Neural Mechanisms of Verb Argument Structure Training in Agrammatic Aphasia

Introduction

Deficits in verb production are well documented in individuals with aphasia. Many agrammatic aphasic speakers show greater difficulty producing verbs compared to nouns (De Bleser & Kauschke, 2003; Jonkers & Bastiaanse, 1996; Luzzatti et al., 2002) with the greatest difficulty associated with argument structure density (Dragoy & Bastiaanse, 2009; Kim & Thompson, 2004). Verb production deficits are also associated with sentence production deficits and improved verb retrieval has been linked to improved sentence production (Mitchum, Haendiges, & Berndt, 1993; Schneider & Thompson, 2003). The Complexity Account of Treatment Efficacy (CATE; Thompson et al., 2003) suggests that treatment proceeding from more to less complex verbs might result in the greatest treatment effects. Further, recent studies examining the neural correlates of recovery from aphasia suggest that such training will influence the neural substrates of verb production.

The purpose of the current study was to examine the effects of training verbs with complex argument structure in sentence contexts on retrieval and verbs with less complex argument structure while examining the neural mechanisms of recovery. It was hypothesized that training ditransitive verbs would result in generalization to less-complex verb types (transitive and intransitive) in both verb naming and sentence production and that these behavioral changes would be associated with observable shifts in fMRI brain activation patterns from pre- to post-treatment.

Methods

Four participants with agrammatic aphasia were trained using ten ditransitive verbs and generalization was examined to 20 transitive and 20 intransitive verbs. For each agrammatic participant, training occurred two days a week for 1.5 hour sessions. The training procedure involved naming the verb from a picture, creating an active sentence, with emphasis on argument structure using written constituent cards, and orally producing the sentence. Verb naming, verb use in sentences, and argument structure production accuracy were measured with daily probes administered before each training session. Performance was evaluated based on the proportion of verbs correctly named in isolation, sentences produced with the correct verb (regardless of argument structure), and sentences produced with both the correct verb and correct argument structure. Participants were trained to a criterion of 80% correct over two consecutive probe sessions. Behavioral data were analyzed using effect sizes calculated according to recommendations from Beeson and Robey (2006).

To assess neural change pre- and post-treatment, the four agrammatic participants as well as 13 age-matched control unimpaired volunteers named 18 intransitive and 18 transitive verbs from 2-second action videos in an event-related functional MRI (fMRI) task. Control participants were scanned once and agrammatic participants were scanned prior to and after training. The verbs used in this task were matched for frequency and body-part association across conditions and the video stimuli were controlled for visual complexity (i.e., the number of animate/inanimate elements in the scene). Overt naming responses were recorded for accuracy and reaction time

using custom-built software designed to reduce scanner noise.

Results & Discussion

For the contrast of transitive>intransitive verb naming, controls showed activation in bilateral BA 44 and BA6; LH BA 40 and 7; and RH BA 2. For the contrast of intransitive>transitive verb naming, controls showed no activation. This pattern of activation reflects increased processing cost for retrieval of verbs with more complex lexical representations, supporting the results of previous fMRI studies (Ben-Shachar et al., 2003; Thompson et al., 2007; and others).

Results of verb argument structure training on behavioral and neural changes in the agrammatic patients showed different patterns across participants (see Figure 1 for fMRI contrasts). Participants 1 and 2 demonstrated behavioral improvement for all dependent measures on both trained and untrained verbs. However, only Participant 2 showed concomitant changes in neural activation patterns, with up-regulated and down-regulated neural activity (both main effects and for the contrast transitive>intransitive) from pre- to post-treatment. Participants 3 and 4 (both of whom showed pre-treatment ability to produce argument structure for verbs correctly named) demonstrated behavioral improvement for verbs in isolation, but only Participant 3 also showed improved production of sentences with both trained and untrained verbs. Both Participants 3 and 4, however, showed pre- to post-treatment changes in neural activation patterns, with both up- and down-regulation for main effects found for Participant 3 and up-regulation for the contrast transitive>intransitive found for both participants.

Overall, changes in neural activation associated with verb argument structure treatment differed somewhat across participants. Both up- and down-regulation of activation was found in perilesional as well as right hemisphere regions and up-regulation for the contrast transitive>intransitive verb naming was found in the right superior temporal gyrus for 3 of 4 participants after three-argument verb training. These findings support fMRI patterns reported for argument structure complexity in similar agrammatic aphasic patients by Thompson and colleagues (in press).

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Figure 1.
Functional MRI contrasts for agrammatic participants (p<.001 uncorrected; k>10).