* between low and high working memory groups



*significant at *p=0.005*,