Automatic activation, interference and facilitation effects in persons with aphasia and normal adult controls on experimental CRTT-R-Stroop tasks

Abstract

The current study investigated the effects of several color word congruent and incongruent "Stroop" tasks, within the context of a reading comprehension test (CRTT-R-$_{wf\text{-}Stroop}$), in persons with aphasia (PWA) (N=25) and normal adults (NA) (N=29). Reading times, percentage of correct responses and CRTT-R-$_{wf}$ scores were examined for the color words. Both groups demonstrated significant vigilance and interference effects on RT ratios reflecting costs in sustained attention, interference/suppression effects and attentional switching. Both groups showed a facilitation effect on the CRTT-R-$_{wf}$ score. Unlike the NA, the PWA showed no attentional effects for the number of correct response on the color adjectives.

Introduction

A very general theory of inefficient attention allocation has been proposed to account for the array of language processing deficits in persons with aphasia (PWA) (McNeil, Odell, & Tseng, 1991). This attentional control of language hypothesis considered the interplay of controlled and automatic processing. They hypothesized that the mechanism responsible for the reduced allocation of resources and the resultant selective processing impairments is an impaired inhibitory mechanism that would serve to limit the generation and maintenance of irrelevant information. Alternative hypotheses also remain viable such as impaired automatic activation, impaired goal maintenance and impaired attentional shifting. To date none of these hypotheses have been tested.

One experimental task that has gained wide acceptance in the psychology literature and clinical practice for assessing various aspects of attention is the *Stroop* task (Stroop, 1935) and it's many variants. These "Stroop" and "Stroop-like" tasks have been commonly used to measure automatic activation, suppression/inhibition, vigilance/goal maintenance and attentional switching (engagement/disengagement) processes in normal and many pathological populations. In the traditional *Stroop* task, a participant is asked to rapidly name the ink color of a printed color word, ignoring or "suppressing" the meaning of the automatically activated word. Because the lexical item is automatically activated in normal readers, the ink color naming is slower when it is different from the printed word (e.g. word "**blue**" printed in "red" ink) which constitutes an <u>incongruent</u> condition, compared to when a <u>congruent</u> condition (e.g. word "**blue**" printed in "blue" ink) or compared to a neutral condition (e.g. a color patch ( ) replacing the word). This *Stroop* effect is typically interpreted as evidence that the word is activated automatically and inhibition of the word meaning to access the perceptual attribute of color slows the color naming response. Greater interference without an accompanying increase in facilitation (the difference between neutral and congruent conditions) has been interpreted as reflecting impaired inhibition, automatic activation, attentional shifts or goal maintenance.

Studies of the Stroop effect in PWA are few. Two group studies in PWA have been identified (Wiener, Connor & Obler, 2004; Cohen, Meier & Schulze, 1983) with the second one written in German. Wiener and colleagues investigated the inhibition process at the lexical-semantic level of language processing in 5 participants with Wernicke's

aphasia and 12 normal adults (NA) using a numerical Stroop-like task. They found a "Stroop" effect for both groups; however, the interference effect for the PWA was significantly larger than for the controls. No facilitation effects were found for either group. They concluded that persons with Wernicke's aphasia had normal automatic activation and a selective deficit of inhibitory control. However, their study had a very small sample size and did not directly test the alternative hypothesis that the overall slowness of the PWA might be due to slow lexical activation in addition to impaired inhibition.

The purpose of the study was to investigate differences among CRTT-R-$_{wf\text{-}Stroop}$ congruent and incongruent conditions for PWA and NA on: 1) reading times, 2) percentage of correct responses, and 3) CRTT-R-$_{wf\text{-}Stroop}$ scores for the color words, relative to each subject's performance on the CRTT-R-$_{wf}$ condition.

Methods

Fifty-four individuals (25 PWA and 29 NA) participated in the study. The PWA met the definition and clinical criteria for aphasia specified by McNeil and Pratt (2001) as evidenced by their performance on the *Porch Index of Communicative Ability* (*PICA*) (Porch, 2001) or *WAB* (Kertesz, 2001). The NA group had no history of brain injury, a self-report of normal language development and/or PICA overall performance at or above the range established for normal adults (13.86) (Duffy & Keith, 1980). For descriptive purposes, all participants were administered the Digit span test from the Wechsler Memory Scale (Wechsler, 1981), and the Trail Making Test, Parts A and B (Reitan, 1958). Demographic and selection data are summarized for the PWA in Table 1 and the NA in Table 2.

All of the participants completed the CRTT-R-$_{wf}$ reading sentence comprehension test, whereby stimuli appear on the screen in a word-by-word self-paced format with each previous word disappearing with the onset of the following word. The five experimental CRTT-R$_{wf\text{-}Stroop}$ conditions were composed of: 1) CRTT-R$_{wf}$ (Control); the standard CRTT-R reading test in which no color word conflicts are present or specifically attended, 2) 100% Neutral (Control) [CRTT-R-$_{wf\text{-}Neutral}$]: sentences with 100% colored nonsense figures that replace the color adjective (e.g., "Touch the  (in color green) circle"), 3) 100% Incongruent [CRTT- R-$_{wf\text{-}100\%\ incongruent}$]: sentences where all ink colors are different from the color word (e.g. "touch the **red** (in blue font) circle"), 4) 70% Congruent [CRTT-R-$_{wf\text{-}70\%\text{-}congruent}$]: subtests with 70% of the sentences with the same lexical item and color (e.g., "Touch the **red** (in red font) circle"), and 5) 30% Incongruent [CRTT-R-$_{wf\text{-}30\%\text{-}congruent}$]: subtests with 30% of the sentences having ink colors that are different from the color word (e.g., "touch the **blue** (in red font) circle").

Reading times (RT), scores and correct rates (CRTT-R scores of 11 and above) for the color word, relative to each subject's performance on the CRTT-R-$_{WF}$ condition served as the dependent measures. That is, all scores were transformed to ratios to equate differences across experimental conditions relative to "baseline" performance levels. This allowed comparison of differences across groups and conditions with different base reading times and scores. As no reading comprehension Stroop task has been reported previously for either NA or PWA, clear directional predictions were difficult to make. However, we predicted a significant *vigilance* (the difference between CRTT-R-$_{wf}$ or CRTT-R-$_{wf\text{-}Neutral}$ and CRTT-R-$_{wf\text{-}100\%\text{-}incongruent}$ conditions) effect for PWA, no *facilitation*

(the difference between CRTT-R-$_{wf}$ or CRTT-R-$_{wf\text{-}Neutral}$ and CRTT-R-$_{wf\text{-}70\%\ congruent}$ conditions) effect for either group, and an interference (the difference between CRTT-R-$_{wf}$ or CRTT-R-$_{wf\text{-}Neutral}$ and CRTT-R-$_{wf\text{-}100\%\text{-}incongruent}$ condition) effect for the NA but not the PWA.

Results

The results of three separate 2 (group) x 5 (condition) ANOVAs were computed for the RT ratios, CRTT-R Score ratios and Correct Score ratios and are summarized in Tables 3, 4 and 5. Both groups showed significantly ($p<.05$ - highlighted in bold and colored) longer RT for the CRTT-R-$_{wf\text{-}100\%\text{-}incongruent}$ (vigilance) and CRTT-R-$_{wf\text{-}30\%\ incongruent}$ tasks relative to both control conditions (CRTT-R-$_{WF}$ and CRTT-R-$_{WF\text{-}Neutral}$). The NA group also showed significantly longer RT ratio on the CRTT-R-$_{wf\text{-}70\%\text{-}congruent}$ condition but the PWA did not (Table 3).

A similar pattern of significant results was found between the two groups for the CRTT-R Score, showing significantly lower scores on the 100% incongruent condition than the control conditions, and significantly higher scores (facilitation) on the 70% congruent condition. However, the NA group demonstrated a significant "Stroop" (interference) effect but the PWA did not (Table 4).

The Correct Score ratios were lower for the 100% and 30% incongruent conditions for the NA group; however, no significant effects were evident for the PWA (Table 5).

Discussion

Both groups demonstrated vigilance and interference (Stroop) effects on RT ratios and the groups did not differ from each other. Six PWA did not show this effect, performing beyond the 95% confidence interval (Figure 1). The PWA demonstrated RT ratios that reflected costs in sustained attention, interference/suppression effects and attentional switching mechanisms for this language comprehension task. Both groups showed a facilitation effect (70% congruence) for the CRTT-R score. Unlike the NA, the PWA showed no attentional effects for the number of correct scores on the color adjectives.

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Table1. Demographic and descriptive measures for the PWA

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

PICA=*Porch Index Communicative Ability* (Porch, 2001); MPO=Months Post Onset; M=male; F=female; TMT=Trail Making Test (Reitan, 1958); Digit Span=recalled item in maximum; * = WAB(Western Aphasia Battery) AQ; ** = digit span score using the WAIS-III guidelines, using the Wechsler form, memory scale form I.

Table2. Demographic and descriptive measures for the NA

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

PICA=*Porch Index Communicative Ability* (Porch, 2001) and norms for NA were obtained from Duffy and Keith (1980); M=male; F=female; TMT=Trail Making Test (Reitan, 1958); Digit Span=recalled item in maximum; ** = digit span score using the WAIS-III guidelines, using the Wechsler form, memory scale form I.

Table 3. **READING TIME** ratio differences among conditions for NA and PWA

NORMAL	CRTT-$R_{wf-Neutral}$	CRTT-$R_{wf-100\%\ incongruent}$	CRTT-$R_{wf-70\%\ congruent}$	CRTT-$R_{wf-30\%\ incongruent}$
CRTT- R_{wf}	.116	**.897***	**.313***	**.646***
CRTT- $R_{wf-Neutral}$		**.763***	**.197***	**.530***
CRTT- $R_{wf-100\%\ incongruent}$			**-.566***	**-.234***
CRTT- $R_{wf-70\%\ incongruent}$				**.333***
APHASIA				
CRTT- R_{wf}	-.079	**.672***	.028	**.435***
CRTT- $R_{wf-Neutral}$		**.751***	.107	**.514***
CRTT- $R_{wf-100\%\ incongruent}$			**-.643***	-.237
CRTT- $R_{wf-70\%\ incongruent}$				**.407***

*significant at $p<.05$

Table 4. **CRTT-R SCORE** ratio differences among conditions for NA and PWA

NORMAL	CRTT-$R_{wf-Neutral}$	CRTT-$R_{wf-100\%\ incongruent}$	CRTT-$R_{wf-70\%\ congruent}$	CRTT-$R_{wf-30\%\ incongruent}$
CRTT- R_{wf}	**.016***	**-.025***	**.021***	-.008
CRTT- $R_{wf-Neutral}$		**-.041***	.005	**-.023***
CRTT- $R_{wf-100\%\ incongruent}$			**.046***	-.018
CRTT- $R_{wf-70\%\ incongruent}$				**.020***
APHASIA				
CRTT- R_{wf}	.060	-.041	**.075***	-.027
CRTT- $R_{wf-Neutral}$		**-.101***	.015	-.087
CRTT- $R_{wf-100\%\ incongruent}$			**.116***	.014
CRTT- $R_{wf-70\%\ incongruent}$				**-.102***

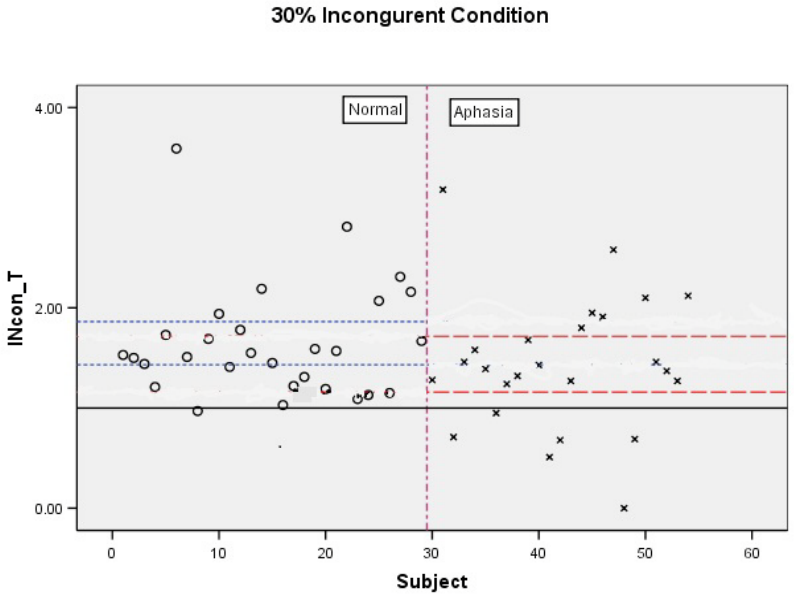
*significant at $p<.05$

Table 5. CRTT-R CORRECT SCORE (11 to 15) ratio differences among conditions for NA and PWA

NORMAL	CRTT-$R_{wf-Neutral}$	CRTT-$R_{wf-100\%\ incongruent}$	CRTT-$R_{wf-70\%\ congruent}$	CRTT-$R_{wf-30\%\ incongruent}$
CRTT- R_{wf}	.022	**-.058***	.026	-.031
CRTT- $R_{wf-Neutral}$		**-.080***	.004	**-.053***
CRTT- $R_{wf-100\%\ incongruent}$			**.084***	.027
CRTT- $R_{wf-70\%\ incongruent}$				**-.056***
APHASIA				
CRTT- R_{wf}	.185	.020	.277	.062
CRTT- $R_{wf-Neutral}$		-.165	.092	-.123
CRTT- $R_{wf-100\%\ incongruent}$			**.257***	.042
CRTT- $R_{wf-70\%\ incongruent}$				**-.215***

Vigilance effect, "Stroop Interference effect, Congruence Interference effect, Congruence Facilitation Effect. *significant at $p<.05$.

Figure 1. Scatter plot of the 30% incongruent ratio (CRTT- R_{wf} minus CRTT- $R_{wf\text{-}30\%\ incongruent}$) of reading times for the NA and PWA.



The solid line indicates the 1.0 baseline ratio calculated relative to the CRTT- R_{wf} condition that serves as the baseline.
The dashed lines represent the 95% confidence interval above and below each group's performance.