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Does articulatory rehearsal help immediate serial recall?☆

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ABSTRACT

Articulatory rehearsal is assumed to benefit verbal working memory. Yet, there is no experimental evidence supporting a causal link between rehearsal and serial-order memory, which is one of the hallmarks of working memory functioning. Across four experiments, we tested the hypothesis that rehearsal improves working memory by asking participants to rehearse overtly and by instructing different rehearsal schedules. In Experiments 1a, 1b, and 2, we compared an instructed cumulative-rehearsal condition against a free-rehearsal condition. The instruction increased the prevalence of cumulative rehearsal, but recall performance remained unchanged or decreased compared to the free-rehearsal baseline. Experiment 2 also tested the impact of a fixed rehearsal instruction; this condition yielded substantial performance costs compared to the baseline. Experiment 3 tested whether rehearsals (according to an experimenter-controlled protocol) are beneficial compared to a matched articulatory suppression condition that blocked rehearsals of the memoranda. Again, rehearsing the memoranda yielded no benefit compared to articulatory suppression. In sum, our results are incompatible with the notion that rehearsal is beneficial to working memory.

1. Introduction

Working memory (WM) for verbal materials is often tested through sequential presentation of short lists, with immediate forward serial recall of the list. Maintenance of these lists is often accompanied by the overt or covert repetition of the memoranda to oneself, a behavior known as *articulatory rehearsal*[1] (Baddeley, 1986). Rehearsal is the most common self-reported maintenance strategy in WM tasks, being reported in about one-third to one-half of the trials (e.g., Bailey, Dunlosky, & Kane, 2011; Dunlosky & Kane, 2007).

Researchers routinely assume that people rehearse because it helps them maintain information in WM. Yet, there is hardly any experimental evidence for a causal link between rehearsal and serial recall performance. The main aim of the present paper is to fill this gap by providing a first experimental investigation on the impact of different rehearsal schedules upon memory over the short-term. In the following, we will motivate our research questions by reviewing the role of rehearsal in WM models and the sparse extant evidence available linking rehearsal to WM recall.

1.1. Rehearsal in WM models

Articulatory rehearsal is usually assumed to be beneficial to WM, and several WM theories assign rehearsal a causal role in WM

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[1] Hereafter we will use the more general (but also shorter) term “rehearsal” to refer to articulatory rehearsal.

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maintenance. According to theories assuming time-based decay (Baddeley, 1986; Camos, Lagner, & Barrouillet, 2009; Cowan, 1999), rehearsal occurs within a phonological store which offsets trace decay by restoring representations to their initial level of activation. In the time-based resource sharing (TBRS) model, other types of reactivation are also possible via the use of an attention-based process known as refreshing. The effects of rehearsal and refreshing are assumed to be additive (Camos et al., 2009; Camos, Mora, & Barrouillet, 2013; Camos, Mora, & Oberauer, 2011; Hudjetz & Oberauer, 2007; Mora & Camos, 2013, 2015). It follows that when rehearsal is blocked, recall accuracy decreases because decay sets in.[2] Likewise, in the embedded processes model proposed by Cowan (2001), it is assumed that WM comprises a focus of attention that holds a limited number of chunks in a more semantic format, whereas other peripheral mechanisms can provide additional (and domain-specific) storage capacity. Among these additional mechanisms/processes, Cowan lists sensory memory and rehearsal (Cowan, 2011). Accordingly, in this model rehearsal is assumed to supplement the capacity of the focus of attention, but to be independent of it.

Recent computational modeling work has cast doubt on the presumed effectiveness of rehearsal for counteracting decay. Lewandowsky and Oberauer (2015) implemented rehearsal in a generic decay model of immediate serial recall and found that its beneficial effect is very limited. Two main problems were identified by this detailed analysis of rehearsal. First, to rehearse a list in correct order, it has to be retrieved in correct order. Any factor jeopardizing accurate list memory, such as decay, also introduces a non-negligible chance of erroneous retrieval during rehearsal. When list items are retrieved in the wrong order during rehearsal, then rehearsal damages the representation of serial order rather than protecting it. Second, rehearsal is not evenly spread among list items – typically, early list items are rehearsed more often, simply because they are available for rehearsal earlier. The uneven frequency of rehearsal introduces uneven strength among list items – in particular, early list items often become so strong that they interfere with retrieval of subsequent list items. This undercuts the beneficial effect of rehearsal: Rehearsal tilts the serial position towards better recall of list-initial items, but leads to little or no overall benefit.

Models that do not postulate decay may also ascribe a causal role to rehearsal by assuming that it increases the accessibility of list items in memory due to the creation of distributed traces of the rehearsed words at multiple time points. Such accounts have been common in the explanation of free recall data (Brodie & Murdock, 1977; Brown, Sala, Foster, & Vousden, 2007; Farrell, 2012; Tan & Ward, 2000). The effect of rehearsal in these models has been described as “repeating, re-ordering, and redistributing the study items” (Tan & Ward, 2000, p. 1606), which clearly is at odds with the goal of keeping track of their order of presentation as required in serial recall tasks. If anything, these theories should predict a cost of rehearsal to serial-order memory. The only way in which these models could account for a beneficial effect of rehearsal for serial order is if the rehearsal output itself preserves the order of the items in the list, as it is the case when participants are attempting forward cumulative rehearsals, that is, rehearsal cycling through the list in its order of presentation.

Interference models of working memory do not resort to rehearsal to explain performance in WM tasks. One such model is the serial-order in a box – complex span (SOB-CS) model (Oberauer, Lewandowsky, Farrell, Jarrold, & Greaves, 2012). Lewandowsky and Oberauer (2015) also explored the role of rehearsal in SOB-CS, and found that rehearsal had essentially no effect on memory. Rehearsal, modelled as cycles of retrieving and re-encoding of items, added nothing to the memory representations. This is because in this model, representations are not getting weaker over time, so there is not much to gain from rehearsing items.

Of course, any computational model implements a number of assumptions about how information is encoded, maintained, and retrieved from WM that can be wrong. The final arbiter should always be, therefore, the empirical data. We will review next the empirical studies assessing the role of rehearsal in WM, and show that the evidence linking rehearsal to WM is lacking.

1.2. Linking rehearsal to WM performance

1.2.1. Blocking rehearsal

Several studies have observed that requiring concurrent articulation of irrelevant material during maintenance of a verbal list reduces recall (e.g., Baddeley & Lewis, 1984; Bhatarah, Ward, Smith, & Hayes, 2009; Camos et al., 2009). Concurrent articulation is assumed to prevent rehearsal, and is therefore often referred to as “articulatory suppression” (AS). The finding that AS impairs verbal serial recall has commonly been interpreted as evidence for the beneficial effect of rehearsal. This interpretation is not compelling, however, because the detrimental effect of AS can also be explained by interference: Articulating irrelevant material introduces representations of that material into WM, where it interferes with the memoranda (Gupta & MacWhinney, 1995; Nairne, 1990, 2002; Oberauer et al., 2012). Moreover, several studies have shown that increasing the length of the period in which participants perform AS (hence arguably preventing rehearsal, and allowing decay to set in) does not lead to more forgetting unless there is variation in the articulated materials (Humphreys et al., 2010; Lewandowsky, Duncan, & Brown, 2004; Lewandowsky, Geiger, & Oberauer, 2008; Lewandowsky, Geiger, Morrell, & Oberauer, 2010; McFarlane & Humphreys, 2012; Phaf & Wolters, 1993; Vallar & Baddeley, 1982) (reviewed by Lewandowsky & Oberauer, 2015). The latter pattern of findings is consistent with an interference explanation, because more variability in the articulated material introduces more interference, but it is not consistent with a decay explanation, which predicts a main effect of time irrespectively of the filler activities performed therein. Clearly, we cannot rely solely on the data from AS manipulations to establish whether rehearsal is beneficial to WM.

1.2.2. Overt rehearsal protocol

Corroborative evidence for a causal role of rehearsal for memory has come from studies in which rehearsal patterns were observed

[2] This prediction follows even if refreshing is not blocked because the effects of rehearsal and refreshing are thought to be additive.