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A new modified listening span task to enhance validity of working memory assessment for people with and without aphasia

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ABSTRACT

Deficits in working memory (WM) are an important subset of cognitive processing deficits associated with aphasia. However, there are serious limitations to research on WM in aphasia largely due to the lack of an established valid measure of WM impairment for this population. The aim of the current study was to address shortcomings of previous measures by developing and empirically evaluating a novel WM task with a sentence-picture matching processing component designed to circumvent confounds inherent in existing measures of WM in aphasia. The novel WM task was presented to persons with ($n = 27$) and without ($n = 33$) aphasia. Results demonstrated high concurrent validity of a novel WM task. Individuals with aphasia performed significantly worse on all conditions of the WM task compared to individuals without aphasia. Different patterns of performance across conditions were observed for the two groups. Additionally, WM capacity was significantly related to auditory comprehension abilities in individuals with mild aphasia but not those with moderate aphasia. Strengths of the novel WM task are that it allows for differential control for length versus complexity of verbal stimuli and indexing of the relative influence of each, minimizes metalinguistic requirements, enables control for complexity of processing components, allows participants to respond with simple gestures or verbally, and eliminates reading requirements. Results support the feasibility and validity of using a novel task to assess WM in individuals with and without aphasia.

Learning outcomes: Readers will be able to (1) discuss the limitations of current working memory measures for individuals with aphasia; (2) describe how task design features of a new working memory task for people with aphasia address shortcomings of existing measures; (3) summarize the evidence supporting the validity of the novel working memory task.

1. Introduction

Working memory (WM) can be broadly defined as "a multi-component system responsible for active maintenance of information in the face of ongoing processing and/or distraction" (Conway et al., 2005, p. 770). Compared to short-term

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memory (STM) (defined as a capacity for temporary storage of presented information) the concept of WM places a stronger emphasis on the notion of active manipulation of information instead of passive maintenance. Over the past 40 years WM capacity has been found to be related to higher cognitive tasks, including learning abilities, verbal reasoning skills, math skills, and language comprehension (Baddeley, 2003; Conway & Engle, 1996; Conway et al., 2005; Cowan, 1999; Engle, Tuholski, Laughlin, & Conway, 1999; Just & Carpenter, 1992). From this perspective, WM may be contrasted with STM in that performance on STM tasks has not been found to be as strongly related to other specific cognitive abilities (Conway & Engle, 1996; Daneman & Carpenter, 1980; Engle, Tuholski, et al., 1999; Turner & Engle, 1989). Given evidence of a relationship between WM and language comprehension in normal language processing and evidence of limited WM capacity in individuals with aphasia (for a review see Murray, Ramage, & Hooper, 2001; Murray, 2004; Wright & Fergadiotos, 2012; Wright & Shisler, 2005), studies of WM play an important role in understanding the nature of aphasia.

Early investigations of WM in aphasia referred to a rather nebulous construct of WM, postulating a limited capacity for language processing in aphasia and its negative impact on linguistic performance. Tompkins, Bloise, Timko, and Baumgaertner (1994) were the first to demonstrate reduced WM capacity in individuals with left hemisphere damage, some of whom had aphasia. Later, Caspari, Parkinson, LaPointe, and Katz (1998) demonstrated a relationship between WM capacity and general measures of language impairment, such as the Western Aphasia Battery (Kertesz, 1982) and Reading Comprehension Battery for Aphasia (LaPointe & Horner, 1979). More recently, researchers have investigated specific aspects of memory impairments in aphasia and their differential relationships with various language abilities (Christensen & Wright, 2010; Friedmann & Gvion, 2003; Laures-Gore, Marshall, & Verner, 2011; Martin & Reilly, 2012; Mayer & Murray, 2012; Sung et al., 2009; Wright, Downey, Gravier, Love, & Shapiro, 2007). A more in-depth understanding of the role that WM plays in language processing in aphasia is important for conceptualizing the nature of aphasia, developing valid and reliable assessment methods, and providing optimal treatment while taking cognitive factors into account. However, despite almost two decades of research on the nature of WM in aphasia, understanding of the construct and its specific relationship to language abilities in aphasia remains limited. Key limitations of the existing research are that: (a) WM tasks have been modified in different ways, making the comparison or aggregation of data across studies problematic (Connor, MacKay, & White, 2000; Ivanova & Hallowell, 2012; Murray et al., 2001; Wright & Fergadiotos, 2012; Wright & Shisler, 2005); (b) WM tasks used with people who have aphasia are often not designed to take into account potentially confounding factors associated with task requirements and measurement validity (Ivanova & Hallowell, 2012; see Wright & Fergadiotos, 2012 for a related argument); and (c) stimulus design and procedures are often not described in sufficient detail, making it difficult to understand specific task requirements, interpret results, and compare findings with those of other studies. In addition to these methodological limitations, previous studies on WM and aphasia have included heterogeneous aphasia groups and the observed effects were interpreted as if they applied to the whole sample. Aside from work by Friedmann and Gvion (2003) no previous study has entailed analysis of the relationships between WM and severity of language deficits within aphasia subgroups. The present study was designed to address these limitations. In this introduction we will briefly review the nature of tasks used to study WM in aphasia and specific associated task design limitations. We will then provide a rationale for a new WM task and describe a study aimed at validating the use of that task with people with and without aphasia.

1.1. Measuring working memory in aphasia

Several different tasks have been used to index WM in aphasia. They may be generally categorized as complex span, N-back, and backward span tasks. Complex span tasks are the focus of the current investigation because: (a) they are among the most widely used measures of WM in behavioral studies of children and adults without neurological, cognitive or language impairments; (b) their construct validity has been substantially supported in the literature (for a review see Conway et al., 2005; Waters & Caplan, 2003); (c) they have been shown to have high internal consistency and test-retest reliability (Kane et al., 2004; Waters & Caplan, 2003); (d) WM span task performance has been consistently related to performance on a broad array of higher-order cognitive tasks, such as verbal reasoning, listening and reading comprehension, math skills, and learning ability (e.g., Conway & Engle, 1996; Engle, Kane, & Tuholski, 1999; Just & Carpenter, 1992; Turner & Engle, 1989); and (e) authors of various theoretical models of WM regard performance on complex span tasks as valid indices of WM (Baddeley, 2003; Cowan, 1999; Engle, Kane, et al., 1999; Just & Carpenter, 1992; Towse, Hitch, & Hutton, 2000) (even though different explanations have been offered as to why a span score represents WM capacity).

Although N-back tasks have also been used (e.g., Christensen & Wright, 2010; Friedmann & Gvion, 2003; Mayer & Murray, 2012; Wright et al., 2007), their use to measure WM capacity has inherent validity problems. Results of numerous studies indicate no significant correlations with performance on complex span tasks in adults without cognitive or language impairments (e.g., Jaeggi, Buschkuehl, Perrig, & Meier, 2010; Jaeggi, Studer-Luethi, et al., 2010; Kane, Conway, Miura, & Colflesh, 2007; Oberauer, 2005; Roberts & Gibson, 2002). Moreover, performance on N-back tasks has been more strongly related to performance on simple span tasks indexing short-term memory (Jaeggi, Buschkuehl, et al., 2010; Oberauer, 2005; Roberts & Gibson, 2002; see Jaeggi, Buschkuehl, et al., 2010 for a detailed discussion on concurrent and construct validity of N-back tasks). Additionally, none of the well-established theories of WM endorse the N-back as a valid measure of WM (see Chein, Moore, & Conway, 2011 for an extended argument).

Similar validity issues have been encountered with backward span tasks. For example, Waters and Caplan (2003) reported that adults without neurological impairments showed that performance on backward span task loads on the same factor as complex span tasks, although Engle, Tuholski, et al. (1999) countered that finding.