JSLHD 2021. Vol. 30, No. 4. 001-015
ISSN 1226-587X / eISSN 2671-7158
Journal of Speech-Language & Hearing Disorders 언어치료연구

ORIGINAL ARTICLE
https://doi.org/10.15724/jslhd.2021.30.4.001
http://jslhd.org/

Conflict Resolution and Goal Maintenance Components of Executive Attention are Impaired in Persons With Aphasia

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Purpose: An understanding of the relationship between attentional deficits and language processing can provide insight into the language disorders in persons with aphasia (PWA). Especially, executive attention is a critical component of the attentional system. However, the relationships among executive attention, language processing and aphasia have not been studied extensively. The purpose of this study was to investigate the role of goal maintenance and conflict resolution in word-level processing in persons with aphasia (PWA).

Methods: Picture-Word Interference (PWI) tasks were used whereby written words were superimposed on pictures in congruent, neutral or incongruent conditions. Ten PWA and 20 normal individuals (NI) categorized words into animal or non-animal. Button press response times (RT) and error rates were measured.

Results: The results revealed that PWA took significantly ($p<.05$) longer RTs than NI for the incongruent and neutral conditions, but there was no significant group difference for the congruent conditions. The NI committed significantly more errors on the lower proportion of the incongruent trial, however, the PWA showed no significant difference between two proportions of the PWI tasks.

Conclusions: The PWA group evidenced impaired conflict resolution and goal maintenance under the PWI tasks. The fact that the PWA group was vulnerable to both demands of conflict resolution and goal maintenance suggests that the PWA group demonstrated impaired executive attention compared to the NI.

Keywords: Executive attention, persons with aphasia, interference task, goal maintenance, conflict resolution

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Received: August 31, 2021
Revision revised: October 12, 2021
Accepted: October 31, 2021

This article was based on the first author's doctoral dissertation from University of Pittsburgh (2011).

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Ⅰ. Introduction

Following the suggestion that the cognitive construct of attention may be related to the impaired language performance in aphasia (McNeil, 1982), the relationship between language processing and attention has been a critical research topic in aphasiology for a long time. That is, researchers have increasingly investigated the notion that linguistic deficits and communication disorders in aphasia go beyond simply an impaired language system. Indeed, language deficits in persons with aphasia (PWA) may be tied to a complex mixture of cognitive deficits (Helm-Estabrooks, 2001, 2002). Helm-Estabrooks (2002) found that the most impaired function after brain damage associated with aphasia is executive attention except for proper language functions. That is, the relationship between language and executive attention can suggest an alternative way to understand language deficits in PWA.

Researchers have introduced and explained the notion of working memory to account for limitations in and disorders of language comprehension. This concept has gained increased interest in aphasia with respect to examining whether a reduced or limited verbal working memory capacity can explain impaired language comprehension and/or poor cognitive performances in PWA (Waters & Caplan, 1996). Understanding working memory (WM) has been considered vital to examining all functions of complex thinking such as reasoning, problem solving, and language comprehension. Its importance becomes evident especially in language processing which must deal with perceiving and producing a sequence of symbols over time (Just & Carpenter, 1992). That is, WM plays a critical role in storing the partial and final products of computations during the comprehension of a stream of words in a text that allows the mental pasting together of ideas that are mentioned separately or are only implied (Daneman & Carpenter, 1980; Carpenter & Just, 1989). Therefore, researchers have studied WM in detail by decomposing it into different components according to their functions. The three common components of storage, processing (computation) and executive attention are generally accepted in most models of WM (Baddeley & Hitch, 1974; Carpenter & Just, 1989; Daneman & Carpenter, 1980; Engle et al., 1999), although there are still diverse views as to what additional components should be included. Despite gross agreements on the general structure of WM, it has been difficult to determine the critical sources of Working Memory Capacity (WMC) that contribute to cognitive and language processing. Whereas most WM researchers have modeled the functions of computation and storage, Engle and colleagues have concentrated on the executive attentional component. In this conceptualization, the constructs of goal maintenance and conflict resolution, under interference conditions, were proposed as core factors underlying the construct of executive attention (e.g., Engle & Kane, 2004; Engle et al., 1999) as it functions with WM. Studying WM in young healthy college students, Kane and Engle (2003) found that executive attention, as measured by the Stroop interference task, accounted for the increase in processing times and error rates. That is, conflict resolution and goal maintenance as measured in low proportion of the incongruent color-word Stroop task accounted for the majority of the variance in performance. However, these effects have not been examined systematically in PWA as a critical component of their attentional resources, which could underlie their language performance and other cognitive processing impairments.

In order to address the function of the executive attention, Engle and colleagues proposed a two-factor theory of executive control (Engle & Kane, 2004). The first control factor is the goal maintenance of the task in active memory. Engle and his colleagues viewed the maintenance of task goal as a resource-demanding endeavor and argued that individuals with high attentional capacity are better able to expend that resource on a continuing basis. The second factor in the executive control of behavior is the resolution of response competition or conflict, particularly when prepotent or habitual behaviors conflict with behaviors appropriate to the current task goal (Engle & Kane, 2004). This perspective is consistent with the Cohen's WM model in which competition resolution depends on activated goal representations (Cohen & Servan-Schreiber, 1992; Cohen et al., 1990). Therefore, the conclusion derived from the executive attention hypothesis was that executive attention ability 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 habitual responding (Conway et al., 2003).

One of the tasks used for the investigation of executive attention is the interference task (Engle et al., 1998). In the interference tasks, participants are requested to respond to the non-prepotent target and inhibit to respond to the strong, overlearned association. Various studies converge in the finding that this task is executive attention demanding. Particularly, inhibition of prepotent item and activation of non-prepotent item in the interference tasks are crucial for the correct response (Engle et al., 1999). For example, to produce the right response in the color word Stroop task that is the most used interference task, participants have to inhibit prepotent responses (word) and activate the non-habitual responses (color).

In an attempt to investigate the relationship between attentional capacity and executive attention, Kane et al. (2001) tested normal functioning individuals with high and low working memory capacity (WMC) on an antisaccade task. In this task, participants needed to resist the strong tendency to shift their attention to the attention-capturing cue to achieve the optimal performance in the antisaccade task. The results showed that the two groups of subjects did not differ in time to identify target letters in the prosaccade condition. However, although both groups were slow in the antisaccade condition, the individuals with low spans were significantly slower and made more errors than the individuals with high spans. The findings indicated that people with low WMC were more vulnerable to the antisaccade condition requiring abilities of conflict resolution and goal maintenance as a function of executive attention. Moreover, experiment 2 measured eye movements across hundreds of antisaccade trials, and the individual with high span showed fewer saccades toward the cue, faster recovery from these saccade errors, and faster correctly guided saccades than the individuals with low span. Kane and colleagues concluded that the resource demands for the goal maintenance and the conflict resolution are increased in the face of interference condition that lead to individual difference between high and low spans.

Another attentional interference task in which the executive attention has been shown to be important is the dichotic-listening task (Cherry, 1953). In some dichotic paradigms, words presented to one ear for oral repetition, while information presented to the other ear is ignored. Conway et al. (2001) investigated a dichotic-listening task to assess the role of executive attention in WM. They had participants shadow words in one ear while ignoring words presented in the other ear. At some point across trials, each subject's first name was presented as a word in the ignored message. At the end of the study, the participants were asked whether they had heard their name during the trial. The results showed that while only 20% of individuals with high-span reported hearing their name, 65% of individuals with low span reported hearing their name. Conway et al. concluded that individuals with low WM spans are less capable than individuals with high WM spans of performing the mental work necessary to block distracting information.

Kane and Engle (2003) also tested individuals with high and low spans in several versions of the Stroop color-word task. They considered that the Stroop task was an example of an executive attention task in which a habitual, over-learned reading response should be repressed to control behavior with the novel color-naming goal. In order to control the requirements for actively maintaining access to task goals, the researchers manipulated the proportion of congruent trials. In the high-congruency condition, most trials presented words that matched their colors, so the goal of ignoring the word was not reinforced to participants in the task environment.

In contrast, the Stroop condition that presented few congruent trials and mostly incongruent trials reinforced the task goal for subjects. A predominance of incongruent Stroop trials was expected to enhance participants' performance in color naming rather than in word naming. Under these circumstances, Stroop interference is likely to reflect the effectiveness of the competition resolution carried out by the external cue, and should be evident in response latencies, that is, in slow but correct responses (Kane & Engle, 2003).

When 20% or 25% of the trials were incongruent, Kane and Engle (2003) found that individuals with low spans had substantially larger error-interference effects than individuals with high spans. These effects indicated that individuals with low span had a deficit in goal maintenance. In contrast, when 100% of the trials were incongruent, modest span effects in RT interference were found. WMC-related differences were not found in errors indicative of goal neglect, but rather in latencies, suggesting a slowed resolution of the conflict between elicited and desired response.

In the field of aphasia research, many investigators claimed that attention may be a critical component of the cognitive system that subtends some or all language processing impairments in persons with aphasia (PWA) (Helm-Estabrooks, 2002; McNeil, 1982; McNeil et al., 1991). From executive attention researchs by Engle and his colleagues, they insisted two specific components, conflict resolution and goal maintenance, determine individual's attentional competence and support one's resource capacity. These two components of executive attention by Engle and his colleagues can lead to a new insight of attentional defects of PWA.

The primary purpose of the present study was to examine the consequences of executive attention in PWA on the interference tasks. PWA and the age-matched controls were requested to do Picture-Word Interference Tasks, which requires Conflict Resolution and Goal Maintenance in a lexical-semantic visual/reading task similar to Stroop interference task.

II. Methods

1. Participants

Ten PWA (4 females, 6 males) and 20 NI (3 females, 17 males) participated in the study. They were recruited through the VA Research Registry approved by the VA Pittsburgh Healthcare System (MIRB# 02935). All participants met the following inclusion criteria: American English as their native language; aged 30 to 80 years old; vision screening with the reduced Snellen chart with 20/40 or better visual acuity (with correction if necessary); performance on the immediate/delayed story retell task of the Assessment Battery of Communication in Dementia (ABCD, Bayles & Tomoeda, 1991) yielding a ratio (the delayed recall/immediate recall × 100) greater than 70% on the delayed recall compared to the immediate recall; Lexical and semantic test greater than

60% accuracy based on PWI stimuli (picture and word). The NI participants also self-reported no history of communication disorder, learning disability, neurological illness, head injury, and psychiatric illness. Their demographic information is ranged in age from 47 to 70 years old (mean=58.0; *SD*=8.5) for PWA and 40 to 74 years old (mean=65.4; *SD*=7.9) for NI. In the homogeneity test, there was on age difference between the two groups. The averaged time post onset of the PWA group was 115.5 months with the range of 36 to 384 (see Table 1 & 2).

2. Apparatus and Stimuli

Data were collected in a sound-attenuated booth and a Dell desktop computer was used to present the stimuli on a Super VGA high-resolution color monitor and record the responses. The binocular viewing distance was 100 cm. E-PRIME 2.0 software (Schneider et al., 2002) was used to control the presentation of stimuli, timing operations, and data collection. Manual reaction times and errors were collected via a Dell keypad board.

The stimuli for the Picture-Word Interference task consisted of the 10 well-known words from two semantic categories (animal and non-animal). One-category set included animals consisting of five exemplars(whale, sheep, horse, moose, camel), and the other non-animal category set consisted of mixed items from five other categories (apple, table, glass, piano, onion). The experimental stimuli for the PWI task were created by placing each of these words within a background line-drawn picture that was of high typicality and discriminability. To create the stimuli (animals and non-animal), line drawings as picture stimuli were chosen from a previous PWI study in which all stimuli were taken from the Snodgrass and Vanderwart's (1980) normed stimuli. In the congruent condition of the PWI tasks, each picture appeared with its corresponding name superimposed. In the incongruent condition, the pictures were paired with words from different categories. In the neutral condition, the stimuli consisted of each word surrounded by a polygon, used for controlling possible interference caused by lateral masking (Lupker & Katz, 1981).

3. Procedure

All data were collected in two separate sessions for each participant requiring approximately 90~120 minutes per session. In the first session, participants completed the informed consent process, screening tasks and several descriptive measures described above. In the second session, participants started with the experimental PWI tasks (practice condition, 19% incongruent condition, and 73% incongruent condition in order) and then completed the rest of descriptive measures.

Participants were seated 100cm distance in front of a Dell Desktop computer with a 19-inch color screen with an attached keyboard placed on the table between the computer and the participant. Participants were required to press two buttons on the right-side of the keyboard; the number “1” (for animal) and the number “2” (for non-animal categories). Participants were instructed to indicate whether the string of letters that appeared on the screen was an animal or non-animal by depressing the appropriate button with their non-dominant (left) hand. Throughout the task, participants rested one finger on each of the two buttons.

The PWI task began with three practice blocks. The first practice block of 30 trials was designed to familiarize the participants with the keypad and experimental stimuli of words, which were all superimposed with their correct labels. The second practice block of 30 trials was designed to familiarize participants with the unclassified line-drawing picture (a polygon). Each word string and picture appeared equally often in practice blocks 1 and 2. The third practice block was designed to familiarize participants with incompatible word and picture stimuli.

In the experimental condition, the two experiment blocks consisted of the less frequent incongruent proportions (19%) and more frequently occuring incongruent proportions (73%) of the PWI task with 280 trials in each condition. The 19% incongruent PWI task was presented first. And then the 73% incongruent proportion task was always presented as the final task. This procedure was used to minimize any possible learning in the interference conditions (Kane & Engle, 2003).

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 (80%)	14.30	2	1.5	4	2.5	42	165	8	57	51	92.5	14.40	1925	5	4	24
103	13.44 (82%)	13.67	1.5	1	3.5	4	44	154	17	41	47	90	11.80	1250	6	3	31
104	10.68 (47%)	11.77	1	1	1.5	1	84	244	15	63	49	95	14.40	1750	4	1	31
105	13.02 (76%)	14.10	1.5	1	2	3	66	176	6	64	49	62.5	12.39	650	4	2	28
106	13.85 (88%)	13.85	2	1	3	4	44	87	6	34	47	85	12.93	2300	7	4	34
108	13.93 (88%)	13.94	1	1	4	4	28	67	9	29	52	100	12.80	1050	6	3	33
109	13.71 (86%)	13.82	2	1.5	3.5	3.5	31	114	6	20	50	85	13.63	3000	6	2	34
110	12.28 (67%)	10.48	1	1	2	1	182	388	9	67	49	80	10.64	2525	2	2	29
111	11.04 (52%)	12.11	1	1	1.5	1	53	136	29	54	48	85	12.03	1725	2	2	28
112	9.58 (36%)	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	.46	.21	1.06	1.37	58.81	110.37	7.26	22.24	2.06	11.35	1.25	757.21	1.78	.97	3.69

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

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	.75	.42	.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

Note. ID=subject number; PICA=Porch Index of Communicative Ability (Porch, 2001); CRTT-a=Computerized Revised Token Test (CRTT-Stroop, McNeil et al., 2008); CS=cleft-subject reading span test (Waters & Caplan, 2003); OS=cleft-object reading span test (Waters & Caplan, 2003); Alph=Alphabet span test (Waters & Caplan, 2003); Subt-2= Subtract-2 WM span test (Waters & 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 & Wanlass, 2001); STMT-Alter=the alternative of Symbol Trail Making test (Barncord & Wanlass, 2001); PPT=Pyramids and Palm Trees test; LDT=lexical decision test (Arvedson, 1986); CRTT-s=Stroop version of Computerized Revised Token Test (McNeil et al., 2010); Gambling=Iowa Gambling test (score); F-D=forward digit pointing span task; B-D=bacward digit pointing span task; Raven=The Raven Coloured Progressive Matrices (Raven, 1956).

All participants were individually tested in a quiet room. The experimenter remained in the room for the entire session. The two PWI tasks (19% and 73%) were presented in separate blocks. For each proportion, the instructions were first presented on the screen and read aloud by the examiner. Participants were told that they would be seeing a series of words superimposed on pictures, and that their job would be to classify each word as to whether it was an animal or not. As well, the experimenter instructed all participants that they would be observed to determine that they never look away from the word or squint their eyes during the task. Finally, all participants were instructed and encouraged to respond as quickly and as accurately as possible. The participants then responded to each of the randomly presented 280 stimuli.

Ⅲ. RESULTS

1. Design

The research design was a 2 × 2 × 3 mixed-model, with group (aphasia and normal) as between-subjects variables, incongruent proportion (19% and 73%) and condition (congruent, neutral and incongruent) as within-subjects variables.

2. Preliminary Analysis

As a preliminary analysis, mean respond time (RT) from the neutral condition of the pretest was used to determine significant RT slowing for the PWA. If there was a significant group effect on the neutral trials of the pretest, response speed would be used as a covariate in the following analyses in order to separate the participants' inhibition capacities from generally slowed information processing.

A one-way ANOVA using Group (NI and PWA) as a between-factor was computed on the inverse transformed RTs (1/RT) of the neutral condition from the pretest. While the PWA (mean=849.33; *SD*=193.39) produced slower average RTs than NI (mean=763.57; *SD*=153.05), the difference was not significant, $F_{(1, 29)}$=1.364, p=.252, Effect Size (ES, η^2)=.21. Thus, the following analyses that assess the interference and facilitation effects on RT did not consider speed of response as a covariate.

3. Conflict Resolution

Conflict resolution was assessed by comparing RTs and error rates among 3 conditions (incongruent, neutral, and congruent conditions) of the 19% incongruent proportion task by group. A 2 (Group: NI and PWI) × 3 (incongruent, neutral, & congruent condition) mixed model was conducted (see Figure 1).

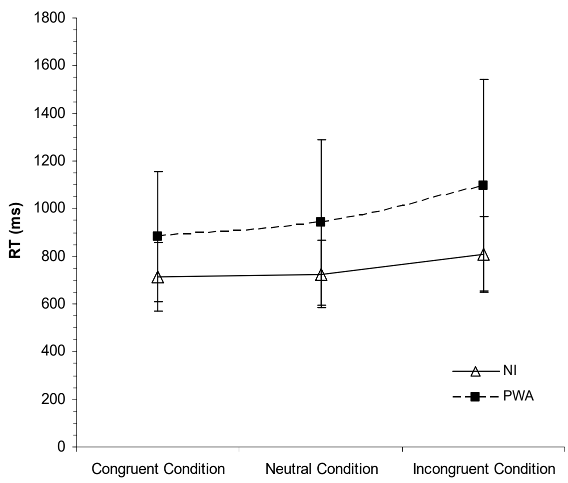

Figure 1. Mean response times for PWA and NI across three conditions in the 19% incongruent proportion of the PWI task

1) Response Times

Response errors (2.8%) and RT outliers (1.5%) were excluded from the reaction time analyses. The mean reaction times for each group and condition in the 19% and 73% incongruent proportion tasks are displayed in

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 and are contrasted in Figure 1.

The analysis revealed significant main effects for Group, $F_{(1, 50.409)}$=7.559, p<.008, ES (r)=.45, and Condition, $F_{(2, 141.742)}$=173.393, p<.0005, ES (r)=.85, but no significant Group × Condition interaction, $F_{(2, 141.742)}$= .134, p=.874, ES (r)=.00.

Post-hoc analysis of the group effect within each condition with a Bonferroni alpha adjustment (p=.017) was conducted. The analysis indicated that RT of the PWA were significantly longer than RT of NI in the incongruent, $F_{(1, 28)}$=6.772, p<.015, ES (r)=.29 and the neutral conditions, $F_{(1, 28)}$=8.379, p<.007, ES (r)=.31, but RT between the groups were not significantly different in the congruent condition, $F_{(1, 28)}$=6.246, p=.019, ES (r)=.29.

Post-hoc analysis of the condition effect within each group using a mixed model with a Bonferroni adjustment (p=.025) was conducted. The analysis indicated that there was a significant condition effect for the NI group, $F_{(2, 157.70)}$=124.151, p<.0005, ES (r)=.83, and the PWA group, $F_{(2, 18)}$=100.00, p<.0005, ES (r)=.92. Pairwise comparisons among conditions for each group indicated that the incongruent RTs were significantly longer than the neutral RTs for both NI (t=11.18, df=157.70, p<.0005, ES (r)=.91) and PWA (t=10.16, df=157.70, p<.0005, ES (r)=.95). The incongruent RTs were also significantly longer than the congruent RTs for both NI (t=2.739, df=38, p<.009, ES (r)=.93) and PWA (t=1.837, df=18, p<.99, ES (r)=.98). Additionally, the RTs for the congruent condition were not significantly different from the neutral condition for the PWA (t=.344, df=157.70, p=.99, ES (r)=.76), but they were significantly different for the NI (t=4.03, df=157.70, p<.0005, ES (r)=.72).

2) Error Rates

The mean error rates for all conditions for both incongruent proportion tasks are displayed in Table 4 for both groups. Aligned rank transformed data of error rate were analyzed with a mixed model.

Mixed model analysis revealed a significant main effect for condition, $F_{(2, 56)}$=27.628, p<.0005, ES (r)=.49, but no significant main effect of Group and no significant Group × Proportion Interaction (see Figure 3).

Post-hoc analysis of the condition effects for each group, using a mixed model with a Bonferroni adjusted alpha (p=.017) was conducted. The analysis indicated that there was a significant condition effect for the NI, $F_{(2, 38)}$=30.258, p<.0005, ES (r)=.61, and the PWA, $F_{(2, 18)}$=6.261, p<.009, ES (r)=.41. Pairwise comparisons among the conditions for each group indicated that error

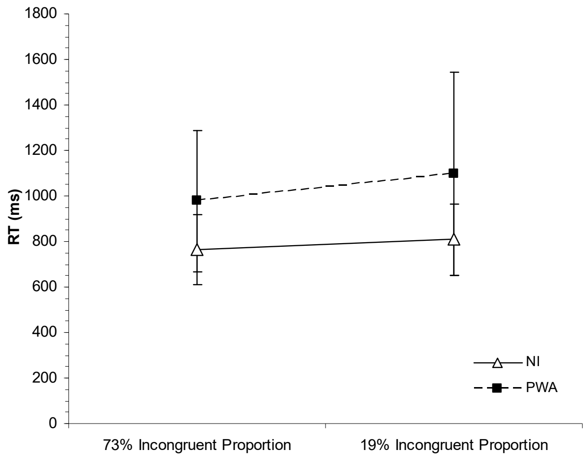

Figure 2. Response time for PWA and NI on the 19% and 73% incongruent proportions

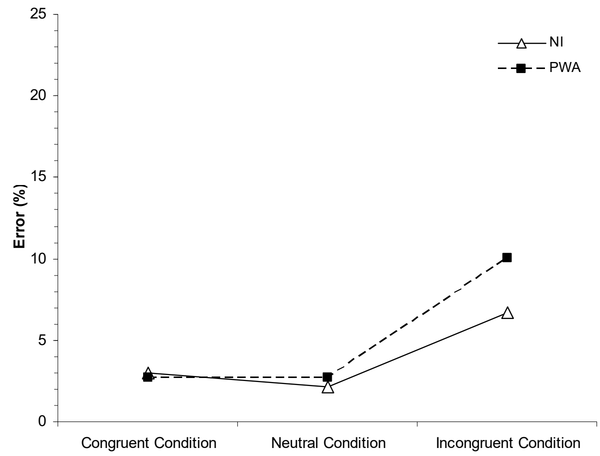

Figure 3. Error rates for PWA and NI across three conditions in the 19% incongruent proportion of the PWI task

Table 4. 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

rate for the incongruent condition was significantly higher than for the neutral condition for both the NI (t=6.00, df=38, p<.0005, ES (r)=.79) and PWA (t=3.06, df=18, p<.013, ES (r)=.64) groups. Error rates for the incongruent condition were significantly higher than for the congruent condition for the NI (t=7.29, df=38, p<.000, ES (r)=.91) and for PWA (t=3.035, df=18, p<.013, ES (r)=.71) groups. Error rates for the congruent condition were not significantly different from the neutral condition for the NI or PWA groups.

4. Goal Maintenance

Goal maintenance was assessed by comparing RTs and error rates for 19% incongruent condition to 73% incongruent condition by group. Therefore, A 2 (Group: NI and PWI) × 2 (Proportion: 19% vs 73%) mixed model was conducted.

1) Response Time

A 2 (group) × 2 (proportion) mixed model comparing RTs between the 19% and the 73% incongruent proportion by group was conducted (see Table 3). The analysis revealed a significant main effect for Group, $F_{(1, 65.397)}$=9.000, p<.004, ES (r)=.35, and proportion, $F_{(1, 66.731)}$=176.067, p<.0005, ES (r)=.85, but no significant Group × Proportion interaction, $F_{(1, 66.731)}$=.101, p=.752, ES (r)=.04 (see Figure 4).

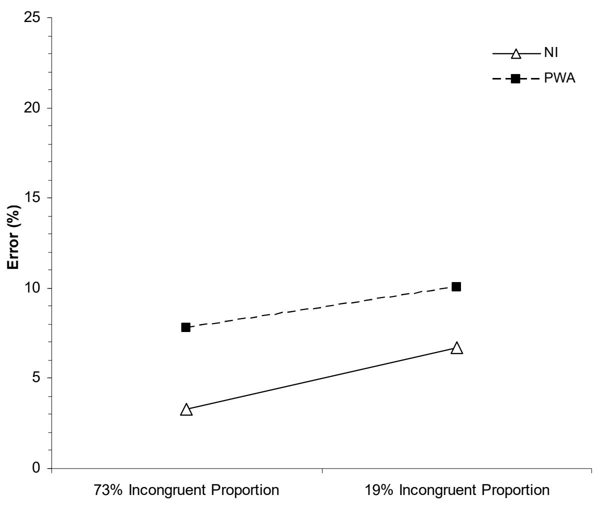

Figure 4. Error rates for PWA and NI on the incongruent conditions in the 19% and 73% incongruent proportions of the PWI task

Group effects for each condition were examined using a mixed model with a Bonferroni adjusted alpha (p=.025). Results revealed that the PWA group produced significantly longer RTs in both the 19%, $F_{(1, 28)}$=8.379, p<.007, ES (r)=.48, and the 73% incongruent proportion tasks, $F_{(1, 28)}$=7.674, p<.010, ES (r)=.46, than the NI. Additionally, the RTs were significantly longer in the 19% than the 73% incongruent proportion task for both PWA, $F_{(1, 46.881)}$=54.404, p<.0005, ES (r)=.73 and the NI, $F_{(1, 29.936)}$=183.868, p<.0005, ES (r)=.86.

2) Error Rates

A 2 × 2 mixed model with error rates for incongruent conditions in the 19% and the 73% incongruent proportion tasks was conducted (Figure 4). The analysis revealed a significant main effect for proportion, $F_{(1, 28)}$=34.631, p<.0005, ES (r)=.74, but no significant Group effect or Group × Proportion Interaction.

Decomposition of the proportion effect for each group with a Bonferroni adjusted alpha (p=.025) indicated that there was a significant proportion effect for the NI, $F_{(1, 19)}$=42.379, p<.0005, ES (r)=.83, but not for the PWA group. Consistent with the hypothesis, the NI committed significantly more errors when responding to the incongruent conditions in the 19% incongruent proportion task than in the 73% incongruent proportion task, but the PWA did not.

3) Analysis of Interference and Facilitation

In order to determine whether the two groups showed significant interference (incongruent minus neutral condition) and facilitation (congruent minus neutral condition) effects, non-parametric tests were conducted among the RTs derived from the neutral, incongruent, and congruent conditions within the 19% incongruent proportion of PWI task within each group. Mean facilitation and interference scores for each group are summarized in Table 5.

Table 5. Facilitation and interference reaction times (msec.) from the 19% incongruent condition for NI and PWA

	Facilitation		Interference	
	Mean	*SD*	Mean	*SD*
NI	-26.24	29.89	90.23	45.62
PWA	-54.12	78.19	184.97	157.05

A Wilcoxon Signed Rank Test was conducted with RTs for comparing the incongruent condition versus the neutral condition and the congruent versus the neutral condition from the 19% incongruent proportion. PWA showed significant facilitation, Z=2.50, N-Ties=0, p<.01, two-tailed, ES=.56, and interference effects, Z=2.80, N-Ties=0, p<.002, two-tailed, ES=.63. Likewise, NI showed significant facilitation, Z=3.21, N-Ties=0, p<.001, two-tailed, ES=.51, and interference effects, Z=3.88, N-Ties=0, p<.001, two-tailed, ES=.61.

To assess group differences, a Mann-Whitney Test was conducted with RTs from the facilitation and interference contrasts derived from the 19% incongruent proportion. A simple comparison showed that PWA showed a significantly larger interference effect than the NI, U=55, N1=20, N2=10, p<.049, two-tailed, ES=.36, but no significant difference in facilitation between two groups, U=80, N1=20, N2=10, p<.40, two-tailed, ES=.16 (See Figure 5).

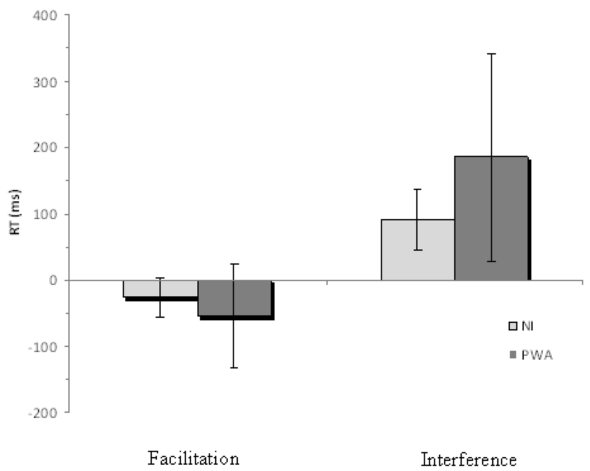

Figure 5. Facilitation and interference effects in the 19% incongruent proportion

4) Analysis of Sensitivity to Proportion Structure on the Iowa Gambling Test

In order to determine whether the two groups had different sensitivity of proportion structure, a Mann-Whitney Test was conducted with total response time and the amount of earned money in the Iowa Gambling Test. There was no significant group difference on the Iowa gambling test for total response time (Z=.70) and amount of money (Z=.48).

5) Analysis of Skew of the Correct Response in the Incongruent Condition of the 19% Incongruent Proportion Task

In order to inspect the difference of goal maintenance ability between the two groups, a Mann-Whitney Test was conducted with the value of skew in the correct incongruent condition of the 19% incongruent proportion task. The results revealed that the PWA group had a significantly more positive skew (skew=2.43) than the NI group (skew=1.36, U=39, N1=10, N2=20, p<.006, two-tailed, ES (r)=.49).

Ⅳ. Discussion & Conclusion

The primary purpose of this study was to examine the role of executive attention in PWA. To examine it, Picture-Word Interference tasks were employed in which visually presented words were superimposed on congruent, neutral, or incongruent pictures in 19% and 73% incongruent proportions. RTs and error rates for the two groups in the 19% incongruent proportion task across congruent, neutral, and incongruent conditions assessed the conflict resolution effects of executive attention within the PWI task. Goal maintenance effects of executive attention were tested by comparing RTs and error percentages between the two incongruent conditions in the 19% and 73% incongruent proportion tasks within each group.

The PWI tasks produced significant condition (congruent, neutral, and incongruent) and proportion (19% and 73% incongruent) effects for the NI group. The notable outcome in the condition and proportion effects was in accordance with results obtained in previous interference studies (Belanger et al., 2010; Kane & Engle, 2003; Engle et al., 1999). These studies reported that healthy non-impaired individuals responded reliably more slowly to incongruent than neutral and congruent conditions and they also responded more slowly and committed more errors in the less frequent incongruent conditions than in more frequently occurring incongruent conditions. Based on the consistency of results between the previous studies and the current study, the data from the NI confirmed the empirical finding that the PWI tasks in the current study provided sufficient demands on both conflict resolution and goal maintenance.

Analyses of the RTs in the 19% incongruent proportion task revealed that both groups demonstrated significantly longer RTs when a word was superimposed on an incompatible picture compared to the congruent or neutral conditions. The group comparison between NI and PWA revealed significant differences in the latency of response in the 19% incongruent proportion task with the PWA group producing significantly longer RTs than the NI group on both the incongruent and neutral conditions but not on the congruent condition; in spite of the fact that the RT difference between PWA and NI on the incongruent condition was larger than on the neutral condition. This finding indicates that the PWA group was relatively more vulnerable than the NI group to the incongruent stimuli than to the neutral and congruent stimuli. The longer RTs for the PWA group on the incongruent conditions are consistent with the hypothesis that PWA have an impairment of executive attention that is attributable to the resolution of linguistic conflict between response relevant lexical information of a word and response irrelevant semantic information of a picture.

PWA and NI produced a facilitation effect. That is, they responded significantly faster on the congruent than on the neutral conditions in the 19% incongruent proportion task. This finding is consistent with Glaser's two route processing model of semantic and lexical information processing in the Picture-Word Interference paradigm (Glaser & Glaser, 1989). Glaser and Glaser (1989) proposed a model that has a semantic system containing all semantic knowledge and a lexicon that contains only linguistic word knowledge. The two systems are assumed to have different input and output functions. The semantic system controls the perception of pictures and the action of physical objects. In contrast, the lexicon is thought to be responsible for the comprehension and production of spoken and written language. Within this conceptualized architecture, the response modality is critical for the production of facilitation or interference effects. In the PWI task, two dimensions of the stimulus are simultaneously activated and the privileged access will depend on the response modality. If the required response of PWI task is spoken, a word superimposed on a picture has the privileged access to the response. In contrast, if the required response is categorization, a picture has the privileged access. Therefore, when a word superimposed with a picture has to be read, participants will directly activate their word nodes within the lexicon. A picture, however, will first have to activate its concept nodes within the semantic system followed by activation of the corresponding word nodes. Therefore, picture naming will take longer than word naming. Conversely, when semantic information is required (e.g., determining the category to which an item belongs), a picture will not have to make the detour through the lexicon. Therefore, if the dimensions of the PWI stimuli are matched (e.g., a word "dog" and a picture of dog), a facilitation effect will be observed because the response relevant picture (picture of a dog) has privileged access to the system that leads to faster selection of the response compared to a word. When the category to which a picture belongs is the required response, Glaser and Glaser (1989) assumed that the semantic system is relevant for its selection. In this case, there will be a facilitation effect through semantic processing activated by the picture. Because the picture has privileged access to the semantic system, a picture will accelerate the categorization response. The finding that PWA gained a significant benefit from the congruent stimuli suggests that the individuals with aphasia in this study were able to use a relatively more intact or less resource demanding semantic processing network compared to the two stages, more resource demanding lexical processing system. That is, when the PWA encountered the congruent picture/word stimuli, they did not need to depend on the lexical processing, but rather activated the semantic node that is one step shorter than single word lexical processing.

Analyses of the error rates extracted from the 19% incongruent proportion task revealed significantly more errors in both groups on the incongruent than on the neutral and congruent conditions. The high error rates on the incongruent conditions are consistent with the expected interference effect for both groups. It was interpreted as that the error rates were also useful for the measurement of conflict resolution. However, the two groups did not differ significantly in errors across the three conditions. This suggests that the measurement of error rates is not particularly sensitive for capturing group differences found with the measurement of RT between the NI and PWA groups.

Analyses of RTs between two different incongruent proportion tasks revealed that the NI group demonstrated significantly longer RTs on the incongruent conditions under the 19% incongruent proportion task than under the 73% incongruent proportion task. This finding is consistent with the theoretical view that an interference task with a smaller proportion of incongruent conditions increases goal maintenance demands (Belanger et al, 2010; Kane & Engle, 2003). Participants should ignore distracting picture information, inhibit semantic information and activate lexical information to achieve a correct and rapid response on the incongruent conditions of PWI task. Theoretically, the 19% incongruent proportion task requires a greater demand on goal maintenance compared to the 73% incongruent proportion task due to the fact that participants receive task goal cues on more trials under the 73% incongruent proportion task. That is, the frequent incongruent trials in the 73% incongruent proportion task remind participants of the task goal to inhibit the picture information and activate the lexical information of the word superimposed on picture.

Analyses of error rates on the incongruent conditions between the 19% and 73% incongruent proportion tasks revealed that the NI participants did produce significantly more errors on the incongruent condition of the 19% incongruent proportion task than the 73% incongruent proportion task. This finding is interpreted as evidence that the NI group was sensitive to the incongruent proportion, whereas the PWA had impaired ability to keep the goal of the PWI task in both proportions that resulted in no difference in error rates between two incongruent proportion tasks. To the degree that goal maintenance is captured through the error rates on the PWI task, the PWA demonstrated an impairment in their ability to maintain the task goal of ignoring the semantic information and activating the lexical information. The PWA group showed a larger response-time facilitation effect relative to NI (RT on neutral trials minus RT on congruent trials) in the 19% incongruent proportion task. This result supports the interpretation that the PWA were impaired in the goal maintenance component of executive attention. That is, the PWA lost the goal of the PWI task in which they were required to categorize the response irrelevant word stimulus instead of response relevant picture stimulus, and they responded to the picture stimulus that lead to a correct and fast response on the congruent conditions. MacLeod (1998) and MacLeod and MacDonald (2000) argued that facilitation reflects a convergence of the two dimensions of the congruent conditions while interference reflects conflict and competition between task-relevant aspects and task-irrelevant aspects of stimuli. They proposed that RTs (in normal populations) on congruent conditions in the color-word Stroop task reflects the combined RTs of slower (response irrelevant) color-naming and faster (response relevant) word reading. Because there was no discrimination between "goal maintaining" color naming and "goal neglecting" word reading, the RT of color word reading reduced the mean latency on the congruent conditions. In the case of the PWI task, facilitation effects reflected the combination of slower (response irrelevant) word categorization and faster (response relevant) picture categorization. Therefore, the fast RTs for pictures reduced the mean RTs on the congruent conditions and resulted in the facilitation effect. The larger facilitation effect in PWA for the 19% incongruent condition task supports the interpretation that the PWA demonstrated an impairment of goal maintenance.

Analyses of the PWI latency distribution for the correct responses in the 19% incongruent proportion task revealed that the PWA group had a significantly more positive skew than the NI group. Kane and Engle (2003) argued that an increased skew of RT distribution on incongruent conditions provided evidence for periodic neglect of the goal. Given that failures in goal maintenance may not be all-or-none (Kane & Engle, 2003), very slow response time reflects that the goal of PWI task was more likely lost but then recovered before an overt error was committed. The larger positive skew for PWA is viewed as confirmatory evidence that PWA group had impaired goal maintenance compared to the NI in the less frequent incongruent proportion.

The analyses of performance on the Iowa Gambling Test revealed that there was no significant group difference on either the time or the amount of money allocated. Both groups demonstrated non-significant differences in decision-making ability based on the proportions structure. Given the fact that there was no group difference on the proportion structure, the different pattern of RTs and error rates between PWA and NI on the PWI tasks is not likely due to group difference in the sensitivity of the proportion structure, but rather to impaired goal maintenance in the PWA. This is interpreted as external evidence to support an executive attention impairment rather than an inability to understand or utilize probability structure per se.

Both groups were also tested on a variety of independent variables like language, WM and executive attention measures. Correlation analyses of these data revealed that the language abilities measured by PICA and CRTT were significantly correlated with the measures of executive attention. The participants with poor PICA scores, CRTT scores and CRTT efficiency scores showed longer response times on the interference conditions of the 19% incongruent proportion task. In addition, executive attention performance was also significantly and negatively correlated with WM and STM. The participants who had longer RTs on the 19% incongruent proportion task (proposed to be a measure of one component of executive attention) showed lower WM capacity and shorter STM. This finding is consistent with a working memory model by Engle and colleagues (1999). They claimed that WM consists of three components, STM, processing/computation, and executive attention. In this conceptualization, WM capacity is determined by executive attention that is composed primarily of conflict resolution and goal maintenance in the face of interfering contexts. Therefore, the significant correlations of WM with RTs in the incongruent condition support the critical role of execution attention in WM. While the averaged WM score from the four WM tests (Water & Caplan, 2003) showed that participants with lower WM took longer time to resolve conflicts in the interference condition, RTs in the 19% incongruent proportion task was not significantly correlated with the CS, OS, and Alphabet WM span measures. The low correlations for some individual WM tests resulted from a floor effect in which those three tests were too hard to obtain a valid span for the PWA. More than half of PWA produced the lowest WM span (<2 span) on the test. These results support earlier findings in normal individuals that participants with low WMC generally produce longer RT on executive attention demanding tasks (Conway et al., 2001; Engle et al., 1999; Kane & Engle 2003).

Results for this study were relatively straightforward and most comparisons of interest were significant and followed the predictions based on the previous literature and on its theoretical underpinnings. However, it is critical to identify some of the limitations of the current study. First, the study included a relatively small number of participants, especially for the PWA group. Group (NI and PWA) × Proportion (19% and 73% incongruent proportions) interactions for error rates were not significant. Low power (power=.118) diminished the possibility of finding an effect of impaired goal maintenance for this measure for the PWA and the possibility that these persons with aphasia actually have impaired goal maintenance remains likely; especially in light of the error findings. The power analysis modeled on G power estimated that at least 73 PWA would be required in this experiment to reach a power of .8.

A second limitation involves the structure of the proportion conditions. In order to maximize goal maintenance effects, the current study chose the 19% and 73% incongruent proportion tasks. Whereas the 19% incongruent proportion task was composed of all three conditions (neutral, congruent, and incongruent conditions), the 73% incongruent proportion task was composed of 23% neutral conditions and 73% incongruent conditions. That is, there was no congruent condition in the 73% incongruent proportion task. The question arises as to whether no congruent conditions in the 73% incongruent proportion task would lead to a unique result compared to that of the 19% incongruent proportion task that included instances of all three (incongruent, neutral, and congruent) conditions. Kane and Engle (2003) examined whether the low congruent proportion task would lead to results similar to those in no congruent proportion task. The result from the low congruent task closely matched the no congruent task in which the low congruent task yielded a significant span difference in RT for the incongruent conditions. Therefore, this does not appear to be a source of bias in the data. However, this effect has not been investigated in detail in the current study and cautious interpretation of results in the PWI task with this participant population is warranted.

The major purpose of this study was to examine whether PWA have impaired executive attention in terms of conflict resolution and goal maintenance as assessed in PWI tasks. The PWA group demonstrated impaired conflict resolution as evidenced from RTs and error rates. They also evidenced impaired goal maintenance from error rates under the incongruent conditions (relative to performance by the NI group). The fact that the PWA group was vulnerable to both demands of conflict resolution and goal maintenance suggests that the PWA group demonstrated impaired executive attention.

Although a number of questions have been raised with respect to confirming and refining characteristics and knowledge of impaired executive attention and its application to aphasia, the current study encourages both researchers and clinicians to consider executive attentional deficits as a possible source of language processing difficulties in PWA. These findings support a relatively long history of identifying attentional impairments as a source of language deficits in PWA. The findings make clear that there are many more questions to be generated and much more research to be accomplished in order to determine how conflict resolution and goal maintenance are linked to language processing in PWA. It is hoped that this experimental study initiates and stimulates theoretical and clinical discussion of executive attentional issues in the assessment and treatment of aphasia.

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