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Working memory treatment in aphasia: A theoretical and quantitative review

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A B S T R A C T

Working memory (WM) is a frequent and long-lasting deficit in patients with aphasia. Progress has been made in our understanding of the nature of WM impairment, by considering deficits at the level of maintenance of item and serial order information (short-term memory), deficits at the level of attentional control, and their complex interactions with language impairment. However, WM treatment studies in aphasic patients remain scarce. This theoretical and quantitative review of 15 single-case treatment studies (24 patients) reveals that WM treatment in aphasic patients is associated with robust near transfer effects and smaller far transfer effects. WM treatment can also raise verbal WM capacity to normal range performance levels. The specificity of WM treatment is more difficult to establish as control tasks/treatments are associated with treatment effects of comparable size as far transfer effects. Existing treatments cover phonological maintenance and control of attention components of WM but do not target difficulties at the level of item interference or serial order processing. In order to improve the specificity of WM treatments, future studies should define WM impairment and treatment targets in a more precise and theoretically informed manner. Also, although the vast majority of reviewed studies meet minimal methodological requirements for single case experimental designs, the use of a larger number of baseline, treatment and control measures is recommended. Finally, publication of treatment studies with negative outcomes should be encouraged as it is currently difficult to estimate the impact of publication bias on observed treatment effects.

1. Introduction

The aim of this critical review paper is to investigate the progress that has been made in the rehabilitation of working memory (WM) impairment in aphasia. WM impairment is a frequent, associated deficit of aphasia and it is also a long-lasting one, being still present in patients that appear to have recovered from their language impairment by showing no residual deficits in standard language measures (Caramazza, Basili, Koller, & Berndt, 1981; N. Martin, Saffran, & Dell, 1996). These WM deficits will continue to cause functional deficits in everyday life such as difficulties in following discussions and in taking notes, and they will prevent a full recovery of social and professional autonomy (Vallat et al., 2005). Different intervention strategies have been proposed, including both restoration and compensation techniques. In order to achieve an accurate understanding of the efficacy and specificity of these techniques, we first need to consider the complex nature of WM impairment in aphasia, in the light of current theoretical models.

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2. The nature of WM impairment in aphasia

WM is a broad concept involving many different components, one distinction being the separation of storage components from processing components (e.g., Engle, Tuholski, Laughlin, & Conway, 1999). There is important theoretical confusion surrounding the terms 'short-term memory' (sometimes defined as the storage component) and 'working memory' (sometimes defined as the processing component). Cowan (2017) highlighted the theoretical conundrum that has arisen from the co-existence of (too) many different definitions and terms for the general function of WM. Given the current theoretical debates, I will use the term WM in a functional, a-theoretical manner and I will avoid opposing the terms 'short-term memory' and 'working memory'. The term 'WM' will refer to the general function of temporary maintenance and will remain neutral as regards the components (e.g., only storage, storage and processing) involved. Critically, in order to maximize theoretical clarity, specific terms will be used to characterize the different components and processes involved in the different WM tasks and situations that will be discussed.

At the theoretical level, the concept of WM has made a long journey since the proposal of the working memory model by Baddeley and Hitch (1974). The initial working memory model contained a phonological loop system for storing verbal information, with a subdivision into in a buffer system, the phonological store, and a refreshing mechanism, the subvocal articulatory rehearsal process. This model also contained a visuo-spatial sketchpad for storing visuo-spatial information, as a well as an attentional supervisory system. This model captured well the observation of patients with apparent isolated verbal WM deficits, as WM was considered to be a separate function from the language system and hence could be impaired in isolation (Vallar & Baddeley, 1984). However, this model did not capture the complex interactions that exist between verbal WM and language processing. These interactions are of particular importance for an accurate understanding of verbal WM deficits in patients with aphasia, as these deficits can be the cause or the consequence of underlying language impairment. For example, patients with reduced semantic processing abilities will show impaired storage abilities for stimuli with a semantic content such as words, but not for nonwords (Majerus, Patterson, & Norris, 2007). Even in patients with so-called isolated verbal WM impairment, a review of published cases showed that the vast majority of these patients initially presented with aphasia, and the severity of their verbal storage deficit correlated with their residual language processing abilities (Majerus, 2009). Progressively, WM models started to acknowledge more explicitly the interactions that link WM and language processing. Some models took a strong position by considering that short-term storage of verbal information is a processing property of the language system and reflects the decay rate of activated language representations (N. Martin & Saffran, 1992). Other models considered interactions between a phonological buffer system and phonological representations in the language system (Baddeley, Gathercole, & Papagno, 1998; R. Martin & Lesch, 1996) or between a specialized semantic buffer system and semantic levels of linguistic representations (R. Martin & Lesch, 1996; R. Martin, Shelton, & Yaffee, 1994). Many patients with aphasia are indeed sensitive to temporal factors in both linguistic and WM tasks, with performance decreasing when linguistic information has to be maintained over time (Majerus, Lekeu, Van der Linden, & Salmon, 2001; N. Martin et al., 1996). The importance of time-based decay in WM is also increasingly supported by studies in healthy adults (Barrouillet, Bernardin, & Camos, 2004; Ricker, Spiegel, & Cowan, 2014; Ricker, Vergauwe, & Cowan, 2016), although other authors continue to challenge the concept of time-based decay (Lewandowsky & Oberauer, 2009; Oberauer & Lewandowsky, 2013). In sum, as shown in Fig. 1, many current models of WM consider that the language processing system is at the basis of verbal WM: time-based decay of language activations can lead to verbal WM impairment particularly for the storage of verbal item information. We should note here that storage of serial order information has been considered to be supported by more specific mechanisms that I will describe below.

Control of interference within the linguistic system has been proposed to further determine verbal item storage capacities. Indeed, patients with aphasia can have intact access to their language representations, but they may have difficulties in inhibiting irrelevant

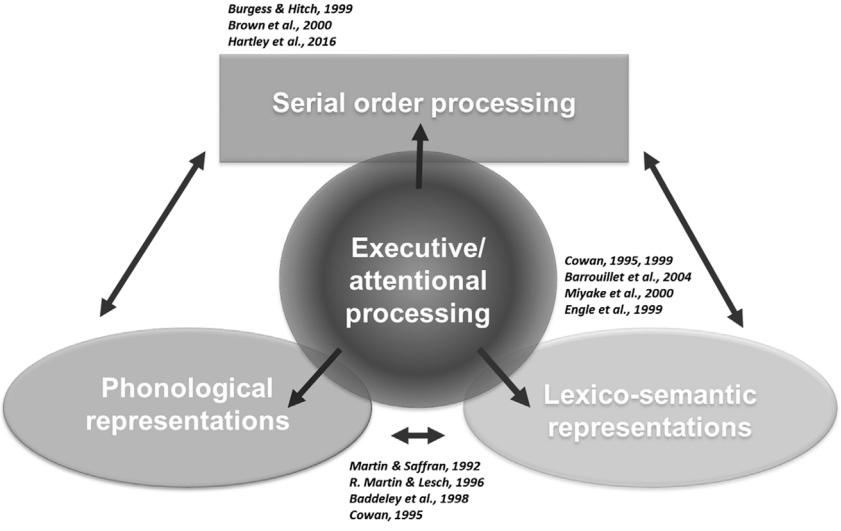

Fig. 1. Overview of WM components examined in this review.