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Research report

Phonology without semantics? Good enough for verbal short-term memory. Evidence from a patient with semantic dementia

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ABSTRACT

Introduction: There is considerable evidence that long-term knowledge has an influence on short-term memory (STM) performance. This reflects the activation of long-term representations involved in perceiving and comprehending spoken language. Still, this type of long-term knowledge might be of two different kinds. STM performance might be facilitated by information about the meaning of the word, or, alternatively, by familiarity with its phonological form.

Methods: We investigated these two alternatives by assessing word span in MC, a patient with semantic dementia. Four different lists of words were used: known words, words whose phonological form was known by the patient although she could not report its meaning, words that the patient did not recognize as words and judged as nonwords, nonwords. The patient's performance was compared to that of six matched controls.

Results: MC did not differ from controls in the first two types of lists and performed at the same level with both, while for words whose phonological form was unknown (and therefore not recognized as words) her performance was comparable to that with nonwords; also, with this type of item, she produced significantly more phonemic substitutions than controls.

Conclusions: The results show that long-term knowledge facilitates immediate serial recall. However, this facilitation is due to familiarity with phonological representations rather than to knowledge of meaning.

1. Introduction

There is considerable evidence that long-term knowledge has an influence on the performance of verbal short-term memory (STM) tasks. For example, memory span for familiar words is higher than for nonwords (Hulme et al., 1991). This STM performance reflects the activation of long-term representations involved in perceiving and comprehending spoken language. Still, the type of long-term knowledge involved might be of two different types. Since a word is an (often arbitrary) association of sound and meaning, STM performance might be facilitated by long-term semantic information about the meaning of the word. Alternatively, STM performance might be facilitated by familiarity with the phonological form of a given word. Typically, knowledge of meaning and knowledge of the phonological form go hand in

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hand, but it is not necessarily so. In particular, the meaning of a word can be accessible, while the word form not, and, conversely, the phonological form can be known even if the meaning is not. The latter option can also occur to foreign speakers, when they know that they have heard that particular word, that they used to know its meaning, but now this is not anymore available. In this paper we explore the issue of which type of long-term information is recruited in STM tasks and challenge the view that an important role is played by semantic knowledge.

The involvement of long-term memory (LTM) in STM tasks has been invoked to explain the higher span for words over nonwords. For example, the *reconstruction* or *redintegration hypothesis* (see Hulme et al., 1997) suggests that when phonological representations set up by list presentation are degraded and cannot be output directly as responses, they undergo a reconstruction process that calls on the long-term representations of the to-be-recalled items. In this process, phonological representations stored in LTM are used as retrieval cues for accessing an acceptable recall candidate. This hypothesis can easily explain why words are better recalled than nonwords, since only words have a stored phonological form that can support reconstruction. It can also explain word frequency effects, if high-frequency words can be accessed faster, enhancing redintegration (Hulme et al., 1997). This model assumes that degraded STM traces are reconstructed in a manner similar to the repair of speech errors in speech production systems, so the crucial role is played by familiarity with the phonological form of the word (as opposed to knowledge of its meaning).

However, Walker and Hulme (1999) studied the effects of concreteness, a semantic variable, and found that concreteness mainly affected the recall of item information rather than order information in a serial recall task. Therefore, they concluded that semantic factors are much more relevant than typically assumed and that redintegration should be broadened to include access to semantic representations (p. 1267), presumably in what concerns the number of items recalled, no matter whether they are in the correct position.

Saint-Aubin and Poirier (2000) proposed a different version for the redintegration hypothesis, which also maintains a role for lexical–semantic representations. This is 'the retrieval-based hypothesis': word presentation creates a phonological representation of the to-be-recalled items, subject to degradation. At recall, phonological representations are output in the appropriate order. The degraded phonological representation of a given item serves as a retrieval cue for accessing the appropriate long-term representation. High frequency and semantic similarity are associated with better item recall, since these factors increase the accessibility of the appropriate long-term representation, including lexical–semantic information (Saint-Aubin and Poirier, 1999, 2000). On the other hand, order errors occur because it is not always possible to uniquely identify one of the list items on the basis of the degraded phonological traces, as phonological features are likely to be embodied in a number of those items. Thus, if a phonological trace has lost most of its distinctive features, the long-term representation of another list item, holding common features, can be erroneously selected in the "wrong" position.

All in all, studies on healthy subjects offer some evidence that STM performance is enhanced by long-term semantic information, but the alternative hypothesis that STM performance is facilitated only by familiarity with the phonological form of a given word cannot be easily dismissed, even more so given the uncontroversial role of phonological coding in verbal STM tasks.

Subjects with semantic knowledge impairment can help to discriminate between these two hypotheses. Patients with semantic dementia (SD), at least before the advanced stage of their disease, are able to correctly repeat and read words whose meaning is lost; they can read regular words and high-frequency exceptions (see for example patient AM in Knott et al., 1997). Also, they retain the ability to learn new phonological sequences, as predicted by their intact phonological STM (Jefferies et al., 2011).

The hypothesis that semantic representations play a role in immediate order recall tasks predicts that SD patients should show a pathological performance when tested with words whose meaning is unavailable to them. On the other hand, the hypothesis that the crucial information in immediate serial recall is the availability of the phonological representation predicts that SD patients should not be impaired with the same word lists if they recognize them as previously known words.

Concerning this issue, Patterson et al. (1994) examined three SD patients. They were submitted to immediate serial recall of short sequences of familiar words. On the basis of their performance in tasks of word comprehension and production, the stimuli were selected individually for each patient as either known or unknown words. All patients showed a marked advantage in recall of known as compared to real but unknown words. Errors consisted of incorrect combinations of correct phoneme sequences in the stimulus string, with a distinctive type of blend error; these blends errors were recombination of parts of items presented in the stimulus list (for example, "mint, rug" became "rint, mug"), the same type of error produced by healthy subjects with nonwords. This phenomenon was explained in terms of a crucial role played by meaning in binding the elements of phonological word forms: blend errors reflect the deterioration of semantic knowledge, which, in the normal system, may be one source of coherence that binds phonological elements into word units.

The idea, stemming from Patterson et al. (1994), that semantics plays a key role in binding phonemes into words and plays a critical role during STM tasks will be now referred to as 'the semantic binding hypothesis'.

However, there are several problems with this study. First, as the authors acknowledge, known and unknown words were not matched for frequency (and we know that frequency has a relevant effect on redintegration); second, unknown words were selected from items on which patients had chosen the wrong alternative when asked to point to a picture corresponding to a spoken word, or given the wrong reply in response to a simple question about a spoken word (does a sparrow have wings?), while those classified as known words were those used in conversation (such as "thinking", "mother") or picture description or items produced in a word fluency task on phonemic cue: these criteria made the stimuli