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# A novel eye-tracking method to assess attention allocation in individuals with and without aphasia using a dual-task paradigm



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### ABSTRACT

Numerous authors report that people with aphasia have greater difficulty allocating attention than people without neurological disorders. Studying how attention deficits contribute to language deficits is important. However, existing methods for indexing attention allocation in people with aphasia pose serious methodological challenges. Eye-tracking methods have great potential to address such challenges. We developed and assessed the validity of a new dual-task method incorporating eye tracking to assess attention allocation.

Twenty-six adults with aphasia and 33 control participants completed auditory sentence comprehension and visual search tasks. To test whether the new method validly indexes well-documented patterns in attention allocation, demands were manipulated by varying task complexity in single- and dual-task conditions. Differences in attention allocation were indexed via eye-tracking measures.

For all participants significant increases in attention allocation demands were observed from single- to dual-task conditions and from simple to complex stimuli. Individuals with aphasia had greater difficulty allocating attention with greater task demands. Relationships between eye-tracking indices of comprehension during single and dual tasks and standardized testing were examined.

Results support the validity of the novel eye-tracking method for assessing attention allocation in people with and without aphasia. Clinical and research implications are discussed.

**Learning outcomes:** Readers will be able to: (1) summarize the nature of dual-task paradigms, (2) identify shortcomings of existing dual-task measures of attention allocation for application to people with aphasia, (3) describe how eye-tracking measures may be recorded and analyzed to reflect differences in attention allocation across conditions, and (4) summarize potential clinical applications for eye-tracking measures of attention allocation.

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## 1. Introduction

### 1.1. Relevance of attention allocation to aphasia

People with aphasia frequently have not only language impairments but also difficulties properly allocating attention resources required for language processing. Attention is a limited resource that can only be allocated to a finite number of tasks (Kahneman, 1973). Attention allocation, the process of allotting attention to a given task in the face of competing tasks and complex or multiple stimuli to be processed, is of particular concern in people with aphasia.

Attention limitations are generally considered to contribute to language comprehension deficits (Hula & McNeil, 2008; LaPointe & Erickson, 1991; McNeil et al., 2004, 2005; Murray, Holland, & Beeson, 1997; Robin & Rizzo, 1988). An increase in task demands requires more attention resources (Murray, 1999); that is, it requires greater cognitive effort, and taxes a finite capacity. Furthermore, the efficiency of attention allocation depends on an individual's ability to assess task demands (Murray, 1999; Robin & Rizzo, 1988). If demands exceed resources, comprehension deficits occur or become more severe.

Understanding impairments in attention allocation in people with aphasia is important in terms of theoretical implications as well as implications for clinical assessment and treatment. Attention allocation deficits, when not recognized and accounted for during assessment, may lead to invalid indexing of language abilities. Attention allocation deficits may negatively affect not only language comprehension but also learning, and thus rehabilitation potential, in individuals with aphasia (Helm-Estabrooks, 2002). It is therefore crucial for clinicians and researchers to understand the interaction between attention allocation and language comprehension, be alert to different types of attention impairments, assess non-linguistic attention deficits in addition to language impairments, and create appropriate treatment plans involving attention allocation.

Valid measures of attention allocation are vital to further elucidation of the relationship between attention and language deficits in aphasia. Unfortunately, there are serious methodological challenges associated with indexing attention allocation in people with aphasia. New methods constructively addressing those challenges are needed. In this light, online eye-tracking methods hold great promise. The goal of this study was to develop and assess the construct validity of a new dual-task method to assess attention allocation during auditory linguistic processing using eye tracking. We tested whether the new method would replicate patterns of results similar to those obtained using more traditional dual-task methods for indexing attention allocation.

### 1.2. Methods for studying attention

Dual-task experiments have been used widely to explore the relationship between language and attention. Results of previous studies indicate that increased attention demands of dual-task conditions tend to impact language comprehension (Blackwell & Bates, 1995; Granier, Robin, Shapiro, Peach, & Zimba, 2000; King & Hux, 1996; LaPointe & Erickson, 1991; McNeil, Matthews, Hula, Doyle, & Fossett, 2006; McNeil et al., 2005; Murray et al., 1997; Tseng, McNeil, & Milenkovic, 1993) and production (Hula, McNeil, & Sung, 2007; Murray, 2000) in people with and without aphasia.

Although there is great variation in specific aspects of dual-task methods designed to study attention allocation, there are two basic methodological approaches across studies: comparisons of performance in single- versus dual-task conditions and simple (or easy) versus complex (or difficult) conditions. In a dual-task experiment, participants are asked to complete a task under two conditions, in isolation and simultaneously with a secondary task. When the two tasks are performed at once, decrements in performance on one task reflect the processing load imposed by the second task. Reduced accuracy and slower reaction times during the dual-task condition are interpreted to reflect resource allocation problems or limited capacity resources due to increased task demands. People without aphasia tend to exhibit a decrease in performance on dual tasks when compared to single tasks in terms of accuracy and response time (Blackwell & Bates, 1995; Granier et al., 2000; Hula et al., 2007; McNeil et al., 2004, 2005; Tseng et al., 1993). In studies including individuals with and without aphasia, those with aphasia tended to demonstrate greater decrements in performance compared to control participants on dual tasks (King & Hux, 1996; LaPointe & Erickson, 1991; Murray, 2000, 2012; Murray et al., 1997; Murray, Holland, & Beeson, 1998). Notable exceptions to these findings are detailed in a study by McNeil et al. (2006) that included only participants with aphasia, in which no dual-task effects were observed and a study by Tseng et al. (1993), in which control participants exhibited a stronger dual-task interference effect than participants with aphasia. The latter was interpreted as a result of greater flexibility in allocation of attention resources according to task demands in individuals without aphasia.

Theoretical accounts for decrements in reaction time and accuracy during dual tasks include models of capacity limitation and the central bottleneck model (Hula & McNeil, 2008; Kurland, 2011; Murray, 1999). According to the limited capacity account, attention is a limited processing resource that is flexibly allocated to varying task demands. When task demands exceed capacity resources, performance decreases, as is often observed when comparing single- to dual-task processing. The central bottleneck model (Pashler, 1994) attributes dual-task performance decrements to a limited ability to process more than one task simultaneously due to a central processing limit. Thus, dual-task processing deficits result from response selection rather than capacity limitation. See Hula and McNeil (2008) for a detailed discussion of models of attention and the role of attention in language processing.

A variety of linguistic and nonlinguistic tasks have been used to demonstrate the effect of attention impairment on linguistic abilities during dual tasks. Examples are an auditory sustained attention task and card sorting (LaPointe & Erickson, 1991); semantic category judgment and tone discrimination (Murray et al., 1997); word-picture matching and speaker

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