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Transfer effects on spoken sentence comprehension and functional communication after working memory training in stroke aphasia

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ABSTRACT

Recent treatment protocols have been successful in improving working memory (WM) in individuals with aphasia. However, the evidence to date is small and the extent to which improvements in trained tasks of WM transfer to untrained memory tasks, spoken sentence comprehension, and functional communication is yet poorly understood. To address these issues, we conducted a multiple baseline study with three German-speaking individuals with chronic post-stroke aphasia. Participants practised two computerised WM tasks (*n*-back with pictures and *n*-back with spoken words) four times a week for a month, targeting two WM processes: updating WM representations and resolving interference. All participants showed improvement on at least one measure of spoken sentence comprehension and everyday memory activities. Two of them showed improvement also on measures of WM and functional communication. Our results suggest that WM can be improved through computerised training in chronic aphasia and this can transfer to spoken sentence comprehension and functional communication in some individuals.

1. Introduction

Individuals with aphasia (IWA) may present with concomitant cognitive deficits including deficits of short-term memory, working memory (WM)[1] (e.g., Friedmann & Gvion, 2003; Mayer, Mitchinson, & Murray, 2016; Nickels, Howard, & Best, 1997; Sung et al., 2009) and executive functions (e.g., Helm-Estabrooks & Albert, 1991; Nicholas, Hunsaker, & Guarino, 2017; Purdy, 2002; Zakariás, Keresztes, Demeter, & Lukács, 2013). WM is a complex cognitive construct referring to processes that support the temporary maintenance *and* manipulation of information (Baddeley, 2012; Engle, 2002; Martin, Kohen, Kalinyak-Fliszar, Soveri, & Laine, 2012). Manipulation in WM involves various processes, such as shifting attentional control between tasks or mental sets, updating and monitoring WM representations, inhibiting prepotent responses, and resolving different types of interference (Friedman & Miyake, 2004; Miyake et al., 2000). Such processes have been considered under the umbrella term executive functions (e.g., Miyake et al., 2000).

There is strong evidence suggesting that WM impairments can negatively influence various language processes in aphasia, such as lexical-semantic processing (Martin et al., 2012; Novick, Kan, Trueswell, & Thompson-Schill, 2009; Robinson, Blair, & Cipolotti, 1998), sentence comprehension (Novick et al., 2009; Sung et al., 2009; Szöllősi, Lukács, & Zakariás, 2015; Wright, Downey, Gravier,

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[1] Short-term memory and WM are related constructs. It is generally acknowledged that short-term memory is responsible for the temporary maintenance and retrieval of information (Caplan & Waters, 2013), whereas WM is generally viewed as the combination of multiple components working together and actively manipulating information in short-term memory (Cowan, 2008). There is a multitude of theoretical accounts describing the relationship between short-term memory and WM. In the present paper we adopt the view that short-term memory is a component of WM (Baddeley, 2012; Cowan, 2008).

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Table 1
Summary of WM treatments including outcome measures of spoken sentence comprehension, spoken discourse, and verbal communication in individuals with aphasia.

Studies	Participant(s)	Treatment procedures	Outcomes on language
Francis et al. (2003)	*n* = 1 (mild chronic aphasia)	Sentence repetition	− TROG, TT, and active reversible sentences
Harris et al. (2014)	*n* = 2 (Broca's aphasia [DS], mild aphasia [AK])	Repetition and recognition tasks with words and non-words	⇑ for DS in semantically anomalous sentence judgements and sentence-picture matching (PALPA 55)
Salis (2012)	*n* = 1 (severe TMA)	Matching listening span with nouns	⇑ TROG; − TT
Paek and Murray (2015)	*n* = 1 (mild anomic aphasia)	*N*-back with pictures/written words, updating with pictures/written words, reading span involving grammaticality judgments and category naming, naming with spaced retrieval, opposite sentence training, reconstitution of words from oral spelling	− RTT; ⇑ %CIUs, CIUs/min in story-telling
Zakariás et al. (2016)	*n* = 3 (moderate chronic anomic [KK] and TMA [BL, BB])	Adaptive *n*-back with letters	⇑ for KK and BL in the TROG-H
Eom and Sung (2016)	*n* = 6 (Broca's, anomic, and Wernicke aphasia)	Repetition-based treatment protocol (active sentences with two- and three-argument verbs, passive sentences, conjoined sentences, and centre-embedded sentences with a subject-relative clause)	⇑ for five participants in sentence picture matching (Sung, 2015) including active sentences with two-argument verbs, active sentences with three-argument verbs, and passive counterparts of active sentences with two-argument verbs
Salis et al. (2017)	*n* = 5 (moderate chronic aphasia)	Matching listening span with nouns	− TROG, TT, ⇑ in the CETI for one participant

Note. ⇑: improvement in the task; −: no change in the task; TROG: Test for the Reception of Grammar; TT: Token test; TMA: transcortical motor aphasia; %CIUs: percent of correct information units; CIUs/min: correct information units per minute; RTT: Revised Token test; TROG-H: Hungarian version of the Test for the Reception of Grammar; CETI: Communication Effectiveness Index; PALPLA: Psycholinguistic Assessments of Language Processing in Aphasia.

Love, & Shapiro, 2007), spoken discourse and functional communication (Frankel, Penn, & Ormond-Brown, 2007; Fridriksson, Nettles, Davis, Morrow, & Montgomery, 2006; Keil & Kaszniak, 2002; Luna, 2011; Penn, Frankel, Watermeyer, & Russell, 2010; Ramsberger, 2005), and reading (Caspari, Parkinson, LaPointe, & Katz, 1998). Spontaneous recovery (Sharp, Turkheimer, Bose, Scott, & Wise, 2010) and responsiveness to language treatment have also been shown to relate to WM skills in aphasia (Brownsett et al., 2013; Lambon Ralph, Snell, Fillingham, Conroy, & Sage, 2010).

With such strong links between WM and aphasia, researchers began to devise experimental treatments that heavily rely on WM, hypothesizing transfer of treatment effects to language functions. In these studies, treatments of WM included one or more WM tasks practised intensively, and treatment effects were measured on components of WM (i.e., near transfer) and language (i.e., far transfer), including spoken sentence comprehension (Eom & Sung, 2016; Francis, Clark, & Humphreys, 2003; Harris, Olson, & Humphreys, 2014; Salis, 2012; Salis, Hwang, Howard, & Lallini, 2017; Zakariás, Keresztes, Marton, & Wartenburger, 2016), reading comprehension (Coelho, 2005; Mayer & Murray, 2002; Sinotte & Coelho, 2007), and spoken discourse (Paek & Murray, 2015; Peach, Nathan, & Beck, 2017). In the next section we discuss in detail treatment studies of WM and spoken sentence comprehension in people with non-progressive aphasia, which is the focus of the present paper.

1.1. Working memory treatments and sentence comprehension

Recent WM treatment studies that aimed to improve spoken sentence comprehension in aphasia reveal mixed findings, possibly due to substantial variations in participant characteristics, treatment tasks, intensity and duration of treatment, as well as variations in the domains and patterns of transfer detected. For example, Paek and Murray (2015) described a patient with mild anomic aphasia and semantic short-term memory deficit. The treatment included various tasks aiming to improve components of WM (i.e., updating, phonological loop) as well as semantic processing (see Table 1). The intervention was delivered remotely (teletherapy) consisting of 20 hourly sessions distributed over four weeks. Although the authors reported improvements in all training tasks, they observed near transfer effects only in one measure of short-term memory (identity span). With respect to far transfer, no substantial change was observed in spoken sentence comprehension. However, greater improvements were found in spoken discourse as measured by story-telling tasks. Additionally, improvements in short-term memory and spoken discourse were maintained at 6-week follow up.

Eom and Sung (2016) conducted a group study with six participants presenting with different types and severity of aphasia (see Table 1). They used a repetition-based treatment, incorporating sentences with varying length and syntactic complexity. The treatment combined repetition of sentences after auditory presentation, reconstruction of sentences by using word cards, and reading sentences aloud. Trained structures included active sentences with two- and three-argument verbs, passive sentences, conjoined sentences, and centre-embedded sentences with a subject-relative clause. Twelve sessions were administered over a month (three hourly sessions a week). With respect to the outcome, participants improved in the repetition of treated and untreated sentences, as well as in WM measured by digit and word span tasks. More importantly, they improved in the comprehension of treated syntactic structures (see Table 1).

Zakariás et al. (2016) used a computerised adaptive training approach (e.g., Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Novick, Hussey, Teubner-Rhodes, Harbison, & Bunting, 2014) utilising an *n*-back task with letters. *N*-back targets components of WM, such as