Conflict Resolution and Goal Maintenance Components of Executive Attention are Impaired in Persons With Aphasia: Evidence from the Picture-Word Interference Task.

Background

The relationship between language processing and attention has been a topic of research in linguistics, psychology and speech-language pathology for a very long time. Following the hypothesis that attention (e.g., Kahneman, 1973) may be related to impaired language performance in aphasia (McNeil, 1982), researchers have increasingly investigated this hypothesis (McNeil, Odell, & Tseng, 1991; Murray, 1999; Robin & Rizzo, 1989; Tseng, McNeil, & Milenkovic, 1993).

In order to investigate a causal relationship between attentional deficits and language disorders in PWA, resource utilization and the interaction between task demand and resource capacity must be quantified. Working Memory (WM) has served as the framework for investigating these relationships. That is, WM has been used as the framework for measuring attentional capacity with the assumption that the primary component of WM is executive attention (Engel, Kane & Tuholski, 1999).

Engle, Kane and colleagues (Conway, Kane, & Engle, 2003; Engle & Kane, 2004) have claimed that the core of WM affecting individual differences is EA; not the storage or processing components of WM. To address the function of executive attention in WM, they proposed a two-factor theory composed of goal maintenance (GM) and conflict resolution (CR) (Engle & Kane, 2004). That is, WM is related to the EA ability that supports the active maintenance of goal-relevant information and competition resolution in the face of interference. This attention ability is most critical in interference-rich conditions because correct responding cannot be achieved via automatic spreading activation among memory representations or by habitual responding (Conway, Kane, & Engle, 2003). For instance, experiments using Stroop tasks controlled by interference and proportion of incongruency have revealed that individuals with low WM spans had substantially larger error and response time (RT) interference effects than individuals with high spans. These effects indicated that individuals with low WM span were less efficient in the goal maintenance component of EA and hence had lower WM capacity (Kane & Engle, 2003).

The primary purpose of this study was to compare the performance of PWA and normal controls on neutral, congruent and incongruent conditions in the Picture-Word Interference (PWI) tasks with two proportions of incongruency, conditions among which CR and GM can be differentially assessed.

METHODS

Ten PWA and twenty unimpaired adults completed the experiment (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). The unimpaired control group had no history of brain injury, a self-report of normal language development and PICA overall performance at or above the range established for normal adults (13.86) (Duffy & Keith, 1980). All participants were administered a battery of descriptive tests (Table 1 & 2).

The stimuli for the PWI tasks were made of the 10 high frequency words and matched pictures from two semantic categories (animal and non-animal). The stimuli were created by placing each of these words within a background line-drawn picture that was of high typicality and discriminability.

The PWI task consisted of three conditions. In a congruent condition, each picture appeared with its corresponding name superimposed. In an incongruent condition, the pictures were paired with words from different categories. In a neutral condition, the stimuli consisted of each word surrounded by a polygon, used for controlling possible interference caused by lateral masking. The incongruent trials were delivered in 19 and 73% proportions.

Participants indicated whether the string of letters that appeared on the screen was an animal or non-animal by non-dominant (left) hand key press. RT and Error Rate (ER) served as dependent variables. Before statistical analyses, RTs were normalized with inverse transform (1/RT) and ERs were converted with Aligned Rank Transform (ART; Wobb, Findlater, Gergle, & Higgins, 2011).

RESULT

Conflict Resolution: Group and Condition effects were assessed by comparing the inverse transformed RTs for correct responses among the incongruent, neutral and congruent conditions in the 19% incongruent proportion, using a 2 (Group) × 3 (Conditions) mixed model (see Table 3 & Fig. 1). PWA showed no significant difference in RTs from the NI for the congruent condition. However, the PWA showed significantly longer RTs than the NI in the incongruent condition ($p < .05$).

Goal Maintenance: Group and proportion effects were assessed by comparing ART converted ERs between 19% and 73% incongruent proportions using a 2 (Group) × 2 (Proportion) mixed model (see Table 4 & Fig. 2). PWA showed no significant difference in ERs between two incongruent proportions. However, NI demonstrated significantly more errors in the 19% than in the 73% incongruent trials ($p < .05$).

Iowa Gambling Test: Previous research (Murray, 1999; Tseng, McNeil & Milenkovic, 1993) has shown significant effects for normal control participants but not for PWA on language tasks requiring the computation of proportion of stimuli occurring in a stimulus set. In order to determine whether these two groups had significantly different sensitivity to proportional structure in a non-linguistic-specific task, the Iowa Gambling Test was administered. A Mann-Whitney Test was conducted with total RT and amount of earned money in the Iowa Gambling Test; an indirect measure of risk taken which relies on an appreciation and computation of proportions. There was no significant group difference for total RT ($Z = 0.70$) or amount of money ($Z = 0.48$) spent; suggesting an intact ability to appreciate proportional structure.

DISCUSSION

The major purpose of this study was to examine whether PWA evidenced impaired EA in terms of CR and GM as assessed via the PWI tasks. Results revealed that the PWA demonstrated impaired CR as evidenced by longer RTs on the interference-rich incongruent condition, but not on the non-interference congruent condition in the 19% incongruent proportion compared to the NI group. GM was impaired in the PWA as evidenced by no difference in ERs in the incongruent conditions between the 19% and 73% incongruent proportions relative to significant difference in the NI group. That is, the NI group utilized the incongruent proportion, whereas the PWA were inefficient at maintaining the goal of the PWI task that resulted in no difference in ERs between two incongruent proportions. The fact that the PWA group was vulnerable to both demands of CR and GM is consistent with the interpretation that the PWA group demonstrated impaired EA.

There were no significant group differences on the Iowa Gambling Test. Both groups demonstrated non-significant differences in decision-making ability based on the proportion structure. This is consistent with the interpretation that the different pattern of RTs and ERs between PWA and NI on these PWI tasks is not likely due to an impaired sensitivity to the proportional structure per se, but rather to impaired GM for these linguistic tasks.

The findings from the current study support a growing body of evidence identifying cognitive impairments as a source or consequence of language deficits in PWA. Further experimental work is required to explain how CR and GM are linked to more language-specific processing deficits in PWA.

References

Duffy, J.R. & Keith, R. (1980). Performance of non-brain injured adults on the PICA: Descriptive data and comparison to patients with aphasia. *Aphasia, Apraxia, and Agnosia. 2,* 1-30.

Engle, R. W., & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In B. Ross (Ed.), *The psychology of learning and motivation* (pp. 145-199). New York: Academic Press.

Engle, R. W., Kane, M. J., & Tuholski, S. W. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. In Miyake, A. & Shah, P. (Eds.), *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control* (pp.102-134). London: Cambridge Press.

Glaser, W. R., & Glaser, M. O. (1989). Context effects in Stroop-like word and picture processing. *Journal of Experimental Psychology: General*, *118*, 13-42.

Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice Hall.

Kane, M. J., & Engle, R. W. (2003). Working memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132,* 47-70.

McNeil, M. R. & Pratt, S. R. (2001). Defining aphasia: Some theoretical and clinical implications of operating from a formal definition. *Aphasiology, 15,* 901-911.

McNeil, M. R., Odell, K., & Tseng, C. H. (1991). Toward the integration of resource allocation into a general theory of aphasia. *Clinical Aphasiology, 20,* 21- 39.

McNeil, R. R. (1982). The nature of aphasia in adults, In N. Lass, L. McReynolds, J. Northern, & D. Yoder (Eds.), *Speech language and hearing*, Vol. II (pp. 692-740). Philadelphia: W. B. Saunders.

Murray, L. L. (1999). Attention and aphasia: Theory, research and clinical implications. *Aphasiology, 13,* 91-112.

Porch, B. E. (2001). *Porch Index of Communicative Ability*. Palo Alto, CA: Consulting Psychologists.

Robin, D. A., & Rizzo, M. (1989). The effects of focal lesions on intramodal and cross-modal orienting of attention. *Clinical Aphasiology, 18*, 62–74.

Tseng, C. H., McNeil, M. R., & Milenkovic, P. (1993). An investigation of attention allocation deficits in aphasia. *Brain and Language, 45,* 276-296.

Wobbrock, J.O., Findlater, L., Gergle, D. and Higgins, J.J. (2011). The Aligned Rank Transform for nonparametric factorial analyses using only ANOVA procedures. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11). Vancouver, British Columbia (May 7-12, 2011).* New York: ACM Press, pp. 143-146.

Table 1. Performance on descriptive and screening measures in persons with aphasia.

			WM				TMT		STMT								
ID	PICA	CRTT_a	CS	OS	Alph	Subt-2	Num	Alter	circle	Alter	PPT	LDT	CRTT_s	Gambling	F-D	B-D	Raven
101	13.33	14.30	2	1.5	4	2.5	42	165	8	57	51	92.5	14.40	1925	5	4	24
103	13.44	13.67	1.5	1	3.5	4	44	154	17	41	47	90	11.80	1250	6	3	31
104	10.68	11.77	1	1	1.5	1	84	244	15	63	49	95	14.40	1750	4	1	31
105	13.02	14.10	1.5	1	2	3	66	176	6	64	49	62.5	12.39	650	4	2	28
106	13.85	13.85	2	1	3	4	44	87	6	34	47	85	12.93	2300	7	4	34
108	13.93	13.94	1	1	4	4	28	67	9	29	52	100	12.80	1050	6	3	33
109	13.71	13.82	2	1.5	3.5	3.5	31	114	6	20	50	85	13.63	3000	6	2	34
110	12.28	10.48	1	1	2	1	182	388	9	67	49	80	10.64	2525	2	2	29
111	11.04	12.11	1	1	1.5	1	53	136	29	54	48	85	12.03	1725	2	2	28
112	9.58	11.41	1	1	1.5	1	184	366	15	96	45	70	11.34	2700	3	2	24
Mean	12.49	12.94	1.40	1.10	2.65	2.50	75.80	189.70	12.00	52.50	48.70	84.50	12.64	1887.50	4.50	2.50	29.60
SD	1.53	1.37	0.46	0.21	1.06	1.37	58.81	110.37	7.26	22.24	2.06	11.35	1.25	757.21	1.78	0.97	3.69

ID= subject number
PICA= Porch Index of Communicative Ability (PICA) (Porch, 2001)
CRTT-a= Computerized Revised Token Test (CRTT-$_{\mathrm{Stroop}}$) (McNeil, Pratt, Szuminsky et al., 2008)
CS= Cleft-subject reading span test (Waters and Caplan, 2003)
OS= Cleft-object reading span test (Waters and Caplan, 2003)
Alph= Alphabet span test (Waters and Caplan, 2003)
Subt-2= Subtract-2 WM span test (Waters and Caplan, 2003)
TMT-Num= the number of Trail Making Test (Amieva et al, 1998)
TMT-Alter= = the alternative of Trail Making Test (Amieva et al, 1998)
STMT-circle= the number of Symbol Trail Making test (Barncord and Wanlass, 2001)
STMT-Alter= the alternative of Symbol Trail Making test (Barncord and Wanlass, 2001)
PPT= Pyramids and Palm Trees test
LDT= lexical decision test (Arvedson, 1986)
CRTT-s = Stroop version of Computerized Revised Token Test (CRTT) (McNeil, Pratt, Szuminsky et al., 2010)
Gambling = Total response time of Iowa Gambling Test (ms)
F-D= Forward digit pointing span task
B-D= Backward digit pointing span task
Raven= The Raven Coloured Progressive Matrices (Raven, 1956)
SD = Standard Deviation

Table 2. Performance on descriptive and screening measures in normal individuals.

			WM				TMT		Symbol T								
ID	PICA	CRTT_a	CS	OS	Alph	Subt-2	Num	Alter	circle	Alter	PPT	LDT	CRTT_s	Gambling	F-D	B-D	Raven
201	14.2	14.8	1.2	1.2	3.5	5	37	122	16	38	50	92.5	12.70	25	7	4	27
202	14.7	14.3	3.5	1.5	5	6.5	25	48	8	26	50	100	14.70	1375	8	4	33
203	14.6	13.7	2	1	4	4	25	74	2	4	49	77.5	12.72	1350	7	4	28
204	14.7	14.7	3	2	4	6.5	28	56	4	17	50	80	14.39	2225	8	3	29
205	14.7	15.0	1.5	1.5	2.5	6.5	25	44	6	15	50	92.5	14.64	2675	8	5	33
206	14.5	14.5	2	2	5.5	5.5	20	77	4	16	51	97.5	14.40	1500	8	7	32
207	14.4	14.4	2	2	3.5	3.5	50	111	9	18	50	100	13.53	2675	5	3	29
208	14.2	14.8	2	2	3	6	17	58	6	33	48	95	13.55	3075	6	5	27
209	14.0	14.4	1	1	4	5	33	82	6	26	50	90	12.62	2175	6	3	31
210	14.2	14.6	2.5	2	4	4.5	27	56	5	64	51	92.5	12.84	2250	6	4	32
213	14.0	13.9	1	1	3.5	3.5	33	67	6	24	47	77.5	12.64	1575	6	5	30
214	14.1	13.9	1	1.5	3.5	4	18	53	4	12	50	85	12.79	100	6	4	22
215	13.9	12.9	1	1	3.5	4.5	53	227	7	72	42	70	11.94	2250	6	4	25
216	14.1	14.0	1	1	3	5	40	75	6	25	45	82.5	14.20	1425	8	3	27
217	14.1	13.8	2	2	3	4	40	10	8	22	49	90	13.86	1525	6	4	27
218	13.9	14.2	2.5	1	3	3.5	19	69	5	22	51	90	13.90	1625	5	4	34
219	14.1	12.9	2.5	1.5	4	5	31	74	4	24	49	90	14.51	2125	7	3	36
220	14.4	14.0	2	2	4	3.5	28	68	6	13	51	85	13.92	1900	7	4	32
221	14.2	14.0	2	2	4.5	5	43	133	10	62	50	82.5	12.66	1975	4	3	25
222	14.5	13.6	3.5	1.5	4	6.5	22	46	4	16	52	92.5	13.92	1025	8	6	32
Mean	13.68	13.73	1.77	1.39	3.38	4.08	45.73	114.90	8.20	35.80	49.07	86.92	13.23	1790.83	5.90	3.57	29.57
SD	1.23	1.05	0.75	0.42	0.98	1.63	40.14	89.42	5.45	22.74	2.21	9.21	1.06	758.30	1.71	1.28	3.53

ID= subject number
PICA= Porch Index of Communicative Ability (PICA) (Porch, 2001)
CRTT-a= Computerized Revised Token Test (CRTT-$_{\text{Stroop}}$) (McNeil, Pratt, Szuminsky et al., 2008)
CS= Cleft-subject reading span test (Waters and Caplan, 2003)
OS= Cleft-object reading span test (Waters and Caplan, 2003)
Alph= Alphabet span test (Waters and Caplan, 2003)
Subt-2= Subtract-2 WM span test (Waters and Caplan, 2003)
TMT-Num= the number of Trail Making Test (Amieva et al, 1998)
TMT-Alter= = the alternative of Trail Making Test (Amieva et al, 1998)
STMT-circle= the number of Symbol Trail Making test (Barncord and Wanlass, 2001)
STMT-Alter= the alternative of Symbol Trail Making test (Barncord and Wanlass, 2001)
PPT= Pyramids and Palm Trees test
LDT= lexical decision test (Arvedson, 1986)

CRTT-s = Stroop version of Computerized Revised Token Test (CRTT) (McNeil, Pratt, Szuminsky et al., 2010)
Gambling = Iowa Gambling test
F-D= Forward digit pointing span task
B-D= Bacward digit pointing span task
Raven= The Raven Coloured Progressive Matrices (Raven, 1956)
SD = Standard Deviation

Table 3. Mean Response Latencies (in Milliseconds) and Standard Deviations, by proportion (19% and 73%), condition (congruent, neutral, and incongruent) and group (NI and PWA).

Probability	Group	Condition					
		Congruent		Neutral		Incongruent	
		Mean	SD	Mean	SD	Mean	SD
73%_IC	NI	.	.	708.49	132.86	763.57	153.05
	PWA	.	.	849.33	193.39	977.70	311.42
19%_IC	NI	712.02	144.02	725.49	142.10	808.65	156.51
	PWA	882.91	272.94	942.17	347.30	1097.12	446.52

Table 3. Mean Error Rates (Percentage), with Standard Deviations, by Group, across conditions in the 19% and 73% incongruent proportions.

Proportion	Group	Condition					
		Congruent		Neutral		Incongruent	
		Mean	SD	Mean	SD	Mean	SD
73%_IC	NI	.	.	3.01	2.94	3.29	3.03
	PWA	.	.	3.80	2.27	7.81	6.71
19%_IC	NI	3.00	3.23	2.13	2.31	6.68	4.59
	PWA	2.72	2.44	2.73	3.62	10.04	9.47

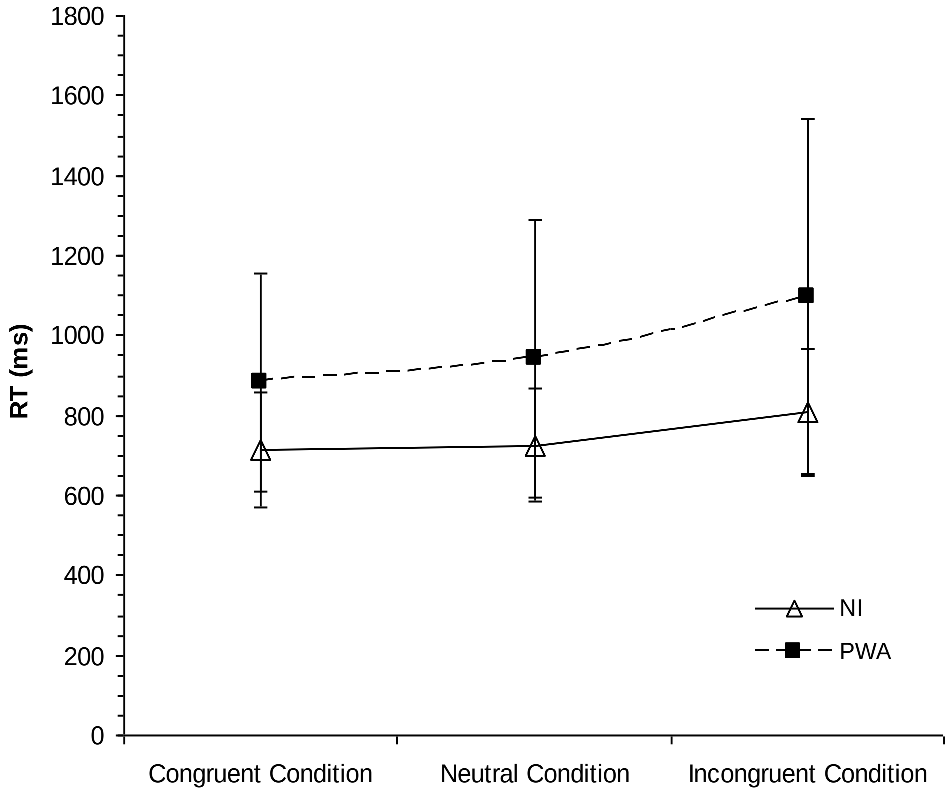

Figure 1. Mean Response Times for PWA and NI across three conditions in the 19% incongruent proportion of the PWI task.

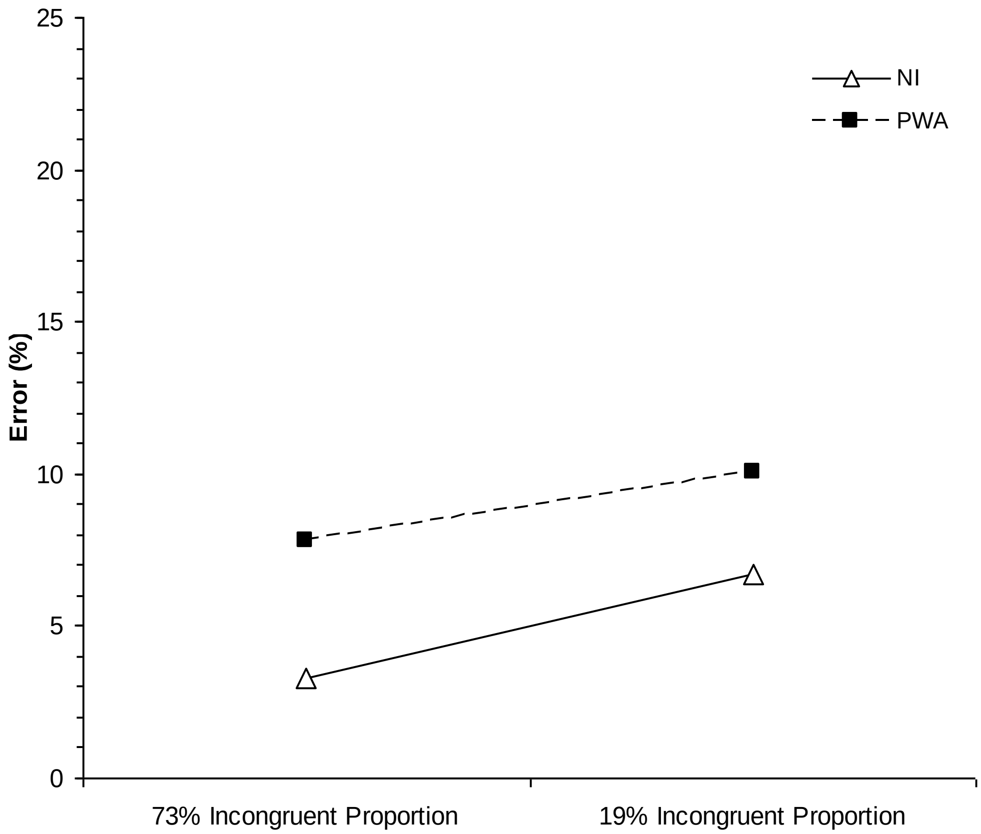

Figure 2. Error rates for PWA and NI on the incongruent conditions in the 19% and 73% incongruent proportions of the PWI task.