Implicit and Explicit Learning in Aphasia

Introduction

Implicit learning is an incidental, inductive learning process that occurs without the use of explicit strategies. To date, few studies have investigated implicit learning subsequent to stroke, and almost all have used visuomotor tasks (e.g., Boyd & Winstein, 2004; 2006; Exner, Weniger, & Irle, 2001; Gomez-Beldarrain, Garcia-Monco, Rubio, & Pascual-Leone, 1998; Orrell, Eves, Masters, & MacMahon, 2007). The present study used a Serial Search Task developed by Goschke and colleagues (2001) to examine implicit and explicit learning of an auditory word sequence in individuals with stroke-induced agrammatic aphasia and healthy age-matched adults.

The present study also included a listening sentence span task to evaluate working memory. Research indicates that many aphasic individuals have working memory impairments, which are highly interrelated with language comprehension and overall aphasia severity (Caspari, Parkinson, LaPointe, & Katz, 1998; Friedmann & Gvion, 2003; Sung et al., 2009; Wright & Shisler, 2005). However, little is known about how working memory deficits relate to learning in aphasia.

Methods

Participants included 10 individuals with chronic stroke-induced agrammatic aphasia (7 male; age 33-74, *M*=55) and 18 age- and education-matched healthy controls (9 male; age 46-74, *M*=61). Aphasic participants exhibited symptoms consistent with agrammatism, as indicated by scores on the *Western Aphasia Battery-Revised* (WAB-R; Kertesz, 2007), *Northwestern Assessment of Verbs and Sentences* (NAVS; Thompson, unpublished), *Boston Naming Test* (BNT; Kaplan, Goodglass, & Weintraub, 1983), and narrative sample analyses (see Tables 1 and 2).

Two versions of the Serial Search Task stimuli were developed. Each version consisted of four monosyllabic concrete nouns arranged in an eight-item sequence (e.g., *shoe desk cake knife cake desk shoe knife).* These words were paired with corresponding black and white line drawings. Stimuli for the listening span task consisted of simple active sentences eight words in length.

On each trial of the Serial Search Task (SST), the four pictures were presented horizontally on the computer monitor, with each of the four locations corresponding with a button on a response pad. The pictures were displayed for 500 ms before one of the four words was presented over the speakers. The participant pressed the button corresponding with the location of the word that was spoken, and a blank screen appeared for 500 ms before the beginning of the next trial (see Figure 1). In each trial, the four pictures were randomly assigned to the four locations. In contrast, the auditory stimuli were presented in the order of the 8-item sequence during most of the experiment, with Blocks 1-6 each consisting of ten repetitions of the 8-item sequence of spoken words (i.e., 80 trials per block). Block 7 consisted of 80 trials with the four words occurring in a pseudorandom order. Block 8 returned to sequenced stimuli with ten repetitions of the sequence. In this paradigm, implicit learning of the sequence is indicated by longer response times when the words switch from a sequenced pattern to a pseudorandom order.

Each participant completed two learning sessions. The first session consisted of the SST under implicit conditions, in which participants were instructed to respond to the spoken words as quickly and accurately as they could. The second session took place 1-3 days later and consisted of the same task with a second, equally complex set of stimuli. Before beginning the

task, participants were explicitly informed of the existence of the auditory word sequence and listened to the sequence once.

After completing the SST, participants performed a listening sentence span task modeled after Daneman and Carpenter's (1980) reading span test. Participants were instructed to listen to sets of sentences and hold the last word of each sentence in memory until prompted to recall aloud the words from that set. The number of sentences presented in each trial varied from two to six, and a yes/no comprehension question regarding the last sentence in the series was presented in each trial.

Results

In both the aphasic and age-matched control groups, reaction times (RT) during the SST under implicit learning conditions increased in the pseudorandom Block 7 compared to the immediately preceding sequenced Block 6, indicating an implicit learning effect for the auditory word sequence. Paired-samples t-tests indicated that the difference in RT was significant for both healthy control participants ($t(17)=3.04$, $p<.01$) and aphasic individuals ($t(9)=2.98$, $p=.016$). Due to the significantly higher overall RTs for aphasic compared to healthy participants, the RT data were converted to percentages for analyses directly comparing the two groups. Each participant's mean RT in the first block of the SST was considered his or her baseline (i.e., 100%). The mean RT of each subsequent block was then expressed as the percentage of the participant's baseline RT (see Figure 2). These percentage values were entered into a 2 x 2 ANOVA with Group (aphasia, control) as a between-subjects factor and Block (Block 6 and Block 7) as a within-subjects factor. The main effect of Block was significant ($F(1,26)=13.77$, $p<.01$). There was no main effect of Group ($F(1,26)=2.30$, $p=.14$) or Group x Block interaction ($F(1,26)=0.03$, $p=.86$).

Under explicit conditions, RTs in the age-matched control group decreased over sequenced blocks and significantly increased from a mean of 745 ms in Block 6 to 928 ms in Block 7 ($t(17)=4.19$, $p<.01$). In contrast, the difference in RT between Block 6 and Block 7 was not statistically significant for the aphasic group ($t(9)=0.71$, $p=.50$). To compare the two groups, RT data were converted to percentages and a 2 x 2 ANOVA was performed, as described above (see Figure 3). Results revealed a significant main effect of Block ($F(1,26)=7.30$, $p=.01$). However, the overall higher RT in Block 7 compared to Block 6 was almost entirely attributable to the control group. This difference between the two groups was indicated by a significant Group x Block interaction ($F(1,26)=6.26$, $p=.02$).

Working memory scores in the healthy control group ranged from 25 to 54 words recalled out of a total possible 60 words ($M=46.2$, $SD=7.6$), whereas scores in the aphasic group ranged from 14 to 38 ($M=25.3$, $SD=7.7$). The difference in scores between the two groups was statistically significant ($t(25)=6.68$, $p<.01$).

Discussion

Results of the present study demonstrate significant implicit learning in individuals with agrammatic aphasia. However, unlike healthy age-matched adults, agrammatic individuals did not learn the auditory word sequence under explicit conditions, when they were consciously aware of the presence of a sequence.

Impaired learning under explicit conditions is in line with previous studies of learning after stroke. Boyd and Winstein (2004; 2006) found that providing explicit information regarding sequential learning tasks aided motor learning in healthy participants but interfered with learning in stroke patients. The authors suggest that providing explicit information may place demands on working memory that are unmanageable for some stroke patients. Individuals with aphasia often exhibit impaired working memory compared to healthy adults, as demonstrated in the present study by significantly lower scores on the listening span task. Consequently, these individuals

may be impaired in applying explicit instruction in learning tasks that involve high working memory demands. However, both implicit and explicit learning processes have the potential to be exploited in language treatment, and further research in this area may help engage individuals with aphasia in learning strategies which will be most beneficial for them.

References

Boyd, L., & Winstein, C. (2004). Providing explicit information disrupts implicit motor learning after basal ganglia stroke. *Learning & Memory, 11*(4), 388.

Boyd, L., & Winstein, C. (2006). Explicit information interferes with implicit motor learning of both continuous and discrete movement tasks after stroke. *Journal of Neurologic Physical Therapy, 30*(2), 46.

Caspari, I., Parkinson, S. R., LaPointe, L. L., & Katz, R. C. (1998). Working memory and aphasia. *Brain and Cognition, 37*(2), 205-223.

Daneman, M., & Carpenter, P. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19*(4), 450-466.

Exner, C., Weniger, G., & Irle, E. (2001). Implicit and explicit memory after focal thalamic lesions. *Neurology, 57*(11), 2054.

Friedmann, N., & Gvion, A. (2003). Sentence comprehension and working memory limitation in aphasia: A dissociation between semantic-syntactic and phonological reactivation. *Brain and Language, 86*(1), 23-39.

Gomez-Beldarrain, M., Garcia-Monco, J., Rubio, B., & Pascual-Leone, A. (1998). Effect of focal cerebellar lesions on procedural learning in the serial reaction time task. *Experimental Brain Research, 120*(1), 25-30.

Goschke, T., Friederici, A., Kotz, S., & Van Kampen, A. (2001). Procedural learning in Broca's aphasia: Dissociation between the implicit acquisition of spatio-motor and phoneme sequences. *Journal of Cognitive Neuroscience, 13*(3), 370-388.

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

Kertesz, A. (2007). *Western Aphasia Battery-Revised*. San Antonio, TX: PsychCorp.

Orrell, A., Eves, F., Masters, R., & Macmahon, K. (2007). Implicit sequence learning processes after unilateral stroke. *Neuropsychological Rehabilitation, 17*(3), 335-354.

Sung, J. E., McNeil, M. R., Pratt, S. R., Dickey, M. W., Hula, W. D., Szuminsky, N. J., Doyle, P.J. (2009). Verbal working memory and its relationship to sentence-level reading and listening comprehension in persons with aphasia. *Aphasiology, 23*(7-8), 1040-1052.

Wright, H. H., & Shisler, R. J. (2005). Working memory in aphasia: Theory, measures, and clinical implications. *American Journal of Speech-Language Pathology, 14*(2), 107-118.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Mean
Western Aphasia Battery-Revised											
Aphasia Quotient	77.6	89.6	65	71.7	80	87.8	58.9	83	74.3	78	76.6
Fluency	5	5	4	4	5	6	2	5	5	5	4.6
Information Content	9	10	8	9	9	9	7	9	8	10	8.8
Auditory Verbal Comprehension	7.8	10	7.5	8.45	8.4	9.6	6.95	9.8	7.45	7.9	8.4
Repetition	9.4	10	6.2	5.1	8.6	10	7.6	8.8	8.4	7.6	8.2
Naming and Word Finding	7.6	9.8	6.8	9.3	9	9.3	5.9	8.9	8.3	8.5	8.3
Boston Naming Test											
Spontaneously Given Correct Responses	57	54	33	49	53	58	31	60	40	38	47.3
Northwestern Assessment of Verbs and Sentences											
Verb Naming											
1 argument verbs	80	100	100	100	100	100	80	100	60	100	92.0
2 argument verbs	90	100	80	100	100	100	40	90	90	100	89.0
3 argument verbs	71	71	71	100	86	86	71	71	71	71	76.9
Verb Comprehension	100	100	100	100	100	100	95	100	100	100	99.5
Argument Structure Production											
1 argument verbs	100	100	80	100	100	100	100	100	100	100	98.0
2 argument verbs	100	100	60	100	100	100	93	100	100	100	95.3
3 argument verbs	67	92	42	58	50	92	42	83	83	83	69.2
Sentence Production Priming Test											
Canonical	53	100	N/A	33	87	100	N/A	93	N/A	N/A	77.8
Noncanonical	20	100	N/A	0	53	87	N/A	67	N/A	N/A	54.4
Sentence Comprehension Test											
Canonical	53	100	N/A	87	93	100	60	87	N/A	60	80.0
Noncanonical	67	87	N/A	80	93	100	60	73	N/A	73	79.2

Table 1. Agrammatic participants' language testing data. N/A= not available (subtest discontinued by participant).

	P1	P2	P3	P4	P5	P6	P8	P9	P10	Mean
Mean length of utterance	6.07	8.07	4.35	4.80	8.04	7.68	5.91	6.15	10.39	6.83
Words per minute	33.06	58.19	35.73	73.48	57.72	40.06	55.68	26.55	81.65	51.35
Percent grammatical sentences	64	82	0	26	54	79	60	74	48	54.11
Noun:verb ratio	1.05	0.98	4.00	1.48	1.02	1.17	1.00	1.50	0.90	1.46

Table 2. Agrammatic participants' narrative speech data. (Speech data for P7 consisted of unintelligible utterances and therefore were not analyzable.)

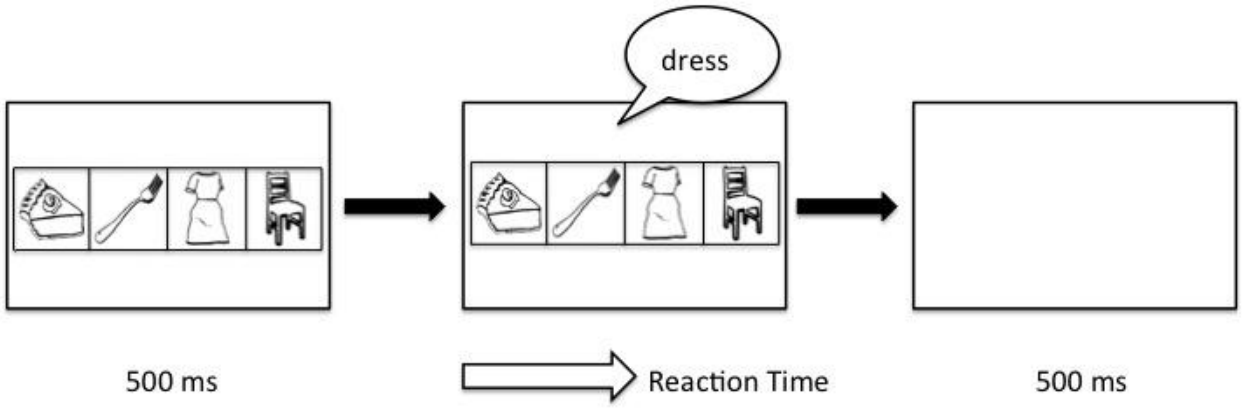

Figure 1. Schematic of one trial of the SST.

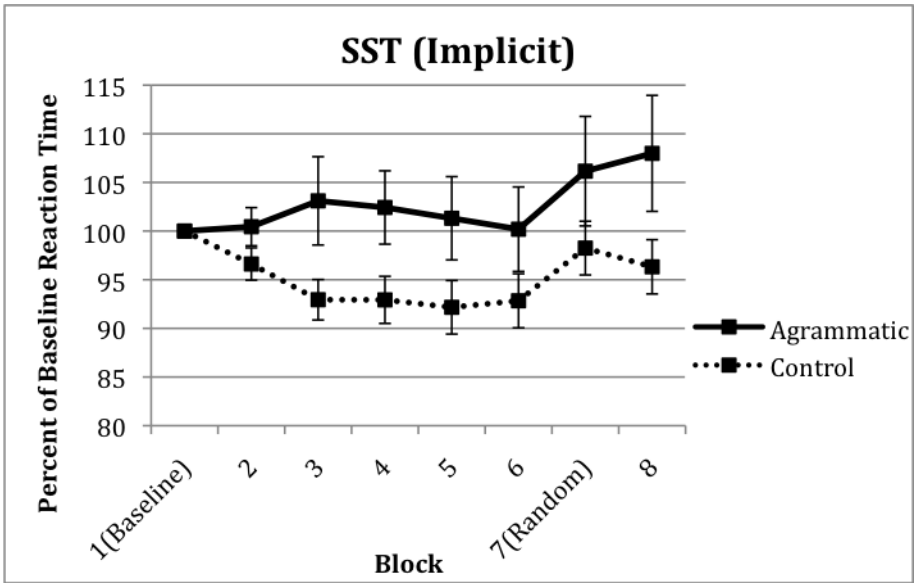

Figure 2. Mean percent of baseline (Block 1) RT across the 8 blocks of the SST under implicit learning conditions in the agrammatic and control groups. Bars represent one standard error above and below the mean.

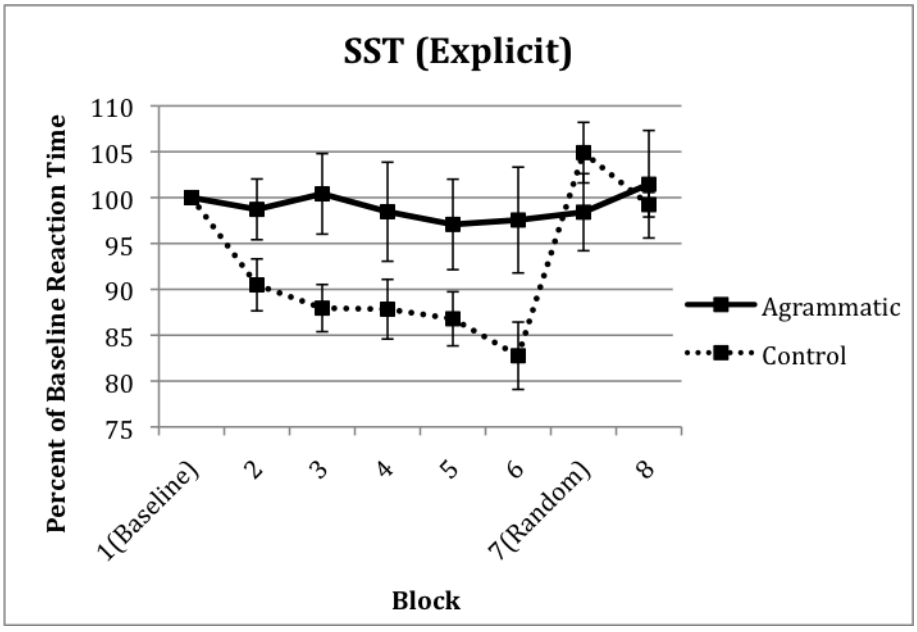

Figure 3. Mean percent of baseline (Block 1) RT across the 8 blocks of the SST under explicit learning conditions in the agrammatic and control groups. Bars represent one standard error above and below the mean.