Examining inhibition during spoken word production in aphasia

The integrity of selective attention in people with aphasia (PWA) is currently unknown. Selective attention, our ability to focus on relevant information and ignore competing stimuli or cognitive operations, is essential for everyday communication. Inhibition, the suppression of unwanted information, is part of selective attention. The purpose of this study was to explore components of inhibition (intentional and reactive) during the process of spoken word production in individuals with aphasia, with the aims of furthering understanding of selective attention and its impairment in aphasia, and improving future aphasia rehabilitation.

Intentional inhibition, often described within the realm of interference control, is the suppression of a distraction. Reactive inhibition is the temporary unavailability of the distractor representation immediately following intentional inhibition. Both types of inhibition yield a slowed target response. Studies of language processes in the presence of distraction have provided evidence of larger interference effects for PWA compared to Controls in multiple domains: during auditory comprehension (Wiener et al, 2002), during reading and picture identification (Lim et al, 2012), and in the Stroop color-word task (Hamilton & Martin, 2005; McNeil et al, 2010). Results of these studies have been interpreted as evidence of limited or misallocated attention in aphasia, and therefore potentially deficient inhibitory function. Without adequate inhibition, finding the right word during conversation may become challenging or impossible due to the erroneous processing of distractions.

While intentional inhibition has been investigated in PWA, reactive inhibition has not. Evidence of impairments in reactive inhibition following neural injury within other clinical populations is mixed (Filoteo et al, 2002, Hogge et al, 2008; McDonald et al, 2005; Vitkovitch, et al, 2002). Hypothetically, if reactive inhibition is diminished, a person may struggle to retrieve a previously suppressed representation, or that representation may be suppressed to a less optimal degree, interfering with current language processes. The present study explored the nature of both types of inhibition during word retrieval in PWA. Before describing the goals of the present study, it is useful to explain how intentional and reactive inhibition are measured.

Intentional inhibition is evident when a more dominant, automatically activated distractor must be overcome to process a simultaneously presented weaker target, typically explored using the Stroop paradigm. In the Stroop color-word task, the participant must name the ink/font color of an orthographically presented color-word in several conditions. The incongruent condition provides evidence of intentional inhibition. For example, the word **RED** is typed in a green font. The participant is expected to say “green.” In this condition, the automatically activated word (red) must be suppressed in favor of the more weakly activated font color (green). The resulting response is slowed relative to the neutral condition (a colored polygon (✹) replacing the color-word) – called an interference effect. These conditions are also sometimes compared to a congruent condition, wherein the color-word and font color match (e.g. the word **RED** typed in a red font), used to explore facilitation.

Once the more dominant color-word has been suppressed in favor of the more weakly activated font color in the incongruent condition, what becomes of the color-word representation? This just-suppressed representation is not immediately available for reactivation, called reactive inhibition (Miyake et al, 2000). This phenomenon is often tested using a negative priming protocol, wherein the distractor on the first (prime) trial becomes the target on the second (probe) trial. One typically responds more slowly to a target stimulus that has just served as a distractor stimulus – also called repeated interference. For example, the word **RED** is presented in a green font on the first (prime) trial. On the subsequent (probe) trial, the word **BLUE** is presented in a red font. The participant must correctly respond "red," though she has just suppressed red in the previous trial. A slower reaction time – or a negative priming effect – is expected on the second (probe) trial compared to an unpaired or first (prime) incongruent trial.

The present study explored inhibition using a Stroop color-word task, comparing PWA to Controls on word naming latency and accuracy, as described by with following research questions (see Figure 1):

RQ1) Is there a significant difference in intentional inhibition and facilitation in PWA compared to Controls?

RQ2) Is there a significant difference in the presence and magnitude of reactive inhibition in PWA compared to Controls…:

a) …when tested with repeated interference?
b) …when tested with facilitation?
c) …when tested with facilitation compared with novel facilitation?

Methods

Participants: Nineteen PWA and 20 age- and education-matched Controls participated in the study (see Table 1). Participants were right-handed, native English speakers, with no history of confounding mental, neurological, or developmental status. All PWA met the diagnostic criteria defined by McNeil and Pratt (2001), as objectified by the Boston Naming Test (Kaplan, Goodglass & Weintraub, 1983), Western Aphasia Battery (Kertesz, 1982), and confirmed by clinical neurology and imaging reports. Participating PWA were at least six months post-onset of left hemisphere stroke, and without severe motor speech impairment.

Procedures: After screening tests (vision, memory, attention), each participant completed a spoken word task. Stroop color-word stimuli and colored polygons were presented in 340 consecutive trials on a computer monitor. Participants were asked to "Name the font color out loud, as quickly and accurately as you can." Response latency was recorded using a head microphone, and accuracy was recorded by an examiner.

Stimuli: Experimental stimuli consisted of five colors and color-words (red, blue, green, pink, white), used in three basic stimuli types: congruent (color-words with matching font color, e.g., "**RED**" in red font), neutral (colored polygon; ✹) and incongruent (color-words with mismatched font color; e.g., "**RED**" in green font). Incongruent trials served as primes for two probe stimuli types: a) incongruent probe (RQ2a: to measure reactive inhibition using repeated interference), where the prime distractor becomes the probe target, e.g., prime is "**RED**" in green font; probe is "**BLUE**" in red font, or b) congruent probe (RQ2b: to measure reactive inhibition using facilitation), where the prime distractor becomes a congruent probe, e.g., prime is "**RED**" in green font; probe is "**RED**" in red font (see Figure 1).

Analysis: Research questions were addressed by group-by-condition interactions: response latency data of correct responses were analyzed via repeated measures ANOVA; accuracy data were analyzed via Mann-Whitney tests.

Results

Results showed that while both groups demonstrated interference effects, these effects were significantly greater for PWA, $t(22.105)=3.298$, $p<.005$. PWA demonstrated no significant facilitation effects; Controls demonstrated significant reverse facilitation effects, $t(29.833)=4.303$, $p<.005$. There were no statistically significant differences in reactive inhibition when comparing groups, but PWA demonstrated a more marked trend toward slowing during the reactive inhibition condition tested with facilitation compared to novel facilitation (RQ2c), $t(18)=3.067$, $p=.006$. Accuracy analyses yielded only one statistically significant group comparison (see Figure 2 and Table 2).

Discussion

If we generalize from participants' performance on these Stroop tasks to their word production ability, these results underscore the challenges interference presents for PWA, indicating potentially diminished intentional inhibition. PWA's reactive inhibition appears equivalent to their neurologically typical counterparts, and therefore may not be a contributing factor in word retrieval impairments of aphasia. However, PWA may have greater difficulty with conflict adaptation during language production. These results provide direction for future research of selective attention in aphasia – ultimately aimed to improve clinical protocols.

References

Filoteo, JV, Rilling, LM, Strayer, RL (2002). Negative priming in patients with Parkinson's disease: evidence for a role of the striatum in inhibitory attentional processes. *Neuropsychology, 16*(2), 230-241.

Hamilton, AC and Martin, RC (2005). Dissociations among tasks involving inhibition: a single-case study. *Cognitive, Affective and Behavioral Neuroscience, 5*(1), 1-13.

Hogge, M, Salmon, E and Collette, F (2008). Interference and negative priming in normal aging and in mild Alzheimer's disease. *Psychologica Belgica, 48*(1), 1-23.

Kaplan, E, Goodglass, H and Weintraub, S (1983). *The Boston Naming Test*. Philadelphia, PA: Lea & Febiger.

Kertesz, A. (1982). *Western Aphasia Battery*. New York: Grune & Stratton.

Lim, KY, McNeil, RM, Doyle, JP, Hula, DW, Dickey, WM (2012). Conflict resolution and goal maintenance components of executive attention are impaired in persons with aphasia: evidence from the picture-word interference task. Presented at the 2012 Clinical Aphasiology Conference, Lake Tahoe, California.

McDonald, CR, Bauer, RM, Filoteo, JV, Grande, L, Roper, SN, Gilmore, R (2005). Attentional inhibition in patients with focal frontal lobe lesions. *Journal of Clinical and Experimental Neuropsychology, 27,* 485-503.

McNeil, MR, Kim, A, Lim, KY, Pratt, S, Kendall, D, Pompon, RH, Szuminsky, N, Fassbinder, W, Sung, JE, Kim, HS, Hammer, K and Dickey, M. (2010). Automatic activation, interference and facilitation effects in persons with aphasia and normal adult controls on experimental CRTT-R-Stroop tasks. Presented at the 2010 Clinical Aphasiology Conference, Isle of Palms, SC.

McNeil, MR and Pratt, SR (2001). Defining aphasia: Some theoretical and clinical implications of operating from a formal definition. *Aphasiology, 15,* 10/11, 901-911.

Miyake, A, Friedman, NP, Emerson, MJ, Witzki, AH, and Howerter, A (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks" a latent variable analysis. *Cognitive Psychology, 41*, 49-100.

Vitkovitch, M, Bishop, S, Dancey, C and Richards, A (2002). Stroop interference and negative priming in patients with multiple sclerosis. *Neuropsychologia, 40,* 1570-1576.

Wiener, DA, Conner, LT, and Obler, LK (2002). Inhibition and auditory comprehension in Wernicke's aphasia. *Aphasiology, 18*(5/6/7), 599-609.

Condition comparisons	Con	Inc (prime)	Neu	Inc probe	Con probe
Intentional inhibition **RQ 1** interference (Inc-Neu) & facilitation (Neu-Con) effects	RED in red	RED in green			
Reactive inhibition **RQ 2a** incongruent probe (*repeated interference*) vs. novel incongruent condition		RED in green		BLUE in red	
RQ 2b incongruent probe (*repeated interference*) vs. congruent (*facilitation*) probe				BLUE in red	RED in red
RQ 2c congruent (*facilitation*) probe vs. novel congruent condition	RED in red				RED in red

Figure 1: Research questions with condition comparisons and example stimuli. The experiment contained 340 total trials: 40 congruent trials, 40 neutral trials, 80 incongruent trials, 80 probe trials (40 incongruent probes, 40 congruent probes), and 100 neutral fillers, presented in pseudorandom order. Each incongruent trial served as a prime for one of the two probe trials. Each probe trial was followed by an unrelated and unanalyzed neutral filler trial to control for lingering suppression effects.

PWA	age	gender	yrs ed	mpo	AOS	dysarthria	Controls	age	gender	yrs ed
P1	67	M	15	23	mild	none	C1	41	F	16
P2	50	M	20	8	none	moderate	C2	45	F	16
P3	70	M	25	32	mild	none	C3	45	F	15
P4	48	F	16	17	none	none	C4	52	F	19
P5	52	M	16	43	mild	none	C5	53	F	14
P6	65	M	23	53	none	none	C6	59	F	12
P7	68	F	14	180	none	none	C7	69	M	16
P8	34	M	12	15	mild	none	C8	66	M	13
P9	58	M	16	47	mild-mod	none	C9	48	M	16
P10	67	F	16	169	none	none	C10	60	F	16
P11	74	M	18	108	none	none	C11	63	M	19
P12	34	F	15	50	none	none	C12	66	F	18
P13	62	F	16	101	none	none	C13	66	F	18
P14	51	F	13	24	moderate	none	C14	61	F	14
P15	69	M	17	126	moderate	mild-mod	C15	43	F	16
P16	48	F	12	40	none	none	C16	56	M	18
P17	61	F	16	24	moderate	mild	C17	60	M	16
P18	62	F	18	159	mild-mod	none	C18	67	F	16
P19	30	F	14	19	moderate	none	C19	67	F	15
							C20	62	M	16
mean	**56.3**		**16.4**	**65.2**			**mean**	**57.5**		**16.0**
sd	**13.1**		**3.4**	**56.7**			**sd**	**9.02**		**1.85**

Table 1. Demographic and descriptive information for PWA (left) and neurologically typical Control participants (right): age, gender, years of education, and for PWA, months post onset (mpo), and presence of apraxia of speech (AOS) and dysarthria.

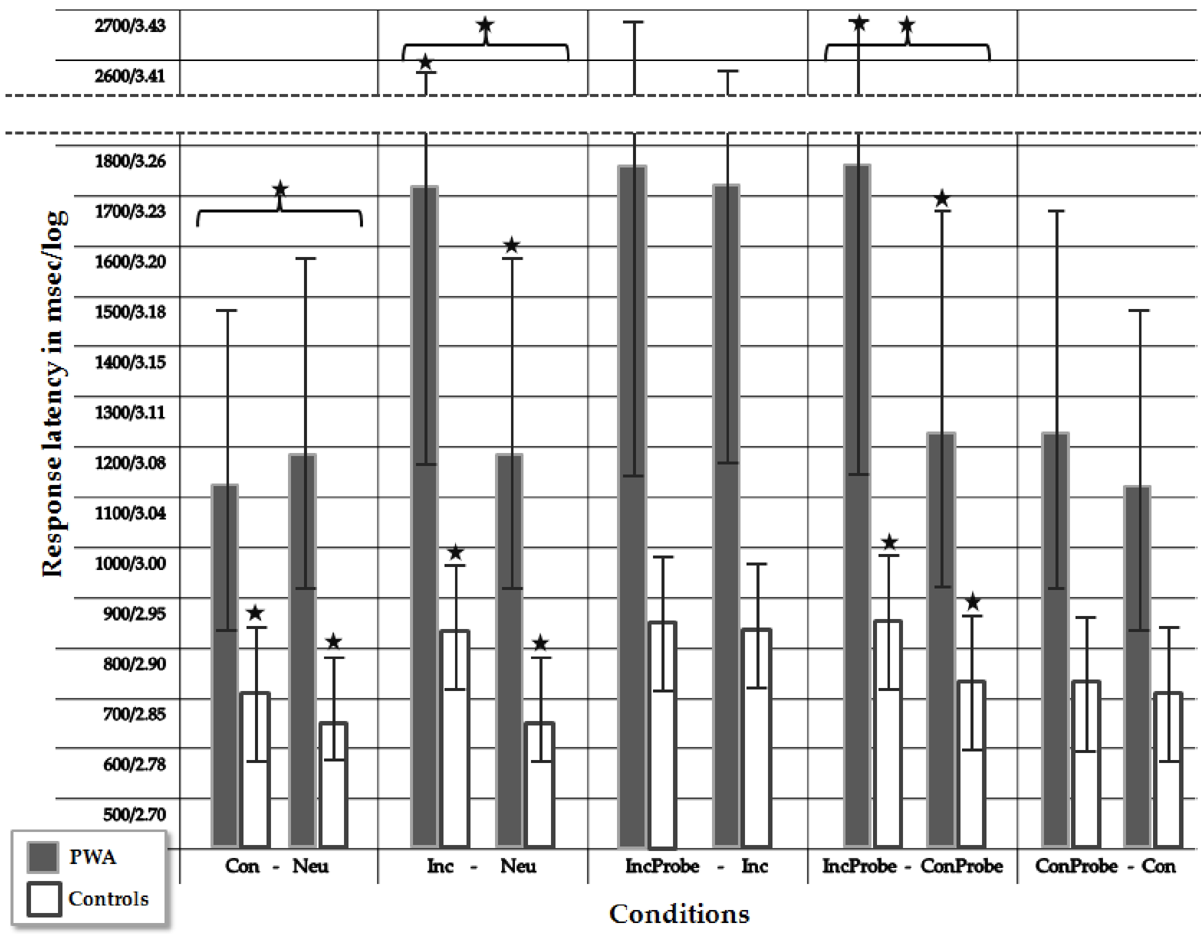

Figure 2. Mean response latencies in msec/log for both groups on all condition comparisons; whiskers indicate 1 standard deviation above and below the mean. Significance (p<.005) indicated a) between groups with bracket and ★, and b) within groups with ★ over both conditions.

* sig p<.005	Intentional inhibition		Reactive inhibition		
	Facilitation Neu – Con	Interference Inc – Neu	a) Repeated interference IncProbe – Inc	b) Facilitation probe IncProbe – ConProbe	c) comparing ConProbe – Con
RESPONSE LATENCY Between groups	p<.005*	p<.005*	p=.786	p<.005*	p=.034
PWA	p=.017	p<.005*	p=.400	p<.005*	p=.006
Control	p<.005*	p<.005*	p=.132	p<.005*	p=.038
ACCURACY Between groups	p=.026	p=.133	p=.069	p=.010	p=.045
PWA	p=.015	p=.024	p=.040	p<.005*	p=.047
Controls	p=.102	p=.007	p=.437	p=.026	p=1.00

Table 2. Research questions with between- and within-group *p*-values for all five research question condition comparisons. Significance level $p < .005$.