The Effects of Locality on Sentence Comprehension in Persons with Aphasia and Normal Elderly Individuals.

Abstract

Gibson (1998; 2000) argued that the distance between the two linguistic elements to be integrated imposes a critical limitation on working memory (WM). The current study investigated the effects of distance on online and offline reading sentence comprehension in persons with aphasia (PWA) and normal elderly individuals (NEI). The results revealed that NEI showed a relatively systematic increase in online reading times and errors to the yes/no questions as a function of a distance manipulation. In contrast, the effects of distance were not evident in PWA.

Introduction

Many theories have been proposed to account for sentence comprehension deficits in PWA. Some researchers argued that sentence comprehension deficits in PWA are related to limitations on WM (e.g., Caspari et al., 1998; Miyake et al., 1994; Sung et al., 2009). However, the precise nature of WM and its relationship to sentence comprehension remains underspecified, especially in PWA. Formalized in his *locality* theory, Gibson (1998, 2000) argued that the distance or locality between linguistic elements that require integration is a critical factor in WM. Gibson reported that the distance or locality-based "integration cost" predicted online processing times in sentence comprehension in young college students. The "integration cost" is a quantified measure of the WM resources required to incorporate each new lexical item into a current syntactic structure. Gibson hypothesized that the integration cost would be heavily influenced by the distance between a linguistic element and the site to which it is attached. The distance is measured by the number of intervening new discourse referents in the sentence, such as a noun phrase or a tensed verb (Grodner & Gibson, 2005; Warren & Gibson, 2002). However, how the distance-based integration cost accounts for online processing of a sentence has not been investigated in persons with aphasia (PWA) or in normal elderly individuals (NEI).

The purpose of the current research was to investigate the effects of systematically manipulating distance on sentence comprehension in PWA and in an age-matched NEI.

Methods

Twenty PWA (age: mean=60, SD=14) and 30 NEI (age: mean=66, SD=12) participated in the study. The NEI passed vision, memory and language screens, and reported no history of communication, neurological, or psychiatric disorder. The PWA were defined by their performance on the *Porch Index of Communicative Ability* (Porch, 2001), the *Revised Token Test* (McNeil & Prescott, 1978), and the *Assessment Battery of Communication in Dementia* (Bayles & Tomoeda, 1993). Descriptive information of linguistic and cognitive tests was provided in **Table 1** for NEI and **Table 2** for PWA.

All participants read 240 sentences including 120 filler sentences presented using a word-by-word, self-paced reading method. The experimental sentences were constructed by manipulating distance, using three modifier conditions (No modifier, Prepositional Phrase (PP), Relative-Clause (RC)), and two linguistic dependencies (subject-verb (SV) and Filler-Gap (FG)). The main verbs in the SV-dependency and the embedded verbs in the FG-dependency sentences were assumed to be a critical integration cost region for each sentence (Grodner & Gibson, 2005). Integration cost and examples of sentence stimuli for each condition are provided in **Table 3**.

Results

Reading times for the verbs (RT) and errors in yes/no questions served as dependent measures. In order to examine the distance effects, a three-way mixed ANOVA was performed with Group as a between-subject factor and Modifier and Dependency as within-subject factors.

In the error data there were significant main effects for Dependency, $F(1, 48)=195.97$, $p<.000$, with more errors found in the FG than the SV sentence type and for Group, $F(1, 48)=25.03$, $p<.000$, with PWA generating more errors than NEI. There was a significant three-way interaction, $F(2, 96)=3.45$, $p<.05$. As a post-hoc analysis, two separate repeated two-way ANOVAs were computed with Dependency and Modifier as factors for each group. In NEI group, there were significant main effects for Dependency, $F(1, 29)=139.33$, $p<.000$, with more errors in FG than SV, and Modifier, $F(2, 58)=6.31$, $p<.005$, with more errors in RC-modifier than No-, $p<.05$, and PP-modifier, $p<.05$; but no significant difference between No- and PP-modifier. A two-way interaction between Dependency and Modifier was also significant, $F(2, 58)=195.97$, $p<.05$, with more errors in the RC- than No-modifier only in FG-dependency. In PWA, there was a significant main effect for Dependency, $F(1, 19)=69.63$, $p<.000$, with more errors in FG- than SV-dependency. No other effects were significant in the two-way ANOVA. Error data are presented in **Figure 1**.

Given that sentence comprehension was measured using yes/no questions, it was examined whether individuals' performance was significantly better, worse or not different from chance level. The 95% CI was calculated for chance-level performance for the number of errors using binomial probabilities (Marascuilo & Serlin, 1988). No NEI performed at or below chance level in the SV-dependency conditions. However, 50% (n=15) of the NEI performed at chance level in the FG-No and FG-PP conditions. Seventy-seven percent (n=23) performed at chance in the FG-RC condition with the rest of participants (n=7) performing significantly better than chance. Twenty-five percent (n=5) of the PWA performed at chance-level in SV-No, SV-PP, and SV-RC conditions. However, 95% (n=19), 80% (n=16), and 85% (n=17) of the PWA performed at chance level in FG-No, FG-PP, and FG-RC conditions, respectively.

RT data were extracted only from the correct responses and from those participants who showed above-chance-level performance. Due to the very limited and unequal number of participants in the six conditions, the analyses were conducted separately for SV- and FG-dependency conditions.

All NEI participants (n=30) and 13 individuals with aphasia performed above chance in the SV-dependency conditions. A mixed two-way ANOVA was computed, with Modifier as a within-subject factor and Group as a between-subject factor. There was a significant main effect for Group, F(1, 43)=238.91, p<.000, with PWA showing significantly longer verb reading times than NEI. The main effect for Modifier was not significant, F(2, 86)=.32, p=.73. The two-way interaction between Modifier and Group was significant, F(2, 86)=4.38, p<.50. NEI showed significantly longer RTs for the RC modifiers than No and PP modifiers ($p<.05$). However, for PWA, there were no significant differences in RT as a function of modifier type. RTs for the SV-dependency conditions are presented in **Figure 2**.

Inferential statistics were not valid in the FG-dependency conditions for RTs, due to the limited number of observations. The RTs of NEI with above-chance level performance are illustrated in **Figure 3**. They showed increased reading times in the FG-PP condition compared to the FG-No condition. However, the shortest RT was found in the most complex condition (FG-RC). There were one, four, and three PWA who performed significantly better than chance for the FG-No, FG-PP, and FG-RC conditions, respectively. Individual variability was huge, as illustrated in **Figure 4**.

Discussion

Although NEI showed systematic distance effects in errors and RT, the effects of distance were not evident in PWA. PWA generated more errors in the FG- than SV-dependency. However, their sentence comprehension was not affected by the manipulation of the modifiers. Their RT data were difficult to interpret due to the very limited observations for FG-dependency conditions after chance-level performers were excluded from the analyses. One might argue that the high rate of chance-level performance in PWA, especially in the FG conditions, is consistent with specific impairments hypotheses (e.g., Grodzinksy, 2000). However, chance-level performance was observed not only in a majority of individuals with aphasia but also in normal individuals, which is not predicted by those hypotheses. The current results are more consistent with resource-related hypotheses, which suggest that sentence comprehension deficits will manifest themselves regardless of the type of aphasia when individuals' capacity is sufficiently taxed or exceeded, either PWA or NEI (e.g., McNeil, 1981; 1982; Caplan et al., 2007). The current results show that this pattern can also appear for NEI.

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Table 1. Descriptive information of linguistic and cognitive tests for normal elderly individuals

ID	PICA		CRTT-A	CRTT-R-WF	PALPA	NAVS-R	F-D	F-W	B-D	B-W	RAVEN
	OA	%ile									
101	14.43	40	14.68	13.12	40	22	6.6	4.4	5.8	2.8	34
102	14.55	55	13.04	11.42	40	22	7	6	6.8	4.8	33
103	14.67	70	14.04	12.82	39	22	5	4.2	4.6	3.6	32
104	14.26	25	14.35	12.75	39	21	5.6	3.4	5	3.4	30
105	14.11	22	14.25	12.63	40	22	7	5	5	4.2	30
106	14.26	25	14.85	12.88	40	22	6	5.4	4.4	3.2	31
107	14.17	20	14.51	12.58	39	22	7	6.6	7	4.2	31
108	14.01	16	14.74	12.91	39	22	6	5.2	6	5	34
109	14.39	35	14.48	13.07	38	22	5.2	4	4	2.6	25
110	13.97	10	14.57	12.81	39	22	6.4	5.2	5	2.6	33
111	13.89	7	14.69	12.51	40	22	6.6	6	5.6	4.8	33
112	14.4	37	14.86	12.67	40	22	6.6	5.2	5.6	4.8	35
113	14.14	20	14.85	12.92	39	22	5.8	4.8	4.6	3.4	26
114	14.01	17	14.68	12.74	39	22	6.8	5	4.4	3.8	29
115	14.38	35	14.58	12.93	40	22	6.8	5.8	5.4	5.4	32
116	13.99	10	14.43	13.39	39	22	7	5	6.2	5	33
117	14.52	50	14.44	12.92	39	22	7	5.6	4.6	3.8	35
118	14.34	37	14.21	12.88	39	22	7	6	6.6	5	31
119	14.56	55	14.57	13.58	40	22	7	5.6	7	5	36
120	14.15	20	14.67	13.37	37	22	7	6	7	5.4	33
121	14.16	20	14.63	12.8	38	22	7	5.6	6	5	28
122	14.08	15	14.67	12.73	40	22	6.8	5	5.4	4.4	30
123	14.2	23	12.77	13.87	40	22	6.4	5.4	6	4.8	32

124	13.87	5	14.63	12.77	39	22	5	3.6	4.4	3	36
125	14.79	85	14.12	12.71	40	22	6	5.4	4.4	3.8	32
126	14.26	25	14.64	12.94	40	22	6	4.8	5.8	4	33
127	14.1	20	14.07	12.76	39	22	5.8	4.6	4	4	33
128	14.33	33	14.41	12.95	40	22	7	6.8	7	6.8	36
129	14.37	35	13.58	12.95	40	22	7	7	7	6.4	36
130	14.39	35	14.84	12.75	40	22	6.8	5.8	5.8	4.2	31
Mean	14.26	30.07	14.4	12.87	39.37	21.97	6.44	5.28	5.55	4.31	32.1
SD	0.23	18.4	0.5	0.4	0.76	0.18	0.64	0.85	0.99	1.03	2.77

SD = Standard Deviation
PICA = Porch Index of Communicative Ability (PICA) (Porch, 2001)
PICA %ile: Norms for the PICA percentile are from Porch (2001) for PWA and from Duffy and Keith (1980) for NI
CRTT-A = Auditory version of the Computerized Revised Token Test (CRTT) (McNeil, Pratt, Szuminsky et al., 2008)
CRTT-R-WF = A reading version of the CRTT
PALPA = Written Word-Picture Matching subtest from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) (Kay, Lesser, & Coltheart, 1992)
NAVS-R = Northwestern Assessment of Verbs and Sentences-Revised (Thompson et al., 2008)
F-D = Forward digit pointing span task (Martin, Kohen, & Kalinyak-Fliszar, 2008)
F-W = Forward word pointing span task (Martin, Kohen, & Kalinyak-Fliszar, 2008)
B-D = Backward digit pointing span task (Martin, Kohen, & Kalinyak-Fliszar, 2008)
B-W= Backward word pointing span task (Martin, Kohen, & Kalinyak-Fliszar, 2008)
RAVEN = The Raven Coloured Progressive Matrices (Raven, 1956)

Table 2. Descriptive information of linguistic and cognitive tests for persons with aphasia

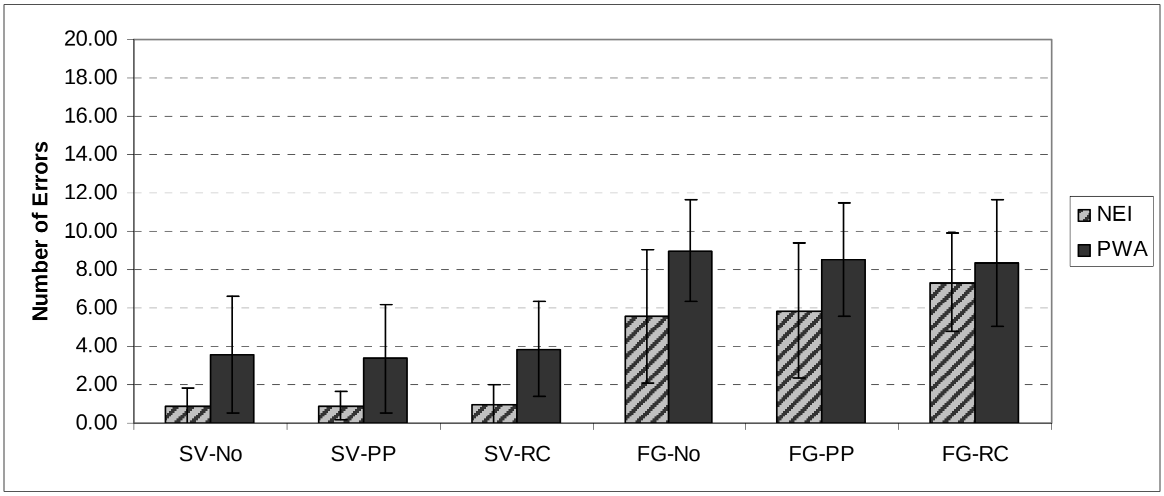
Participant ID	PICA		CRTT-A	CRTT-R-$_{WF}$	PALPA	NAVS-R	F-D	F-W	B-D	B-W	RAVEN
	OA	%ile									
201	11.21	54	11.27	10.67	36	19	3	2.4	2.2	2	30
202	13.14	78	14.38	10.85	40	22	5.8	5.2	3.8	3.8	20
203	11.22	54	12.21	12.28	37	19	2.8	1.8	1.6	1.6	33
204	12.48	69	12.4	10.45	37	21	3.2	2.4	3	2.2	14
205	12.27	66	11.93	12.75	37	22	4.4	3.4	5	3	32
206	14.04	89	13.43	11.72	39	22	6	4.8	3	2.8	33
207	13.21	79	12.99	11.00	40	21	5.6	5	4	4.6	25
208	13.06	77	12.37	12.05	35	21	4.6	2.2	3.8	2.2	33
209	12.73	72	10.93	12.53	39	22	3.4	2.8	4.2	3.4	35
210	13.58	84	14.37	12.6	39	22	5	3.6	3.2	3	23
211	12.85	74	12.44	12.31	40	22	4.4	3.6	4	3	32
212	13.46	82	13.53	12.68	39	22	5.8	5	5	3	32
213	12.52	69	14.31	11.93	40	20	3.6	2.2	2.6	2	12
214	13.86	88	11.6	12.81	37	22	4.8	3.8	3.8	3	34
215	12.77	73	13.02	11.62	40	22	3.8	2.4	2.4	2.4	27
216	14.09	90	14.44	12.71	40	22	4.8	3.2	3.4	2.4	23
217	14.21	92	14.43	13.03	40	22	7	5.6	5	4	34
218	13.04	76	12.91	11.37	40	22	6.2	4.2	4	4	27
219	13.56	84	13.12	12.00	40	22	5	3.8	4.8	3	35
220	13.36	10.07	14.1	12.77	40	22	5	4	3	2.4	34
Mean	13.03	73.00	13.01	12.01	38.75	21.45	4.71	3.57	3.59	2.89	28.40
SD	0.83	18.22	1.11	0.79	1.62	1.00	1.16	1.14	0.97	0.78	6.91

Table 3. Examples of sentence stimuli for each condition with integration cost

Condition	Example of sentence stimuli	"Integration Cost" on the verb (***called***)
SV-No	The nurse ***called*** the doctor in the morning.	1
SV-PP	The nurse from the clinic ***called*** the doctor in the morning.	2
SV-RC	The nurse who was from the clinic ***called*** the doctor in the morning	3
FG-No	The doctor who the nurse ***called*** visited the patient in the morning.	3
FG-PP	The doctor who the nurse from the clinic ***called*** visited the patient in the morning.	4
FG-RC	The doctor who the nurse who was from the clinic ***called*** visited the patient in the morning.	5

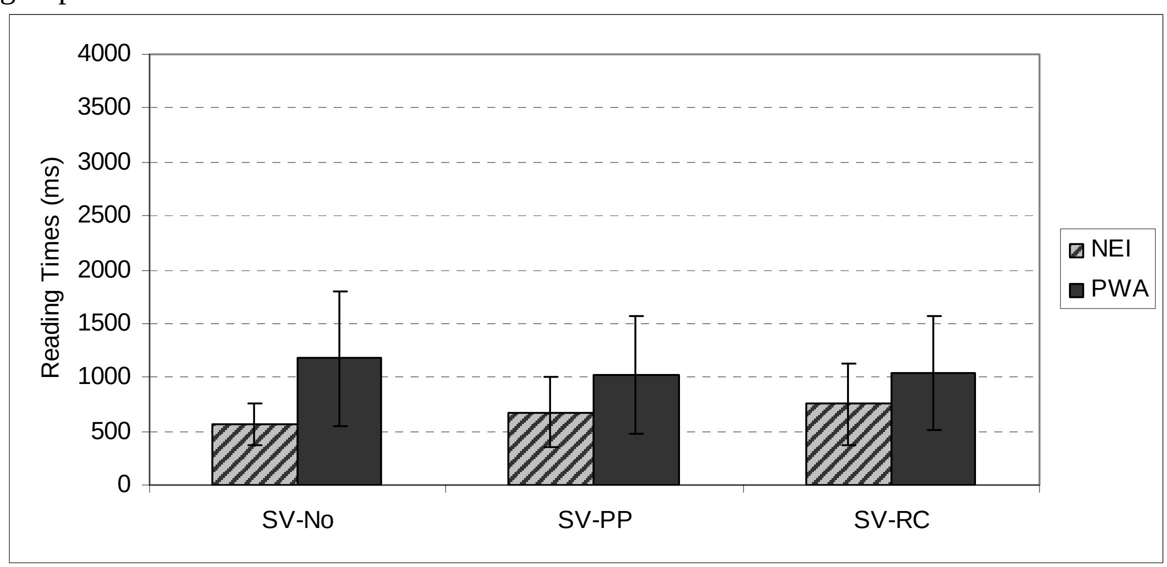
SV-No = Subject-Verb dependency with No modifier
SV-PP = Subject-Verb dependency with Prepositional Phrase modifier
SV-RC = Subject-Verb dependency with Relative Clause modifier
FG-No = Filler-Gap dependency with No modifier
FG-PP = Filler-Gap dependency with Prepositional Phrase modifier
FG-RC = Filler-Gap dependency with Relative Clause modifier

Figure 1. Number of errors to the yes/no questions for each condition in both groups



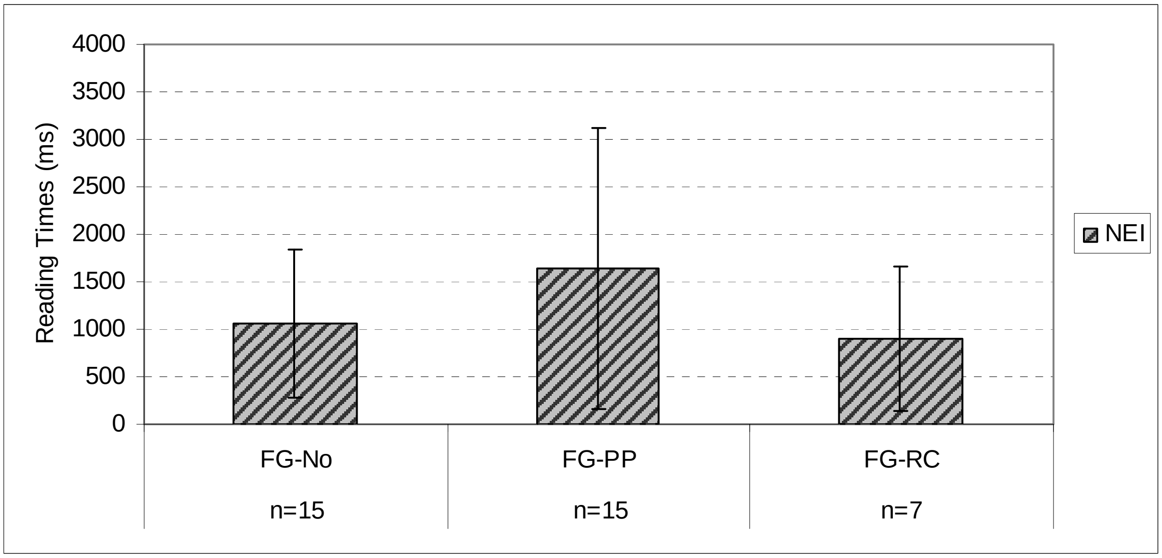
Note: NEI=Normal Elderly Individuals; PWA=Persons with Aphasia; SV-No= Subject-Verb dependency with No modifier; SV-PP= Subject-Verb dependency with Prepositional Phrase modifier; SV-RC=Subject-Verb dependency with Relative-Clause modifier; FG-No= Filler-Gap dependency with No modifier; FG-PP= Filler-Gap dependency with Prepositional Phrase modifier; FG-RC= Filler-Gap dependency with Relative Clause modifier.

Figure 2. Reading times on the verb for Subject-Verb dependency conditions in both groups.



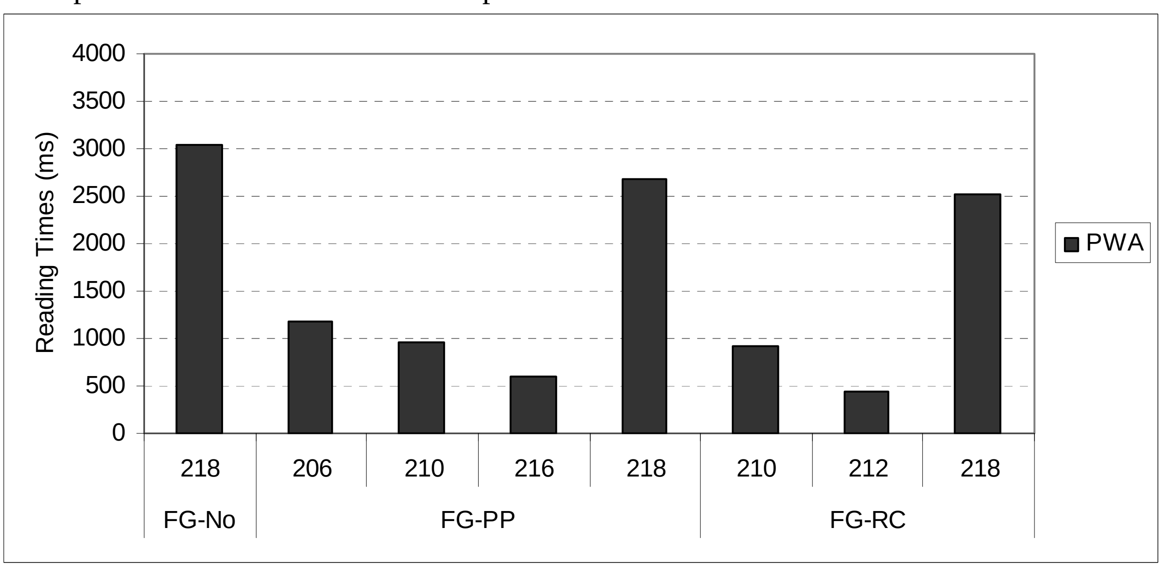
Note: NEI=Normal Elderly Individuals; PWA=Persons with Aphasia; SV-No= Subject-Verb dependency with No modifier; SV-PP= Subject-Verb dependency with Prepositional Phrase modifier; SV-RC=Subject-Verb dependency with Relative-Clause modifier; FG-No= Filler-Gap dependency with No modifier; FG-PP= Filler-Gap dependency with Prepositional Phrase modifier; FG-RC= Filler-Gap dependency with Relative Clause modifier.

Figure 3. Reading times on the verb in the Filler-Gap dependency conditions in normal elderly individuals with above-chance level performance.



Note: NEI=Normal Elderly Individuals; FG-No= Filler-Gap dependency with No modifier; FG-PP= Filler-Gap dependency with Prepositional Phrase modifier; FG-RC= Filler-Gap dependency with Relative Clause modifier.

Figure 4. Reading times on the verb in the Filler-Gap dependency conditions in persons with aphasia with above-chance level performance.



Note: PWA=Persons with Aphasia; FG-No= Filler-Gap dependency with No modifier; FG-PP= Filler-Gap dependency with Prepositional Phrase modifier; FG-RC= Filler-Gap dependency with Relative Clause modifier.