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Sentence processing in aphasia: An examination of material-specific and general cognitive factors

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ABSTRACT

The purpose of this study was to characterize further the nature of sentence processing deficits in acquired aphasia. Adults with aphasia and age- and education-matched adults with no brain damage completed a battery of formal cognitive-linguistic tests and an experimental sentence judgment task, which was performed alone and during focused attention and divided attention or dual-task conditions. The specific aims were to determine whether (a) increased extra-linguistic cognitive demands (i.e., focused and divided conditions) differentially affected the sentence judgement performances of the aphasic and control groups, (b) increased extra-linguistic cognitive demands interact with stimulus parameters (i.e., syntactic complexity, number of propositions) known to influence sentence processing, and (c) syntactic- or material-specific resource limitations (e.g., sentence judgment in isolation), general cognitive abilities (e.g., short-term and working memory test scores), or both share a significant relationship with dual-task outcomes. Accuracy, grammatical sensitivity, and reaction time findings were consistent with resource models of aphasia and processing accounts of aphasic syntactic limitations, underscoring the theoretical and clinical importance of acknowledging and specifying the strength and nature of interactions between linguistic and extra-linguistic cognitive processes in not only individuals with aphasia, but also other patient and typical aging populations.

1. Introduction

Over the last 25 years or so, there has been a steady accrual of evidence within the aphasia literature establishing the influential relationship between extra-linguistic, cognitive processes and aphasia symptoms and outcomes (Murray, Holland, & Beeson, 1997a, 1997b, 1997c; Baldo, Paulraj, Curran, & Dronkers, 2015; Brownsett et al., 2014; Dignam et al., 2017; Marinelli, Spaccavento, Craca, Marangolo, & Angelelli, 2017; Martin & Saffran, 1999; Murray, 2012, 2017a; Paek & Murray, 2015; Petroi, Koul, & Corwin, 2014; Tompkins, Bloise, Timko, & Baumgaertner, 1994; Ziegler, Kerkhoff, Cate, Artinger, & Zierdt, 2001). That is, regardless of aphasia profile, difficulties across the cognitive domains of attention (e.g., Lee & Pyun, 2014; Murray, 2012; Villard & Kiran, 2015), memory (e.g., Mayer & Murray, 2012; Valilla-Rohter & Kiran, 2013; Vukovic, Vuksanovic, & Vukovic, 2008), and executive functioning (e.g., Baldo et al., 2015; Dean, Della Sala, Beschin, & Cocchini, 2017; Murray, 2017a) have been identified among individuals with aphasia, which can negatively affect their language abilities at the phonological, morphosyntactic, lexical-semantic, pragmatic, and discourse levels (Caplan, Michaud, & Hufford, 2013; Dean et al., 2017; Friedmann & Gvion, 2007; Meteyard, Bruce, Edmundson, & Oakhill, 2015; Murray, 2000, 2012; Murray, Holland, & Beeson, 1997c, 1997a; Penn, Frankel, Watermeyer, & Russell, 2010; Tompkins et al., 1994; Ziegler et al., 2001). Importantly, this line of research has afforded support to contemporary conceptualizations of not only aphasia, in which deficits in cognitive functions other than language are accredited with generating or intensifying linguistic symptoms (Hula & McNeil, 2008; Kurland, 2011; Murray & Kean, 2004), but also more broadly, the neurobiology of language, in which diffuse cortical and subcortical structures and distributed connectivity support language in concert with other functional processes and control mechanisms (Cahana-Amitay & Albert, 2015; Meyer, Cunitz, Obleser, & Friederici, 2014; Tremblay & Dick,

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2016; Xing, Lacey, Skipper-Kallal, Zeng, & Turkeltaub, 2017).

Despite this ever-growing research base, additional examination of the presence and nature of relationships between specific linguistic abilities and cognitive functions among individuals with aphasia is needed given both the theoretical and applied implications of such research (Moineau, Dronkers, & Bates, 2005; Murray, 2004, 2017b; Oliveira, Marin, & Bertolucci, 2017; Salis, Hwang, Howard, & Lallini, 2017). For example, if a certain linguistic process proves functionally distinct from other aspects of cognition, such a finding would inform the architecture of modular approaches to conceptualizing language, as well as clinically indicate that remediation for that linguistic process when impaired would need to focus specifically on training or compensating for that linguistic process. In contrast, if a potent relationship between a certain linguistic process and other cognitive processes is established, such a finding would provide support to non-modular or distributed views of language and more broadly, cognitive processing, and specify that remediation for that linguistic process when impaired could instead or additionally target the related cognitive processes to abate the effects of the impaired linguistic process.

The purpose of the current study was to delineate further the relationship between specific linguistic and extra-linguistic cognitive abilities in aphasia and thus, the processing or resource model of aphasia, by examining interactions between sentence processing and several cognitive skills, including short-term (STM; supporting temporary storage of nominally processed information) and working memory (WM; supporting temporary storage of information while concomitantly processing that information for a particular intention) abilities, among individuals with aphasia and adults with no brain damage using a dual-task paradigm. Sentence or syntactic processing abilities were of interest given that sentence processing deficits are common irrespective of aphasia type (Caplan, Waters, & Hildebrandt, 1997; Dick et al., 2001; Wilson & Saygin, 2004). Furthermore, there are longstanding deliberations regarding whether such abilities are qualitatively or quantitatively compromised in aphasia (e.g., Grodzinsky, 2000 vs.; Caplan, Waters, DeDe, Michaud, & Reddy, 2007) as well as other language disorders (e.g., specific language impairment; for a review, see Montgomery, Gillam, & Evans, 2016). That is, with respect to aphasia, some researchers propose that syntactic processing is qualitatively affected, at least in certain types of aphasia, by linguistic-specific structural impairments (Grodzinsky, 1984, 2000; Mauner, Fromkin, & Cornell, 1993; Sullivan, Walenski, Love, & Shapiro, 2017). Alternately, and in accord with resource or cognitive accounts of aphasia, other researchers characterize the deficit as quantitative in nature, often positing cognitive impairments (particularly STM and WM problems) as a source of impedance to syntactic computations (Caplan et al., 2013, 2007; Murray et al., 1997c; Patil, Hanne, Burchert, De Bleser, & Vasishth, 2016). Indeed, within one of the most recently forwarded models of sentence processing in aphasia, the rational inference hypothesis, the role of memory and executive function or higher order cognitive abilities is acknowledged (e.g., Gibson, Sandberg, Fedorenko, Bergen, & Kiran, 2016).

Several lines of evidence align favorably with the proposition that sentence processing deficits in aphasia instead or at least in part reflect extra-linguistic challenges versus solely degraded or lost syntactic competence (for a critique of linguistic-specific structural accounts, see Caplan et al., 2007). First, when completing syntactic processing tasks in which other linguistic and/or extra-linguistic task demands have been restrained (e.g., cloze tasks, grammaticality judgments), individuals with aphasia appear able to use syntactic knowledge, with better syntactic performance during restrained versus unrestrained tasks (Caplan et al., 2007; Linebarger, Schwartz, & Saffran, 1983; Murray et al., 1997c). Second, variable sentence type effects as well as dissociations in the performances of individuals with aphasia have been identified when completion of different types of off-line tasks such as sentence-picture matching or act-out tasks has been contrasted (Caplan et al., 1997, 2007, 2013). Third, when approaches that allow examining online syntactic processing (e.g., eyetracking; auditory moving window presentation) have been used, the response patterns of individuals with aphasia match those of their non-brain-damaged peers during correct responses, thus supporting that underlying syntactic operations are intact (Caplan et al., 2007, 2013; Dickey & Thompson, 2006; Hanne, Sekerina, Vasishth, Burchert, & De Bleser, 2011a). Fourth, investigators have documented that performance of extra-linguistic cognitive tests, particularly STM and WM measures, are related to or predict the ability of individuals with aphasia to perform certain syntactic operations (Slevc & Martin, 2016) or comprehend sentence-level material (Caplan et al., 2013; Friedmann & Gvion, 2007; Pettigrew & Hillis, 2014; Wiener, Tabor Connor, & Obler, 2004). Fifth, a few recent intervention studies have documented that some individuals with aphasia show improved sentence comprehension abilities following practice of treatment activities that focus on strengthening or supporting STM or WM skills (e.g., repetition or listening span tasks), without ever directly targeting comprehension (Eom & Sung, 2016; Salis, 2012; Zakarias, Keresztes, Marton & Warte, 2016). Finally, it is important to note that this resource or processing account of sentence processing difficulties in aphasia is commensurate with explanations of other linguistic symptoms in aphasia (e.g., lexical-semantic processing or retrieval; Murray, 2000; Moineau et al., 2005) as well as changes in sentence processing associated with other acquired neurogenic disorders (e.g., Parkinson's disease, Colman, Koerts, van Beilen, Leenders, & Bastiaanse, 2006; Alzheimer's disease, Small, Kemper, & Lyons, 2000) or typical aging (DeCaro, Peelle, Grossman, & Wingfield, 2016; Goral et al., 2011).

As an example of earlier work exploring the interface of cognitive factors with sentence processing in aphasia, Murray et al. (1997c) had adults with and without mild aphasia perform a listening task that required grammaticality judgments under isolation, focused attention, and divided attention or dual-task conditions. Sentence type was constrained to a simple canonical frame to ensure greater than chance grammaticality judgement performances among the aphasic participants, and to focus on extra-linguistic cognitive versus syntactic complexity issues. During optimal listening conditions (i.e., isolation condition), there were no group differences in accuracy or grammatical sensitivity, whereas during the more complex attention conditions, differences were apparent. If the aphasic adults had specific, syntactic competence impairments, substantial differences between aphasic and control groups should have been evident even during the isolation condition because the syntactic processing requirements of the grammaticality judgment task remained the same across conditions. Instead, these aphasic adults were able to make the necessary syntactic analyses during the isolation condition, but were significantly less able to do so during focused and divided attention conditions. Furthermore, although performance of the secondary task (i.e., tone discrimination task) did not overtly require language, the resources upon