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Short-and long-term memory determinants of novel word form learning

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ABSTRACT

It is widely assumed that a strong positive link exists between memory and vocabulary development. Nevertheless, the exact involvement of short-term memory (STM) and long-term memory (LTM) is poorly understood. STM for serial order information is argued to play a crucial role in temporarily maintaining and refreshing the order of phonemes representing novel word forms. LTM for serial order information, in contrast, is involved in the consolidation of phoneme sequences into unitary word form representations. Here, we tested 131 6-year-old children on tasks that targeted STM for serial order versus item information, on a Hebb repetition task targeting long-term serial order learning, and on a paired-associate novel word learning task. Bayesian analyses revealed a strong correlation between STM for serial order information, and both the initial and final stages of word form learning. LTM was associated with the final stages of word form learning. These findings are discussed in light of existing theories about the role of memory in language.

1. Introduction

In the past decades, a large number of studies have investigated the link between verbal short-term memory (STM) and vocabulary development. A series of correlational studies have shown reliable associations between STM tasks such as nonword repetition, immediate verbal serial recall, digit span, and vocabulary measures like novel word learning tasks (Baddeley, Gathercole, & Papagno, 1998; Gathercole & Baddeley, 1990; Gathercole, Willis, Emslie, & Baddeley, 1992; Gupta & MacWhinney, 1997; Gupta, 2003; Gupta et al., 2004). Baddeley, Papagno, and Vallar, 1988 were among the first to provide evidence for the verbal memory hypothesis of word learning in a neuropsychological patient. In their case study, they observed very poor paired-associate word learning abilities in a patient exhibiting a selective impairment of verbal STM. A large set of studies in children have also shown that nonword repetition is a reliable predictor of second language vocabulary learning (Gathercole, Hitch, Service, & Martin, 1997; Service & Kohonen, 1995). Nevertheless, although there is considerable evidence for an association between verbal STM and vocabulary development, prior studies remain relatively vague about the nature of the precise cognitive processes that underlie this association. One important aspect to consider when studying vocabulary learning is that learning a new word entails two main subcomponents: First, the learning of the phonological representation of the new word, or the learning of the word form, and second, the mapping of this word form to its meaning (semantic representation; Swingley, 2010). In the present study we will focus on one specific aspect of vocabulary

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learning, namely the acquisition of *word forms* (i.e. the phonological representation of a word) in the absence of meaning in order to examine the role of serial order memory in phonological form learning as directly as possible.

It is nowadays well-accepted that language is sequential in nature (Hsu & Bishop, 2014; Saffran, Aslin, & Newport, 1996). Burgess and Hitch (1992), for instance, postulated in their connectionist model of STM that when a new word is encountered, the phonemes of this word will be activated in the sublexical system and the STM system will simultaneously encode and temporarily maintain the order of activation of these phonemes in the sublexical system. This will allow the reactivation of the new word form with each phoneme in its correct serial position. Acquiring the phonological form of a word is thus obviously driven by learning the serial order of its constituent phonemes. In order to shed new light on the cognitive processes underpinning novel word form learning, an increasing number of STM models focusing on serial order processing have emerged (2006, Burgess & Hitch, 1999; Gupta, 2003; Page & Norris, 2009a, 2009b). Many of these models further suggest to make a distinction between the mechanisms driving the recall of item (i.e., the identity of the items) versus serial order (i.e., the serial order amongst these items) information (Brown, Preece, & Hulme, 2000; Burgess & Hitch, 1992, 1999, 2006; Gupta, 2003, 2006; Gupta & MacWhinney, 1997; Henson, 1998; Majerus & Boukebza, 2013; Majerus & D'Argembeau, 2011; Majerus, Poncelet, Elsen, & Van der Linden, 2006; Majerus, Poncelet, Greffe, & Van der Linden, 2006; Page & Norris, 2009a, 2009b). They suggest that the recall of item information depends on the temporary activation of the language system, while order information is stored in a specific STM system (Brown et al., 2000; Burgess & Hitch, 2006; Gupta, 2006; Majerus & D'Argembeau, 2011). In other words, the recall of item information is assumed to be affected by knowledge encoded in the language system such as (sub)lexical and semantic knowledge, while the recall of serial order information is much less influenced by this knowledge (Majerus & Boukebza, 2013; Majerus & D'Argembeau, 2011; Nairne & Kelley, 2004; Poirier & Saint-Aubin, 1996; Saint-Aubin & Poirier, 2005). According to these findings, the existence of an association between item STM and vocabulary measures is likely to reflect the common reliance on current language knowledge. Because serial order recall is known to be less affected by language knowledge (Nairne & Kelley, 2004), it has been assumed that the observation of a link between serial order STM and vocabulary measures would provide evidence for a specific and language-independent association between STM and vocabulary development (Leclercq & Majerus, 2010). At the same time, some models, like for instance the (C-)SOB models, do not consider a distinction between item and order codes and assume that item and order information of to-be-recalled lists are processed simultaneously and may thus be supported by a single mechanism. According to these models, serial order is encoded via item-to-context association mechanisms, and the encoding strength of to-be-recalled items decreases across serial position since only what is novel at each item position is encoded. At recall, a context cue is used to find an individual context-item association, which may sometimes be distorted by the encoding of other context-item associations. After recall, an item is subsequently suppressed (Farrell & Lewandowsky, 2002; Farrell, 2012; Oberauer, Lewandowsky, Farrell, Jarrold, & Greaves, 2012). Thus, it seems that the maintenance of order is directly affected by list items (Camos, Lagner, & Loaiza, 2017). These models however, have difficulties in accounting for item and order processing dissociations that have been observed at behavioral and neural levels. In addition to the studies mentioned at the beginning of this paragraph, neuropsychological and neuroimaging studies further support the distinction between item and order information processing. Functional neuroimaging studies (Henson, 1998; Majerus, Poncelet, Greffe et al., 2006, 2010a; Majerus, Poncelet, Van der Linden, & Weekes, 2008; Majerus, 2013; Marshuetz, Smith, Jonides, DeGutis, & Chenevert, 2000) have shown activation of distinct brain networks for item (i.e., bilateral temporal regions) versus order processing (i.e., left and right intraparietal sulci). Neuropsychological studies have also observed dissociations between item and serial order STM abilities (Majerus, Norris, & Patterson, 2007).

In the light of this item-order dissociation, Majerus and colleagues have tried to clarify the nature of the association between verbal STM and novel word form learning by using tasks allowing to make a distinction between item and serial order recall performance (Leclercq & Majerus, 2010; Majerus & Boukebza, 2013; Majerus, Poncelet, Elsen et al., 2006; Majerus, Poncelet, Greffe et al., 2006). These studies have demonstrated the existence of a specific association between STM for serial order, compared to item information, and word form learning. In their study, Majerus and Boukebza (2013) hypothesized that especially serial order STM would support the learning of unfamiliar phoneme sequences. Given that a considerable number of words in any language are rearrangements (or anagrams) of the same set of phonemes (e.g., leaf vs. flea, eat vs. tea), the exact order of phoneme sequences is essential to differentiate these word forms. According to Majerus and Boukebza (2013), serial order STM not only seems to support the temporary maintenance of the phoneme sequences defining a novel word, but also facilitates the capacity to distinguish two phonologically similar words (see also Smalle et al., 2016). In order to control for the impact of language knowledge, Majerus and Boukebza administered two STM tasks to a developmental sample of children – one maximizing serial order demands and another maximizing item information demands. Serial order STM was assessed via a serial order reconstruction task minimizing item STM requirements by providing all items at recall. Item STM was measured via a single nonword delayed repetition task whose consonant-vowel-consonant (CVC) structure allowed to minimize the opportunity to make serial order errors (Leclercq & Majerus, 2010). In order to operationalize novel word form learning, the children were asked to learn the names of aliens in a paired-associate novel word learning task. The findings obtained in this study showed that serial order STM predicts novel word form learning above and beyond item STM, relational learning abilities, and non-verbal intellectual efficiency. These results demonstrate that especially serial order STM is involved in the temporary maintenance and reactivation of to-be-learned phonological word forms.

Other recent studies have tried to better understand how exactly these sequential short-term representations are mapped into stable long-term representations (Szmalec, Duyck, Vandierendonck, Mata, & Page, 2009; Szmalec, Page, & Duyck, 2012). To study the transition from STM to long-term memory (LTM), these studies used the Hebb repetition paradigm. In the Hebb repetition paradigm (Hebb, 1961), participants perform an immediate verbal serial recall task of repeating (Hebb) sequences and non-repeating (filler) sequences of nine digits, with the Hebb sequence being repeated on every third trial. Hebb observed that the recall for repeated sequences gradually increased compared to non-repeating sequences. This observation is known as the Hebb repetition effect (HRE).