Currently, there is increasing empirical and clinical interest in the integrity of nonlinguistic, cognitive processes (e.g., attention, working memory) in aphasia, and the relationship between these processes and aphasic symptoms and outcomes (Laures, 2005; Moineau et al., 2005). Indeed, recent findings support an emerging conceptualization of aphasia in which deficits in cognitive functions other than language may generate or intensify linguistic impairments (McNeil & Doyle, 2000; Murray & Kean, 2004). The purpose of the current study was to specify further this processing or resource model of aphasia by examining interactions between sentence processing and general cognitive skills in aphasic patients using a dual-task paradigm. Although previous findings indicate that cognitive factors can negatively influence sentence processing in healthy (Kilborn, 1991; Wingfield et al., 2006), aphasic (Murray et al., 1997; 1998), and other patient populations (Colman et al., 2006), these prior investigations did not sufficiently examine whether (a) cognitive factors interact with parameters known to influence sentence processing (i.e., syntactic complexity, number of propositions), or (b) material-specific limitations (i.e., grammaticality judgments during a non-distracting condition), general cognitive abilities (i.e., cognitive test scores), or both are important predictors of dual-task outcomes.

Accordingly, this study determined whether sentence processing deficits in aphasia are associated, as least in part, with cognitive limitations by having adults with aphasia or no brain damage complete a grammaticality judgment task alone and in competition with a tone discrimination task. Task demands were manipulated by varying listening condition (single vs. dual task) and sentence type. Sentence stimuli were constructed to examine the effects of syntactic complexity and number of propositions, and thus, to delineate whether there is a separate resource pool uniquely dedicated to syntactic processes (Friedmann & Gvion, 2003; Kave & Levy, 2005) or whether the same resources used for syntactic processes are also used in other cognitive tasks (Kolk et al., 2003; Wilson et al., 2003). To evaluate syntactic complexity effects, judgments of active versus passive sentences were compared as greater syntactic demands are associated with processing passives' noncanonical order of thematic roles (Drai & Grodzinsky, 2005); to examine proposition effects, active versus conjoined sentences were contrasted as the larger sets of verb-related thematic roles in conjoined sentences have greater postinterpretive processing demands (Rochon et al., 2000). The hypotheses tested were: (a) compared to controls, aphasic adults would exhibit greater distraction and dual-task interference because of their concomitant cognitive deficits; (b) based on previous findings (e.g., Murray, 2005), the aphasic adults' dual-task outcomes would be related to both material-specific and general cognitive abilities; and, (c) if syntactic processing is dependent on an isolated resource system, there would be no disproportionate increase in syntactic complexity effects across listening conditions, whereas general cognitive resources would be implicated if syntactic and propositional complexity effects were similar across the listening conditions.

Methods

Subjects. Participants included 23 adults with and 26 adults without aphasia (Table 1). Groups were matched for age and education, and all subjects met inclusionary hearing, vision, and praxis criteria. According to the *Aphasia Diagnostic Profiles*, aphasic subjects had mild to moderate aphasia and represented a variety of aphasia types.

Test Battery. All subjects completed: (a) forward and backward Visual Memory Span, (b) an auditory-verbal working memory protocol, and, (c) *Test of Everyday Attention*.

Dual Task Procedures. Subjects completed grammaticality judgment and tone discrimination tasks under five listening conditions: (a) *Isolation* - each task completed without distraction, (b)

Focused Attention - secondary, competing tone stimuli were presented, but only the grammaticality task was completed (only one response required), (c) *Divided Attention #1* - both tasks (two responses required) completed giving priority to the grammaticality task (i.e., 75% grammaticality/25% tone priority condition), (d) *Divided Attention #2* - both tasks completed with equal emphasis (50/50% priority condition), and (e) *Divided Attention #3* - both tasks completed giving priority to the tone task (25/75% priority condition).

The *Grammaticality Judgment Task* required listening to lists of 60 sentences recorded by a female speaker and via a computer key press response indicating whether each sentence had "good" or "bad" grammar. For each list, there were 20 active, 20 passive, and 20 conjoined, present tense sentences, half of which were grammatically correct (Table 2). Verb agreement violations were created by affixing an incorrect suffix to the main verb; this locus of ungrammaticality was selected so that the type of sentence construction was evident prior to the point at which subjects should make their grammaticality judgments. For each list, the mean temporal location of ungrammaticality was matched among the three sentence types. Incorrect suffixes were perceptually dissimilar to the correct suffix, and sentences were piloted to assure that these "small" modifications were perceptible. Lists were matched for mean sentence length, with grammatically correct and incorrect sentences randomized within each list.

The *Tone Discrimination Task* required discriminating thirty 500 Hz and thirty 2000 Hz pure tones presented in a random order. During the Isolation condition, tone duration was the average length of the sentence stimuli; for the remaining conditions, tone and sentence durations were matched, with an equal number of high and low tones superimposed upon grammatically correct and incorrect sentences. All stimuli were prepared and administered using a PowerMac, SoundEdit®, and PsyScope (Cohen et al., 1993) which allowed on-line computation of accuracy and reaction time (RT).

<u>Data Analyses</u>. Accuracy, A´ (a measure of grammatical sensitivity that adjusts for systematic response bias and estimates the proportion of correct responses; Grier, 1971) and RT data were analyzed via a series of repeated measures ANOVAs. Bivariate correlations of dependent measures with continuous variables (e.g., cognitive test results) were calculated separately for each group to investigate factors associated with experimental task performances.

Results and Summary

Collectively, accuracy, A´, and RT results (Tables 3-4, Figures 1-2) were consistent with previous findings documenting that complex attention conditions negatively affect sentence processing in healthy and aphasic adults (Angwin et al., 2006; Dick et al., 2001; Murray et al., 1997). As predicted, the aphasic group demonstrated greater distraction and dual-task interference on both the sentence and tone tasks. Furthermore, the aphasic group was poorer at exploiting speed-accuracy trade-offs and at following the prescribed attention priorities during dual-task conditions (e.g., give 75% of your attention to the tone task). Correlational findings supported the second hypothesis that both material-specific and general cognitive factors would be associated with the dual-task outcomes of the aphasic group: Their sentence and tone dual-task performance decrements were significantly related to demographic (e.g., age), cognitive (e.g., attention test outcomes), as well as linguistic (e.g., auditory comprehension subtest outcomes) variables. Lastly the findings were most consistent with the hypothesis that sentence processing, including syntactic analysis, draws from a general cognitive (Kolk et al., 2003; Papagno & Cecchetto, 2006) versus domain specific resource system (Caplan & Waters, 1999; Rochon et al., 2000) given that for both subject groups' responses to all sentence types were vulnerable to the increased task demands of the dual-task conditions; furthermore, both

accuracies and RTs for passive and conjoined sentences were disproportionately worse than those for actives during the dual-task conditions, particularly for the control group. Accordingly, these findings inform resource models of aphasia and language processing by further delineating interactions between syntactic and general cognitive abilities in both patient and normal populations.

Table 1. Group Characteristics and Select Test Data

Variable		Aphasic (n = 23)	Control (n = 26)
Age (years)	M	57.5	61.1
	SD	12.9	13.7
	Range	32-83	30-80
Education (years)	M	14.5	15.2
	SD	1.7	1.5
	Range	12-16	12-16
Time Post Stroke (months)	M	48.2	
	SD	42.0	
	Range	6-168	
Gender (Male: Female)		16:7	10:16
Aphasia Diagnostic Profiles (Standard Scores)			
Auditory Comp.	M	12.9	
	SD	3.0	
	Range	8-17	
Aphasia Severity	M	117.3	
	SD	16.2	
	Range	88-135	
Auditory-Verbal Working Memory (# recall errors)	M	20.5	6.9
	SD	10.8	4.3
	Range	6-42	0-13
Test of Everyday Attention (standard scores)			
Elevator Counting With Distraction	M	7.7	11.4
	SD	3.3	2.0
	Range	3-13	6-13
Telephone Search With Counting	M	6.3**	11.8
	SD	4.1	3.4
	Range	0-15	6-19
WMS-R Visual Memory Span (%iles)			
Forwards	M	45.9	65.7
	SD	34.1	21.4
	Range	2-98	32-98
Backwards	M	52.8	70.5
	SD	26.2	20.7
	Range	2-96	36-99

Table 2. Examples of Grammaticality Judgment Stimuli

Active Sentences	
	The suspicious professor is reading the difficult text.
	The lottery losers are curses their bad luck.
Passive	
	The holiday ham is being sliced by the waiter.
	The gardenias are being uproots by the gopher.
Conjoined	
	The dogs are catching sticks and chasing squirrels
	The farmer is sowing buckwheat and spreads fertilizer.

Note. Incorrect sentences are in italic font.

Table 3. Accuracy (% Correct) and Reaction Time (ms) Group Means, Standard Deviations, and Ranges for the Grammaticality Judgment Task.

Data Type	Condition	Group		Sentence Type: Active	Passive	Conjoined
Accuracy	isolation	Aphasic	M	94.8	92.6	91.3
			SD	5.9	9.5	8.3
			Range	80-100	70-100	75-100
		Control	*M*	*98.5*	*98.7*	*97.7*
			SD	*2.7*	*3.1*	*4.9*
			Range	*90-100*	*90-100*	*80-100*
	focused attention	Aphasic	M	84.3	87.8	81.5
			SD	12.4	17.6	15.8
			Range	55-100	45-100	50-100
		Control	*M*	*96.9*	*99.2*	*96.5*
			SD	*3.2*	*1.8*	*3.9*
			Range	*90-100*	*95-100*	*85-100*
	divided attention #1	Aphasic	M	87.8	84.6	79.3
			SD	14.9	11.9	19.1
			Range	50-100	50-95	40-95
		Control	*M*	*98.8*	*98.3*	*94.4*
			SD	*2.6*	*3.7*	*6.4*
			Range	*90-100*	*85-100*	*75-100*
	divided attention #2	Aphasic	M	81.5	80.4	77.6
			SD	16.9	14.8	14.3
			Range	40-100	50-100	55-95
		Control	*M*	*97.1*	*91.7*	*92.7*
			SD	*3.5*	*4.7*	*6.5*
			Range	*90-100*	*80-100*	*70-100*
	divided attention #3	Aphasic	M	84.6	74.3	80.7
			SD	14.1	12.6	15.2
			Range	50-100	45-90	50-100
		Control	*M*	*97.5*	*85.4*	*93.8*
			SD	*3.5*	*4.2*	*6.4*
			Range	*90-100*	*80-95*	*80-100*
Reaction Time	isolation	Aphasic	M	4497.4	3956.7	4256.5
			SD	537.0	468.7	523.1
			Range	3666-5605	3218-4841	3513-5187
		Control	*M*	*3926.8*	*3401.4*	*3655.7*
			SD	*330.4*	*275.5*	*225.6*
			Range	*3277-4448*	*3013-4081*	*3252-4168*

focused attention	Aphasic	M	4286.5	3897.0	4110.5
		SD	554.3	609.2	535.0
		Range	3541-5683	3107-5510	3422-5210
	Control	*M*	*3694.5*	*3224.3*	*3425.9*
		SD	*232.2*	*212.2*	*237.9*
		Range	*3239-4074*	*2874-3751*	*3031-3890*
divided attention #1	Aphasic	M	5396.4	4876.4	4935.8
		SD	701.2	619.4	525.3
		Range	4309-7364	3877-6044	3944-5978
	Control	*M*	*4604.8*	*4148.5*	*4335.9*
		SD	*332.3*	*287.7*	*337.5*
		Range	*3982-5204*	*3632-4704*	*3700-5164*
divided attention #2	Aphasic	M	4971.9	4678.4	4877.4
		SD	487.4	524.9	457.5
		Range	4060-5986	3585-5557	4276-5621
	Control	*M*	*4371.0*	*4070.7*	*4251.4*
		SD	*359.4*	*402.6*	*320.1*
		Range	*3765-4943*	*3335-4673*	*3637-4815*
divided attention #3	Aphasic	M	4982.2	4587.9	4683.4
		SD	539.1	518.4	408.2
		Range	3927-5942	3513-5902	3668-5266
	Control	*M*	*4400.2*	*4104.4*	*4252.7*
		SD	*437.6*	*367.8*	*376.8*
		Range	*3665-5212*	*3351-4692*	*3541-4917*

Note. Divided Attention #1 = 75/25% condition in which subjects are asked to allot 75% of their attentional capacity to the grammaticality task and 25% to the tone task; Divided Attention #2 = 50/50% priority condition in which subjects are asked to distribute equally their attention to both tasks; Divided Attention #3 = 25/75% condition in which subjects instructed to allot 25% of their attentional capacity to the grammaticality task and 75% to the tone task.

Table 4. A´ Sensitivity Score Group Means, Standard Deviations, and Ranges for the Grammaticality Judgment Task.

		Group	
Condition		Aphasic	Control
isolation	M	.96	.99
	SD	.04	.01
	Range	.89-1.00	.96-1.00
focused attention	M	.89	.99
	SD	.12	.01
	Range	.62-.99	.96-1.00
divided attention #1	M	.89	.99
	SD	.13	.01
	Range	.56-.98	.95-1.00
divided attention #2	M	.86	.98
	SD	.13	.02
	Range	.50-.98	.94-1.00
divided attention #3	M	.86	.96
	SD	.12	.02
	Range	.50-.98	.92-.98

Note. A´ = 1.00 is interpreted as 100% correct or perfect discrimination (Grier, 1971; Linebarger et al., 1983).

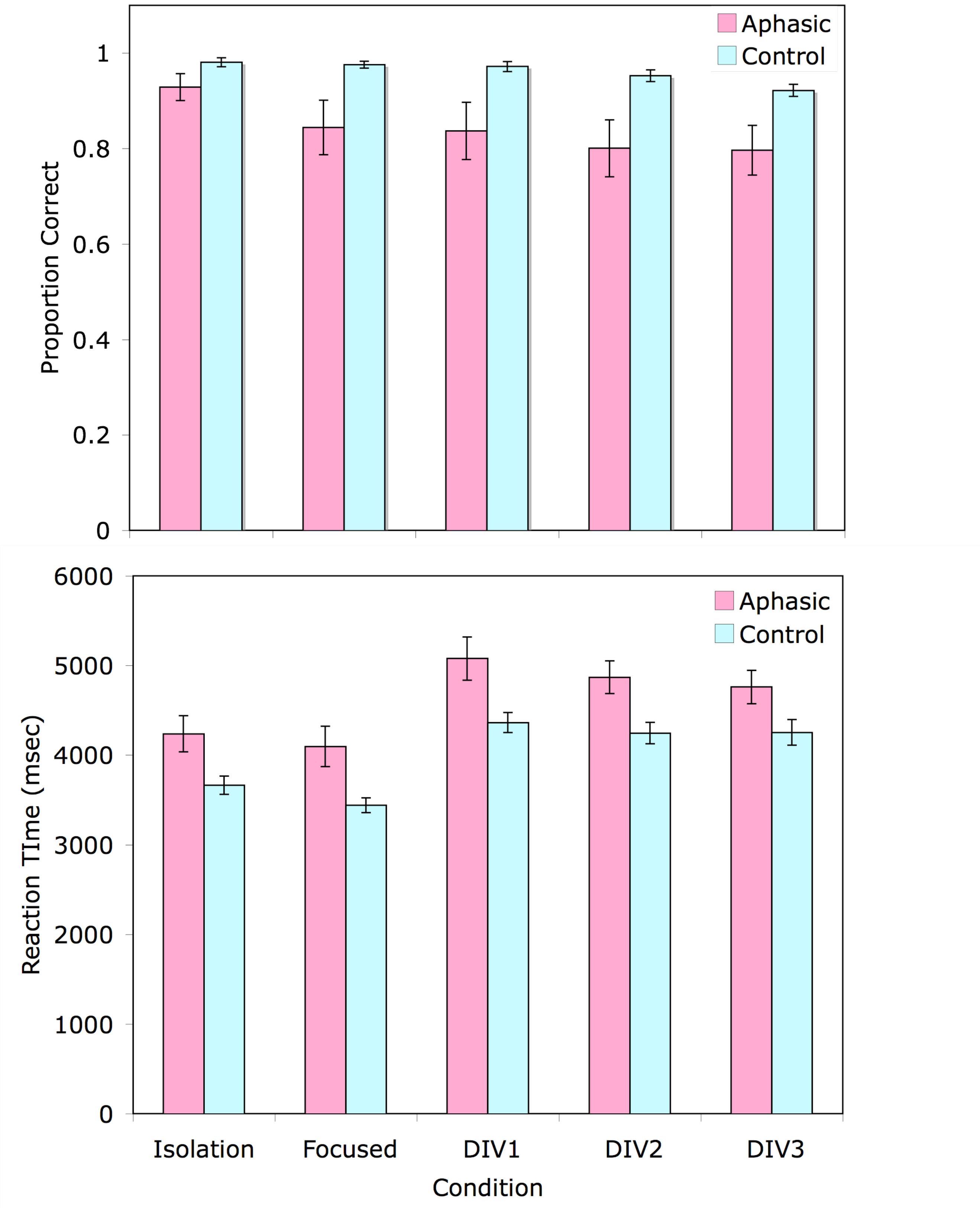

Figure 1. Mean proportion of correct grammaticality judgments (top) and reaction times (bottom) (and 95% confidence interval bars) for each group across each listening condition.

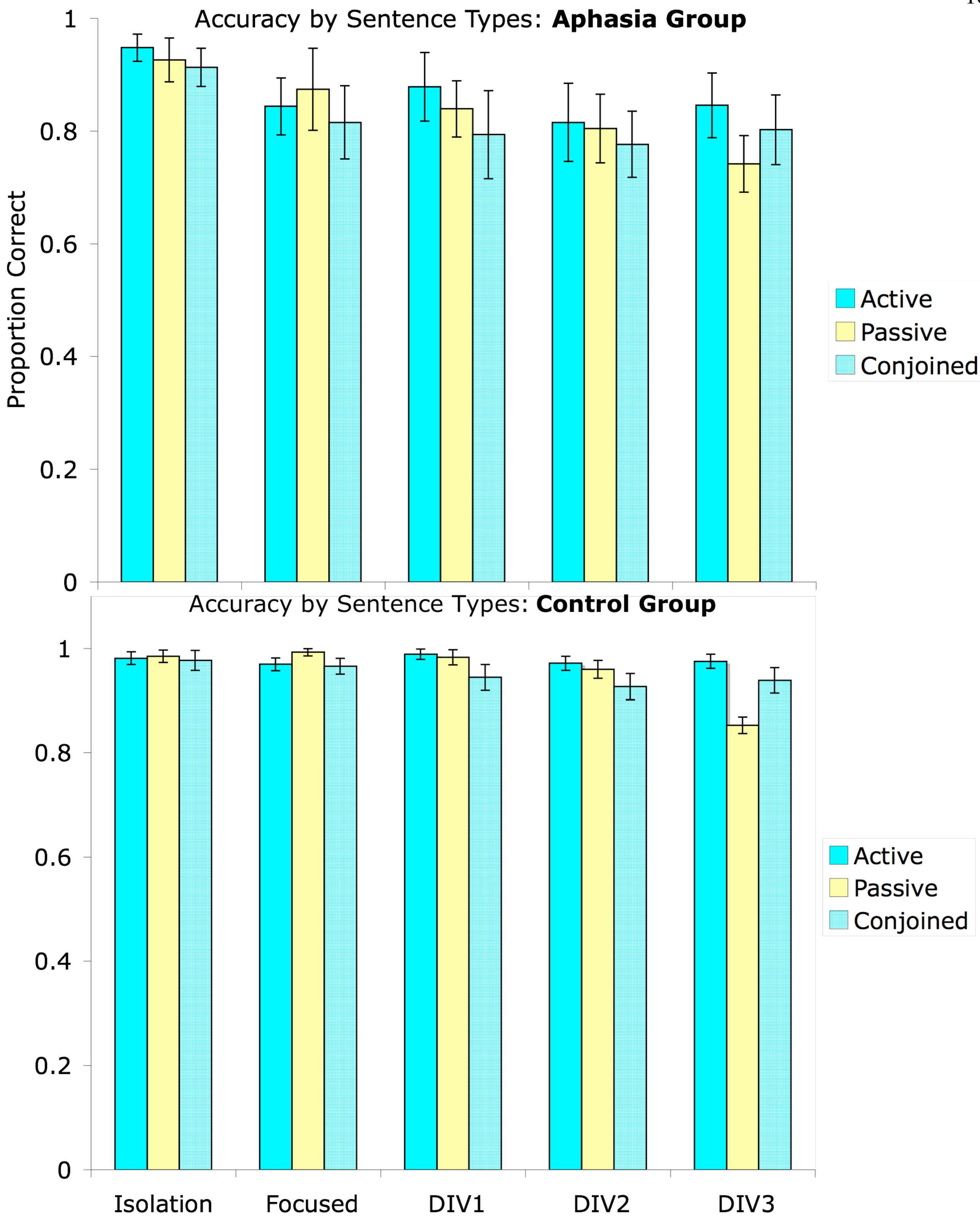

Figure 2. Mean proportion correct (and 95% confidence interval bars) of grammaticality judgments for each sentence type across each listening condition for the aphasic (top) and control (bottom) groups.