Introduction

Individuals with aphasia frequently have not only a language impairment but also difficulties properly allocating attention resources required for language processing. This limitation of attention is generally considered an important contributor to deficits in language comprehension (LaPointe & Erickson, 1991; McNeil et al., 2004; McNeil et al., 2005; Murray, Holland & Beeson, 1997; Robin & Rizzo, 1988) and formulation (Murray, Holland & Beeson, 1998).

Many researchers have used dual tasks to explore the relationship between limited attention and language comprehension. Individuals with aphasia have been shown to exhibit difficulty allocating attention efficiently on dual-tasks compared to single-tasks and their shortage of capacity resources leads to greater deficits during dual-task performance compared to single-task performance (LaPointe and Erickson, 1991; Murray et al., 1997; Tseng, et al., 1993). Individuals free of neurogenic impairment also have been shown to perform less accurately on dual tasks than on single tasks (Bates & Blackwell, 1995; Murray et al., 1997).

Potential confounds of traditional dual tasks include (1) the lack of ecological validity of allocating attention to two novel tasks, (2) the complexity of verbal instructions, especially for language-impaired participants, (3) reliance on off-line as opposed to on-line measures, and (4) challenges associated with response requirements.

Eye-tracking methods have the potential to avoid such confounds associated with traditional dual-task methods. First, ecological validity is likely to be greater because simple viewing tasks involved in eye tracking are more natural and intuitive than many dual tasks. Second, participants are not required to understand complex instructions about the nature of the response required for any given task; participants are simply asked to look naturally at images on a computer monitor (Hallowell, Wertz & Kruse, 2002). Third, eye-tracking methods allow for on-line indexing of processing occurring while the participant is presented with a verbal stimulus and is engaged in a comprehension task Odekar, Hallowell, Lee, & Moates (in press). Resource allocation can be assessed at different points in time while language comprehension takes place, as opposed to simply attempting to determine whether resource allocation was impaired or not. On-line measures have the potential to be more sensitive to increases and decreases of attention allocated over time. Fourth, participants are not required to respond verbally, in writing or with gestures. This may reduce important response confounds in experimentation. Fifth, no conscious planning of responses is required of participants (Hallowell, Wertz & Kruse, 2002).

It was the goal of this study to develop a method to assess attention allocation during auditory linguistic processing using a novel dual-task eye tracking method. For a visual search task, participants were trained to find a visual target in a display that included one target and three nontarget foils. In an auditory linguistic processing task sentences were presented. Attention demands were manipulated by varying the complexity of each of the tasks. Changes in attention demands were indexed through performance on the visual search task using eye-tracking measures.

It was hypothesized that an increase in attention demands would be observed for performance on the dual task compared to performance on the visual search task. A

greater discrepancy in performance between single- and dual-task conditions for individuals with aphasia compared to control participants was expected.

Method

Participants. Twenty-seven participants with aphasia participated. Presence of brain damage, time post onset, site, and extent of lesion were verified through medical records. Aphasia was assessed with the Western Aphasia Battery (WAB-R, Kertesz, 2007). Thirty-two control participants were included. They were self-reportedly free of neurogenic impairment and passed a cognitive screening. Prior to participation in the study all participants passed a vision and hearing screening.

Procedure

Visual search. Multiple-choice image displays containing one target and three foil images were shown to the participants. All images shared a variety of image characteristics (size, shape, and complexity). The target image differed from the remaining foil images with respect to one of those image characteristics. Sixty trials were presented each lasting 4000 ms. Participants were instructed to "Look at the different image."

Listening task. Participants were instructed: "Listen carefully to the words." They listened to the verbal stimulus while they looked at a blank computer screen. Immediately after the sentence was completed, a multiple-choice image display was presented with one image, the target image, corresponding to the stimulus sentence and three images being foils.

Dual-task. Participants were presented with the visual search task and the verbal stimulus simultaneously and were asked to: "look at the different image and listen carefully to the words."

Eye movements of all participants were monitored and recorded at 60 Hz using an LC Technologies Eyegaze remote pupil center/corneal reflection system.

Stimuli

Visual search. Multiple-choice displays included one image in each corner. Thirty simple visual search displays contained three identical foil images and one target image that was different in terms of complexity. Thirty complex displays included one target imager and three identical foil images with different orientations.

Verbal stimuli linguistic task. Thirty simple and 30 complex sentences had approximately the same number of words/syllables and the same number of verbs. Simple sentences had a simple subject-verb-object sequence while complex sentences included an embedded relative clause.

Visual stimuli linguistic task. Sixty displays containing simple visual stimuli controlled for color, size, and shape were created. In each image two visual stimuli were presented. One image in each display corresponded to the sentence stimulus (target image) while three images were foils.

Analysis

A fixation was defined as a stable eye position of at least 100 ms with a range of motion limited to four degrees vertically and six degrees horizontally (Manor & Gordon, 2003). The dependent eye tracking measure was the proportion of fixation duration allocated to target images (pft), defined as the total duration of fixations on a particular image, divided by the total of fixation durations on all four images in the display.

Research Questions and Results

1. Will attention demands for the visual search task be less during the single-task condition compared to the dual-task condition?

A two-way ANOVA with the two factors group (aphasia and control) and task (single and dual) was conducted. Results indicated significant differences for the main effects of group $F(1, 110) = 81.62$, $p < .001$, $\eta^2 = .43$ and task $F(1, 110) = 14.84$, $p < .001$, $\eta^2 = .12$.

2. Will attention demands be greater for complex visual search tasks compared to the simple visual search tasks in the single-task condition?

A two-way ANOVA with the two factors group (aphasia and control) and complexity (simple and complex) was conducted. Results indicated significant differences for the main effects of group $F(1, 115) = 54.75$, $p < .001$, $\eta^2 = .33$; and complexity $F(1, 115) = 39.34$, $p < .001$, $\eta^2 = .26$.

Additional analyses, too extensive to summarize here given proposal length limitations, address the influence of overall aphasia severity, severity of language comprehension deficits, and age and education on eye tracking measures of attention.

Discussion

A significant decrease in pft was observed (1) from single compared to dual task conditions, (2) simple to complex stimuli, and (3) when comparing the control group to the group of individuals with aphasia. The results indicate more efficient attention allocation during single task conditions and for simpler task items across conditions. Further, control participants consistently had less allocation difficulties compared to individuals with aphasia. Results support the validity of eye tracking as a tool to assess attention allocation in individuals with and without aphasia and across tasks with varying complexity.

References

Blackwell, A., & Bates, E. (1995). Inducing agrammatic profiles in normals: evidence for the selective vulnerability of morphology under cognitive resource limitation. *Journal of Cognitive Neuroscience, 7*(2), 228-257.

Hallowell, B. Wertz, R., & Kruse, H. (2002). Using eye movement responses to index auditory comprehension: An adaptation of the revised token test. *Aphasiology,* 16, 587-594.

Kertesz, A. (2007). Western aphasia battery. San Antonio, TX: Harcourt Assessment, Inc.

LaPointe, L.L. & Erickson, R.J. (1991). Auditory vigilance during divided task attention in aphasic individuals. *Aphasiology, 5*(6), 511-52

Manor, B. & Gordon, E. (2003). Defining the temporal threshold for ocular fixation in free-viewing visuocognitive tasks. *Journal of Neuroscience Methods, 128*, 85-93.

McNeil, M.R., Doyle, P.J., Hula, W.D., Rubinsky, H.J., Fossett, T.R.D. & Matthews, C.T. (2004). Using resource allocation theory and dual-task methods to increase the sensitivity of assessment in aphasia. *Aphasiology, 18*(5,6,7), 521-542.

McNeil, M.R., Matthews, C.T., Hula, W.D., Doyle, P.J., Rubinsky, H.J., & Fossett, T.R.D.(2005). A dual-task tool for quantifying normal comprehension of aphasic connected speech production: a constructive replication. *Aphasiology, 19*(3,4,5), 473-484.

Murray, L.L. (2004). Cognitive treatments for aphasia: Should we and can we help attention and working memory problems? *Journal of Medical Speech-Language Pathology, 12*(3), xxv-xl.

Murray, L.L. (2002). Attention deficits in aphasia: presence, nature, assessment, and treatment. *Seminars in Speech and Language, 23(*2), 107-116.

Murray, L.L. (2000). The effects of varying attentional demands on the word-retrieval skills of adults with aphasia, right hemisphere brain-damage or no brain-damage. *Brain and Language, 7,2* 40-72.

Murray, L.L. (1999). Attention and aphasia: theory, research and clinical implications. *Aphasiology, 13*(2), 91-111.

Murray, L.L., Holland, A.L., & Beeson, P.M. (1998). Spoken language of individuals with mild fluent aphasia under focused and divided-attention conditions. *Journal of Speech, Language & Hearing Research, 41*(1), 213-227 **.**

Murray, L.L. & Holland, A.L. & Beeson, P.M. (1997). Auditory processing in individuals with mild aphasia: a study of resource allocation. *Journal of Speech, Language & Hearing Research, 40*(4), 792-808.

Odekar, A., Hallowell, B, Lee, C, & Moates, D. (in press). Validity of eye movement methods and indices for capturing semantic (associative) priming effects. *Journal of Speech, Language and Hearing Research*.

Tseng, C.-H., McNeil, M.R. & Milenkovic, P. (1993). An investigation of attention allocation deficits in aphasia. *Brain and Language, 45,* 276-296.