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Non-linguistic learning and aphasia: Evidence from a paired associate and feedback-based task

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ABSTRACT

Though aphasia is primarily characterized by impairments in the comprehension and/or expression of language, research has shown that patients with aphasia also show deficits in cognitive-linguistic domains such as attention, executive function, concept knowledge and memory. Research in aphasia suggests that cognitive impairments can impact the online construction of language, new verbal learning, and transactional success. In our research, we extend this hypothesis to suggest that general cognitive deficits influence progress with therapy. The aim of our study is to explore learning, a cognitive process that is integral to relearning language, yet underexplored in the field of aphasia rehabilitation. We examine non-linguistic category learning in patients with aphasia ($n=19$) and in healthy controls ($n=12$), comparing feedback and non-feedback based instruction. Participants complete two computer-based learning tasks that require them to categorize novel animals based on the percentage of features shared with one of two prototypes. As hypothesized, healthy controls showed successful category learning following both methods of instruction. In contrast, only 60% of our patient population demonstrated successful non-linguistic category learning. Patient performance was not predictable by standardized measures of cognitive ability. Results suggest that general learning is affected in aphasia and is a unique, important factor to consider in the field of aphasia rehabilitation.

1. Introduction

While we have some understanding of how individuals with post-stroke aphasia relearn language, why some patients respond to treatment while others do not remains a looming question in the field of aphasia rehabilitation (Best & Nickels, 2000; Kelly & Armstrong, 2009).

Much progress has been made in the field, such that clinicians and researchers are equipped with means of assessing aphasia (Spreen & Risser, 2003), model frameworks of language processing and impairment that help describe the nature of deficits and guide therapy (Howard & Hatfield, 1987). Studies have explored therapies and tasks, demonstrating that many are efficacious in improving language function in patients with aphasia (Holland, Fromm, DeRuyter, & Stein, 1996; Kiran & Sandberg, 2011). In spite of this progress, we still do not fully understand the mechanisms of therapy (Ferguson, 1999) nor are we able to prescribe the most appropriate treatments for patients based on their language deficits and cognitive profiles (Best & Nickels, 2000; Kelly & Armstrong, 2009). We suggest that while research has progressed in terms of developing assessments and therapies for aphasia, learning is a process that is integral to relearning language and therefore to rehabilitation, yet is insufficiently represented.

Traditional research in aphasia has predominantly focused on the role of brain regions specialized for language, however a growing body of lesion and neuroimaging research now recognizes that language is part of an extensive network of connected brain regions that subserve not only language, but processes such as working memory and cognitive control (Tomasi & Volkow, 2012; for review Turken & Dronkers, 2011). Accordingly, an increasing number of studies in aphasia rehabilitation acknowledge the important contribution of multiple factors of cognition to therapy outcomes and communicative success (Fridriksson, Nettles, Davis, Morrow, & Montgomery, 2006; Helm-Estabrooks, 2002; Keil & Kaszniak, 2002; Ramsberger, 2005). Researchers have identified skills that might be important towards constructing and retrieving language, such as attention (Erickson, Goldinger, & LaPointe, 1996; Hula & McNeil, 2008; Lesniak, Bak, Czepiel, Seniow, & Czlonkowska, 2008; Murray, 2012; Peach, Rubin, & Newhoff, 1994), executive function (Keil & Kaszniak, 2002; Lesniak et al., 2008; Ramsberger, 2005; Zinn, Bosworth, Hoenig, & Swartwelder, 2007), concept

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knowledge (Chertkow, Bub, Deaudon, & Whitehead, 1997) and memory (Helm-Estabrooks, 2002; LaPointe & Erickson, 1991).

In exploration of a cognitive skill important for language, Chertkow et al. (1997) examined sentence comprehension in aphasia and drew attention to a subset of patients with aphasia who showed semantic deficits that extended into nonverbal domains of object representation and concept knowledge. Jefferies and Lambon Ralph (2006), Jefferies, Patterson, and Lambon Ralph (2008) and Noonan, Jefferies, Corbett, and Lambon Ralph (2009) further explored this question comparing the behavior of patients with semantic dementia (SD) with patients with semantic aphasia (SA). Results suggested that in many cases SA patients have preserved conceptual knowledge, but impaired executive function, this impairment impacting their control over semantic activation. Studies exploring new verbal learning in aphasia have shown that learning ability is related to patient' profiles of linguistic (Grossman & Carey, 1987; Gupta, Martin, Abbs, Schwartz, & Lipinski, 2006) and cognitive (Freedman & Martin, 2001) strengths and deficits. Patient phonological and semantic short-term memory skills, for example, appear to influence patient abilities to engage in phonological learning (word translation learning) and semantic learning (new definition learning, Freedman & Martin, 2001).

Probing the relationship between verbal and non-verbal tasks in aphasia, many studies have demonstrated a disparity between language skills and non-linguistic ability (Basso, De Renzi, Fagolioni, Scotti, & Spinnler, 1973; Chertkow et al., 1997; Helm-Estabrooks, 2002). These studies illustrate that patients with aphasia can have differing degrees of impairment in both verbal and nonverbal domains. Though degrees of impairment can differ in these domains, they remain related, researchers postulating a contribution of non-linguistic cognitive impairments to the online construction of language (Hula & McNeil, 2008) and to transactional success in functional communication in aphasia (Ramsberger, 2005). In addition, some researchers have found that treatment related outcomes are best predicted by non-linguistic skills such as executive function and monitoring, rather than by language ability (Fillingham, Sage, & Lambon Ralph, 2005a, 2005b). Studies such as these draw attention to the interconnectedness of cognitive, non-linguistic factors and language, and to the importance of exploring nonverbal domains as a means of better characterizing and understanding the deficits that surface in aphasia.

We suggest that not only are nonverbal cognitive-linguistic processes important to the retrieval and construction of language in conversation, but that nonverbal *cognitive* processes might be important in the relearning or reaccess to language that is brought about through therapy. More specifically, we identify learning as a critical process involved in language relearning subsequent to stroke. Support for this hypothesis comes from recent neuroimaging studies in aphasia that explore the association between treatment related changes and neural structures and activation. Menke et al. (2009), for example, found evidence for a relationship between short-term improvements with therapy and bilateral activation of the hippocampus, a structure critical to memory. Shortly thereafter in a diffusion tensor imaging study, Meinzer et al. (2010) showed a correlation between success with language therapy and the structural integrity of the hippocampus and surrounding fiber tracts. Studies that explore novel lexical, semantic and syntactic learning in healthy individuals have shown the engagement of similar structures (Breitenstein et al., 2005; Maguire & Frith, 2004; Optiz & Friederici, 2003) suggesting that comparable mechanisms may underlie the processes of language rehabilitation and novel learning in healthy individuals (Menke et al., 2009; Rijntjes, 2006). Goldenberg and Spatt (1994) examined the correlation between success with therapy and lesion location and volume. Researchers found that patients who showed limited improvements in therapy had lesions that were close to, or that included portions of the entorhinal cortex, an important structure in the relay of information between the neocortex and the hippocampus considered critical to learning and memory (Eichenbaum, Otto, & Cohen, 1992; Squire, 1992). While we do not know the exact mechanisms by which aphasia rehabilitation leads to functional outcomes, researchers concluded that results demonstrate the involvement of explicit learning in aphasia rehabilitation (Goldenberg & Spatt, 1994). For these reasons, we aim to use nonverbal learning in aphasia as a window into learning, proposing that a better understanding of these mechanisms could be essential in the diagnostic characterization of patients with aphasia.

Research in other patient populations, such as Parkinson's disease, Alzheimer's disease, frontotemporal dementia and amnesia, has emphasized the importance of understanding subtleties of learning ability in patients with brain damage (Filoteo, Maddox, Ing, Zizak, & Song, 2005; Knowlton & Squire, 1993; Knowlton, Squire, & Gluck, 1994; Koenig, Smith, & Grossman, 2006; Koenig, Smith, Moore, Glosser, & Grossman, 2007; Shohamy et al., 2004) that we suggest is also essential in aphasia. Knowlton et al. (1994), for example, conducted an experiment exploring the ability of patients with amnesia to learn stimulus outcome associations between geometric cards and weather conditions. Previous research had shown that despite deficits in episodic memory, patients with amnesia were capable of learning some types of information. Knowlton et al. (1994) found that an alternate means of instruction administered through gradual trial-by-trial feedback, allowed amnesic patients to overcome memory deficits and learn probabilistic card-condition pairings as well as controls. This study demonstrated that for the case of amnesia, characteristics of the to-be-learned material were not the factor confounding learning; rather, it was the method of instruction and the way in which memory systems were recruited to support learning that facilitated success. While differential patient success with language learning might very well be affected by semantic, phonological and grammatical characteristics of target material, additional cognitive mechanisms that are independent of verbal processing skills might also contribute to language learning.

One study of high pertinence to the methods of the current paper is by Koenig et al. (2006) examining learning in patients with frontotemporal dementia (FTD). In their study, researchers explored participant abilities to learn to categorize novel animals, comparing rule-based and similarity-based paradigms. Researchers found that different profiles of learning arose among patients with semantic dementia (SD) and patients with progressive nonfluent aphasia (PNFA), the PNFA group showing impaired rule-based learning. Aphasia associated with frontotemporal dementia is distinct from stroke-related aphasia; however we draw attention to this study because researchers implemented nonverbal learning as a means of isolating learning in patients with language impairments, and drew further attention to the distinct processes involved in different methods of learning.

Despite the breadth of research dedicated to nonverbal learning in other populations with brain damage, and the identified impact of instruction method on success with learning, no recent study has explored nonverbal learning in stroke-related aphasia. An exploration into nonverbal learning offers the potential to determine whether patients with aphasia experience language deficits that are supported by an intact cognitive foundation for learning, or whether deficits in language occur in the context of degraded cognitive architectures to support learning. If patients learn novel nonverbal information as well as controls, results will suggest that the observed variability in learning in aphasia is