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The role of speech production in auditory-verbal short-term memory: evidence from progressive fluent aphasia

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Abstract

We report investigations of auditory-verbal short-term memory (AVSTM) in a patient with progressive fluent anomic aphasia. Despite having apparently normal AVSTM as measured by digital span, FM was significantly impaired in immediate serial recall of short sequences of familiar words, and even in reproducing a single word after a filled delay of just a few seconds. In both tasks, unlike normal subjects, she produced numerous phonological errors, often consisting of phonological segments from the intended target word concatenated with segments from other words in the stimulus sequence. Her success in these tasks was modulated (i) consistently by word frequency (high > low), (ii) inconsistently by word imageability (high > low), and (iii) most dramatically by 'nameability': that is, FM was much more likely to reproduce a word correctly in AVSTM if it was a word that she could also produce successfully in picture-naming tasks. On the basis of these and additional experiments designed to exclude other interpretations, we conclude that AVSTM may be crucially supported by activation of the lexical phonological representations responsible for production of content words in speech. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Auditory-verbal short-term memory; Anomia; Speech production; Lexical phonological representations; Progressive fluent aphasia

1. Introduction

Many aphasic speakers exhibit poor performance on auditory-verbal short-term memory tasks. The relationship between impairments in language and these frequently associated problems in short-term memory (STM) is however still relatively poorly understood. Much early neuropsychological work concerned cases with an apparently selective impairment in short-term memory which left other language related processes relatively intact. In particular, several important cases were described where marked phonological STM impairment co-existed with unimpaired speech production (see for example, [49,55]). This pattern naturally suggests that normal phonological short-term memory processing is not required for the planning and production of speech [14].

What of the converse, however? That is, what impact does impairment to speech production processes have on short-term memory? The evidence here is relatively limited, in part because many studies of short-term memory have specifically excluded consideration of cases with an evident speech production deficit. Gathercole and Baddeley [14], however, expressed a widely held view that whilst speech production resources do not contribute significantly to short-term storage, speech production processes normally involved in articulatory planning may be recruited to sustain the short-term memory trace through a process of subvocal rehearsal. Evidence for this proposal comes from a study of six dyspraxic patients by Waters et al. [57], all of whom had difficulties in high-level motor speech planning. Although able to perform a range of STM tasks, these patients showed a profile similar to normal subjects performing under conditions of articulatory

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suppression, suggesting a failure of the normal rehearsal process. This particular study focused on the control and planning of articulatory gestures. The role played by higher-level lexical components of the speech production system in many short-term memory tasks has been left substantially unexplored in the STM literature.

One programme of research that assumes an important connection between speech production and short-term memory processes, is that by Martin and Saffran [36–38]. Martin and Saffran attempt to explain the naming, repetition and serial recall performance of a series of language impaired cases using an interactive activation model of speech production developed by Dell [8,10]. In this model, the representations that are assumed to subserve short-term memory and those that accomplish speech production/comprehension are one and the same. The model provides an account of imageability and frequency effects observed in the serial recall of language impaired patients, and offers an explanation of how these effects vary with serial position, and as a function of the type of impairment that the patient has sustained (e.g. semantic or phonological). Since the model assumes that speech production and short-term memory representations are entirely shared, it is hard to see how it could provide a satisfactory account for the cases of selective STM impairment reported by Shallice and Butterworth [49] and Vallar and Shallice [55]. A more recent version of this approach [11,37], which distinguishes separate channels for input and output processing systems, may nevertheless be able to account for patients with STM deficits but unimpaired speech production.

R. Martin and colleagues put forward a view which is in many respects similar to that of Martin and Saffran, but one which from the outset is designed to account for cases of selective STM impairment where single word processing remains intact [39,40]. Like Martin and Saffran, R. Martin and colleagues assume that lexical and semantic representations may make an important contribution to short-term memory performance. However, unlike Martin and Saffran they consider short-term storage to be distinct from language processing mechanisms. STM is regarded as a limited capacity buffer containing interlinked lexical, semantic and phonological representations which are the *products* of the language processor. By assuming this division between storage and processing, R. Martin and colleagues are able to account for the influence of long-term memory (LTM) factors on STM performance, but also for STM cases who have apparently unimpaired single word processing (MS, [39]; JB, [49]; PV, [55]). In these cases, the buffer can be assumed to be compromised, but the language processor remains intact.

Knott et al. [33] have also provided evidence that lexical and semantic representations support serial recall and, in addition, play an important role in maintaining the phonological structure of the STM trace. Knott et al. described a case of progressive fluent aphasia or semantic dementia, AM, with good digit span in the context of impaired serial recall of content words. AM showed a pervasive pattern of semantic effects in his auditory-verbal short-term memory (AVSTM), and in particular a marked superiority for serial recall of sequences of 'known' over 'unknown' words. This manipulation, first employed by Warrington [56] in a study of semantically impaired patients, contrasts STM performance on lists composed either of words on which the patient still succeeds in other tasks reflecting underlying knowledge (e.g. picture naming or word-picture matching), or of words on which the patient fails in these same tasks. AM's performance in serial recall tasks was characterised by abundant phonemic errors, with a frequency shown to be related to semantic factors. These errors were strikingly similar to those produced by normal speakers repeating sequences of nonwords [52]. This finding suggests that loss of normal efficient support from lexical and/or semantic representations leads to a disruption of phonological short-term memory processing; in tasks requiring overt recall, this becomes apparent as errors in which the phonological word-form breaks up.

Effects of semantic and lexical variables on STM have not gone unnoted in the normal literature on short-term memory [27,28,45,46]. Hulme et al. [28] attempted to account for lexical effects within the phonological loop framework developed by Baddeley and colleagues [1,2,4]. The phonological loop consists of two components: a short-term store where a phonological trace is encoded but is subject to rapid decay, and a rehearsal mechanism which is used periodically to refresh the contents of the store and so extend the life of the trace. According to Hulme et al. [28], when a partially decayed trace is retrieved from the loop (which is assumed indifferent to lexical status), knowledge about the structure of words stored in the phonological lexicon is used to reconstruct the trace to its original sequence. Hulme et al. likened this process of reconstruction to the 'pattern completion' property exhibited by connectionist networks.

Many views of the immediate serial recall process (e.g. [6,20,38]) assume that lexical information is used immediately at encoding to enrich the phonological record. By contrast the reconstruction account of Hulme et al. [28] proposes that lexical influences in immediate serial recall occur only immediately prior to recall, when items are retrieved from phonological storage. This, however, is only one of several potential views of how a lexical reconstruction process might operate. On a language based model of AVSTM which