INTERACTIONS BETWEEN SHORT-TERM AND LONG-TERM MEMORY IN THE VERBAL DOMAIN

EDITED BY ANNABEL THORN AND MIKE PAGE

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Psychology Press
Taylor & Francis Group
HOVE AND NEW YORK

First published 2009 by Psychology Press
27 Church Road, Hove, East Sussex BN3 2FA

Simultaneously published in the USA and Canada
by Psychology Press
711 Third Avenue, New York, NY 10017, USA

Psychology Press is an imprint of the Taylor & Francis Group, an Informa business

First issued in paperback 2013

Typeset in Times by Garfield Morgan, Swansea, West Glamorgan
Cover design by Design Deluxe

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Interactions between short-term and long-term memory in the verbal domain / edited by Annabel Thorn and Mike Page,
p. cm.
ISBN 978-1-84169-639-3 (hardback)
1. Memory. 2. Short-term memory. 3. Long-term memory. 4. Verbal ability. 5. Verbal behavior. I. Thorn, Annabel, 1972- II. Page, Mike, 1966-
BF371.156 2008
153.1*3—dc22

2007048596

ISBN 978-1-84169-639-3 (hbk)
ISBN 978-0-415-64864-6 (paperback)

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Annabel S. C. Thorn and Mike P. A. Page

Introduction

Investigation of the association between memory systems dedicated to the retention of information over the short or long term has occupied the minds of psychologists for many years. The idea that human memory is not a single system that operates across all time frames, but rather comprises dissociable short- and long-term memory components, goes back to William James (1890). James distinguished between primary memory, which he viewed as our awareness of what has just happened, and secondary memory, proposed to be our knowledge of events that have left our consciousness and are therefore part of the "psychological past". More than fifty years later the notion of dissociable short- and long-term memory systems was supported by Hebb (1949), who suggested that the distinction between primary and secondary memory has a neurophysiological basis; the former, he proposed, reflects temporarily reverberating electrical activity in the brain, whereas the latter results from permanent synaptic changes.

The distinction between short- and long-term memory systems was captured in the highly influential "modal model" of memory proposed by Atkinson and Shiffrin (1968). According to this model, incoming information is first processed by parallel sensory buffers and then enters a limited capacity short-term store. To enter long-term memory, Atkinson and Shiffrin proposed that information must be "copied" from the short-term store, with transfer occurring via rehearsal processes. The proposal that information can only gain access to long-term memory via short-term storage has been one of the most widely debated features of this model. For example, a number of reports document neuropsychological patients with grossly impaired short-term memory span who show generally unimpaired long-term learning (Basso et al., 1982; Shallice & Warrington, 1970), a cognitive profile that is not consistent with the assumption that all information must pass through short-term memory in order to be stored in long-term memory. Having said that, such patients do show a specific deficit in their ability to learn long-term representations of sequences (e.g., novel word-forms), suggesting that a modified view may be viable, in which the representation of a *sequence* in short-term memory is a necessary precursor of the storage of that sequence in long-term memory.

Notwithstanding the problems with the modal model account, consideration of the extent to which short- and long-term memory systems are interrelated continues to drive memory research today. Understanding of the detailed mechanisms and processes underpinning the operation of short-term memory has considerably advanced since the modal model was first proposed, with the publication of a number of successful models, both conceptual and computational, that have proved capable of accounting for a wide range of experimental data. At the conceptual level, much work has been driven by the working memory (WM) model of Baddeley and Hitch (1974), and its influence has been seen in computational models of immediate serial recall, such as those of Burgess and Hitch (1992, 1999), Henson (1998) and Page and Norris (1998). Other modellers, notably Neath and Brown (2006), have constructed models that depart from the WM framework and that challenge some of its core assumptions, while alternative conceptual frameworks have been proposed by Jones and colleagues, among others (Jones, Macken, & Nicholls, 2004).

A key issue in the discussion that surrounds these alternative conceptions, is the relationship between short-term and long-term memory. Our aim in bringing this book together was to document where researchers are currently positioned, both empirically and theoretically, with respect to their understanding of the interrelationship between the two. Because understanding of verbal memory systems is relatively better advanced, the focus of this volume is on memory in the verbal domain. The chapters contributed to the book have been written by leading researchers in the field, and represent research perspectives and techniques from both sides of the Atlantic. These chapters draw on cognitive, developmental and neuropsychological research and reflect both conceptual and computational approaches to theorising. Each chapter makes an important contribution in its own right towards a fuller understanding of the interrelationship between short- and long-term memory in the verbal domain. As a collection, the chapters also raise a number of important questions that will undoubtedly inform and direct future research endeavours in this field.

Current perspectives

The book opens with two chapters from research groups for whom the notion of separable short- and long-term memory systems remains questionable. The chapter by Surprenant and Neath (Chapter 2) is a robust denial of the distinction between short- and long-term memory. The authors draw attention to problems with the evidence-base upon which the distinction has traditionally been built, discussing what they see as the nine "lives" of short-term memory. Surprenant and Neath present a powerful argument on a number of grounds. It would be disingenuous to pretend that we, as Editors, are neutral in this matter and we remain of the belief that the notion of a short-term verbal store, dedicated to the storage of ordered information, can be spared most, if not all, of the lives they claim it has lost. Life 1, for example, concerns the extent to which the proposed rapid rate of decay of information in short-term memory (which contrasts with long-lasting retention in long-term memory) is really demonstrated by the Brown–Peterson paradigm, yet the filled retention intervals associated with this paradigm are typically much longer than the assumed duration of the short-term store. Surprenant and Neath give only the briefest consideration to Baddeley and Scott's (1971) finding of a sharp drop in performance over the first five seconds of a single-trial Brown–Peterson style experiment, a finding that we believe merits further discussion, particularly given that Baddeley and Scott used only a single trial, thus ruling out an effect of proactive interference. Life 2 questions the dual-store logic with respect to the representational form of information in short- and long-term memory but the phonological-store hypothesis (and many of the computational models based on it) asserts that it is the order of list items that is stored in the short term, not, for example, their status as words, their meaning, etc. Long-term memory is undoubtedly consulted during presentation of a novel word-list (at the very least to recognise the words), but there can be no prior long-term memory representation of the word-order that can be so consulted. Life 3 concerns capacity estimates, proposed to be limited in short-term memory and unlimited in long-term memory. The argument here is again not as strong as it might be, first, because the task in which Nairne and Neath (2001) demonstrated comparable "capacity limits" in long-term memory did not require serial recall of memory items, and second because many recent computational, process models (as opposed to abstract, mathematical models like that of Schweickert, Guentert, & Hersberger, 1990) can simulate differences, for words and nonwords, in the function that relates span to speech rate, without abandoning the notion of a short-term store for serial order. Lives 4 and 5 are about free recall, and therefore are outside the (necessary) application of the phonological loop that is specialised for immediate serial recall (though see below, with reference to Ward et al., Chapter 3). Life 6 discusses the time-based word-length effect as evidence for time-based decay but here we would note that failures to replicate Baddeley, Thomson, and Buchanan's (1975) original word-length effect finding have rarely measured the *times* at which words were recalled, which seems likely to be relevant to a test of *time-based* decay. Life 7, regarding the extent to which the phonological similarity effect can be seen as a manifestation of proactive interference, provides some defence of the unitary view, but does not contradict the separate stores' view: there are several successful computational models of the phonological similarity effect that correspond to the type of short-term memory that Surprenant and Neath argue against. Life 8 concerns the merits or otherwise of decay, particularly in relation to a two-stimulus comparison task used by Cowan, Saults, and Nugent (2001). However, since this task is not one that demands memory for serial order, the results are not immediately relevant to the discussion of a component of short-term memory dedicated to maintenance of order information. Likewise, the discussion in regard to Life 9, the extent to which neuropsychological dissociations provide evidence for a separable short-term memory system, covers many interesting topics, including patients' performance on tasks other than those that require serial recall, but does not discuss a key finding in relation to the so-called short-term memory patients, that is, their almost complete inability to perform immediate serial recall, in the presence of almost completely preserved long-term memory.

By giving these very brief counter-arguments to some of Surprenant and Neath's points, it is far from our intention to attempt to close the issue down. Rather, in the absence of a chapter here dedicated to a response to Surprenant and Neath's analysis, we did not want to leave the general reader with the impression that the matter is decided either one way or the other. Undoubtedly though, on the issue of whether or not human memory comprises a separable short-term memory system, Surprenant and Neath's contribution constitutes perhaps the most powerful case for the prosecution yet committed to print.

Ward et al. raise similar issues in their chapter (Chapter 3). They examine the distinction between a short-term store (STS) and a long-term store (LTS). The distinction is suggested by classic results using the free recall and serial recall tasks, and they describe the results of experiments designed to examine its continued viability. With regard to free recall, and on the basis of several of their own recent experiments, they argue forcefully that both primacy and recency effects can be accounted for by a single recency-based mechanism. Their approach, in which participants' rehearsals are made explicit by requiring them to be overt, has also revealed ways in which other factors, like presentation frequency and list length, can be seen to operate via effects on rehearsal schedules, and thence item recency. The authors do acknowledge, though, that the apparent selectively disruptive effect of a short, filled retention interval on the recency effect remains somewhat difficult to explain under their pure recency account.

In a similar vein, they question the evidence for a mechanism involved in the immediate serial recall (ISR) task that is distinct from that employed in free recall. Their arguments are made with respect to a strict interpretation of Baddeley and Hitch's (1974) position. Baddeley and Hitch's original data suggested that the size of the recency effect in free recall was unaffected by a serial-recall load. Ward and colleagues describe more rigorous and, it turns out, successful attempts to replicate and extend this result, but express some unease about the seemingly clean division, between mechanisms underlying such ostensibly similar tasks, that the results imply. Proponents of the working memory model (like ourselves) might be less uneasy. The phonological loop component of working memory has always been characterised as a system specialised for keeping speech-based material in the correct serial order in the short term. From this perspective, it would not be considered a *necessary* component underlying performance in the free recall task. That is not to say, however, that it might not be used in some forms of the free recall task, such as the free recall of shortish lists without a retention interval. Any mechanism capable of serial recall of a list of a given length is also *sufficient* for free recall of that list. For example, if asked to free recall the list *2,8,4*, it would not be surprising if an experimental participant replied "2, 8, 4", thus maintaining serial order above and beyond the requirements of the task. In experiments with lists that are short by the standards of free recall experiments (eight words), Bhatarah, Ward, and Tan (2008) did indeed find that participants were flexible in the resources that they could bring to bear on the task. Whether this means that a short-term serial ordering mechanism is used *whenever* free recall is required, even for lists of twenty or thirty words or, over the long term, in memory for parking spots or last season's rugby fixtures, is less clear.

Their results have led Ward and colleagues to a preferred position in which STS and LTS, as manifested in ISR and free recall tasks, are considered to be aspects of a unitary "episodic" store that is sensitive to recency. This position will not be that adopted by all their readers, but their experimental work continues to challenge "classical" views of the relationship between short- and long-term memory. In their future work they identify the key issue of forward report-order in a recency-based episodic system. It is easy to forget that many of the classic models of short-term serial recall are themselves recency-based, because stored material is sensitive to either delay or interference. In models such as that of Burgess and Hitch (1999) or Page and Norris (1998), though, the recency is that of the forward-going representation of the list itself, rather than just that of the items within it. It will be interesting to see whether and how that notion is incorporated within a unitary episodic store.

For the remaining chapters in the book, the notion of separable systems for the retention of information over the short or long term is less controversial. These chapters look in detail at various facets of the ways in which short- and long-term memory are interrelated. Allen and Baddeley (Chapter 4) discuss data that bear on the recently proposed "episodic buffer" component of the working memory model, the function of which is to bind information from the short-term storage subsystems and from long-term memory into integrated representations or episodes. Allen and Baddeley explore the role of the episodic buffer in relation to experiments on recall of meaningful sentences. They propose, with reference to the results of two experiments, that within-sentence binding proceeds relatively automatically, that is, in the absence of significant executive resources. They are careful to make a distinction between the sort of binding that is a function of long-term memory (such as might be manifest in the recall of the sentence "To be or not to be"), and that which reflects the more temporary association of lexical items (as in their example, "Noisy flashes emit careful floods"). In relation to the work of Gupta, and Page and Norris (both this volume), we might want to make the distinction even clearer by referring to the former as chunking (cf. Miller, 1956) and the latter as genuine binding. We will return to this point below.

An important message of Allen and Baddeley's chapter is that binding is not simply coactivation in long-term memory. In the classic statement of the "binding problem", namely the correct association of shape with colour when presented with a red triangle and a green square, it is importantly the case that all the long-term lexical concepts "red", "green", "triangle" and "square" are activated at the same time. It is the ability to associate these concepts together temporarily and flexibly that is crucial to a discussion of binding. It seems from Allen and Baddeley's work that the process of building a bound representation from a sentence, or series of related sentences, is less resource demanding than might have been supposed. As the authors note, these data, together with those of Jefferies, Lambon Ralph, and Baddeley (2004), suggest some modification of the way in which the episodic buffer is presumed to interact with the phonological loop component of the WM model. Specifically, there appears to be some relatively automatic generation, in the buffer, of a thematically bound representation of sentence material, driven by the arrival of (in this case) verbal material over time, though not necessarily via its storage as a sequence (cf. Caplan & Waters, 1999). In this respect, the buffer truly lives up to its "episodic" tag, inasmuch as its contents comprise a relationally bound configuration, as opposed to simply an array of activated items.

Cowan and Chen's chapter (Chapter 5), although at first sight located in the same theoretical territory as Allen and Baddeley's, is, on closer inspection, more specifically concerned with chunking. Cowan and Chen begin by exploring the possibility that immediate memory performance results from the combining of information from two sources, namely from the immediate focus of attention and from an activated portion of long-term memory. Important to their conception is the idea that long-term memory can encompass a system that is capable of rapid learning of new associations. In this regard, their long-term memory is more redolent of an episodic memory system than, say, a semantic system, given that rapid (indeed, single-trial) learning is a defining characteristic of the former. Cowan and Chen suggest that chunk formation can proceed quickly enough to be of use in tasks such as free recall of supra-span lists of words or, in the case of the experiments they describe, lists of previously associated word-pairs; they also propose a role for a more traditional-style phonological short-term memory specialised in the retention of order information across list items, at least for lists short enough for such a mechanism to be effective. Importantly, the chunking to which Cowan and Chen refer seems likely to involve distinct mechanisms from those involved in the binding which Allen and Baddeley describe. The data described by Cowan and Chen show that