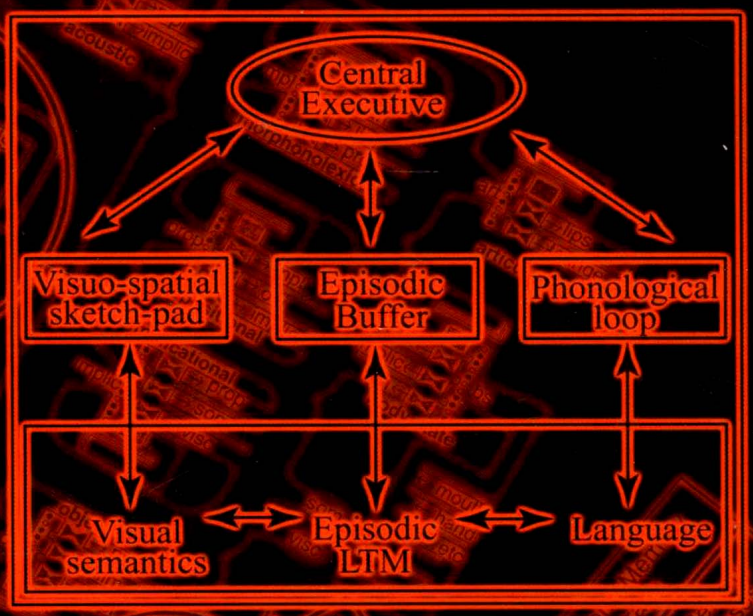
# Working Memory in Perspective

Edited by Jackie Andrade

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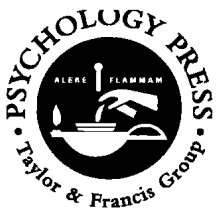

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**To my family**

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# Preface

The model of working memory proposed by Alan Baddeley and Graham Hitch in 1974 is one of the longest lived and most widely used models in cognitive psychology. This book was inspired by my suspicion that many of the researchers who used the model did so despite unease about its imperfections. It seeks to evaluate the working memory model more critically and comprehensively than is possible in journal papers. Achieving this aim involved a huge amount of hard work and commitment from the contributors. The process began with each contributor submitting a draft chapter which evaluated the strengths and weaknesses of the working memory model, compared it with competing models in their field, and commented on their vision of the future of the model. Each contributor reviewed the chapters of several other contributors. We then met for three days to discuss our chapters and try to reach a consensus in our evaluation of the working memory model. This meeting was funded by the US Army, European Research Office under contract number N68171-99-M-6084. I am very grateful for their support, and particularly for the encouragement I received from Dr Michael Strub, then at the European Research Office. I would like to thank Victor Buchanan and his staff at The White Swan hotel, Pickering, North Yorkshire, for keeping us so comfortable and well fed that the long hours of heated discussion flew past.

After the Pickering meeting, contributors revised their chapters, often extensively, re-read other people's revisions, and commented on my Introduction and Conclusion chapters. I then asked them to revise their chapters again, to ensure consistency of style and coherence of arguments across the book as a whole. I am indebted to all the contributors for the exceptional effort they have devoted to this project. In particular, I would like to thank Jon May for helping with every aspect of the book, inside and outside of working hours, and John Towse for his unflagging efforts at perfecting my own chapters.

Three editors helped to bring this project to fruition. I am grateful to Vivien Ward for her enthusiasm and encouragement, and to Caroline Osborne, Kristin Susser and staff at Psychology Press for guidance during preparation of the manuscript.

JACKIE ANDRADE
*Sheffield, March 2001*

# Foreword

*Alan D. Baddeley and Graham J. Hitch*

Towards the end of our first joint grant, we received an invitation from Gordon Bower to write a piece in the forthcoming volume of *The Psychology of Learning and Motivation*. We were delighted, but also had misgivings; we had really not properly sorted out our model, but on the other hand it seemed too good an opportunity to miss, so we accepted. The present volume indicates that we were right on both counts, it was indeed a good opportunity, and if we had waited until everything was sorted out, we would still be waiting. We are therefore very pleased to welcome a book that indicates that the concept of working memory continues to present a stimulating challenge to colleagues at the same stage of career as we were when we first proposed our model. They indicate that the model continues to generate new findings, and to stimulate theoretical controversy, and hence that it continues to earn its living. We particularly like the attempt to link the various chapters by requiring the authors each to answer a series of questions. Indeed, we were sufficiently intrigued by this device to be encouraged to try to answer them ourselves. Below (briefly!) are our answers.

*What did we get right?*

We think we were right to propose a fractionation of the older concept of short-term memory, and to emphasise the functional significance of our proposed multi-component system. In doing so, we produced a model that had more obvious links with areas outside the traditional concern of memory. The range of topics and approaches within the present volume indicates that that has indeed been a useful feature of the model. Our division into separable phonological, visuo-spatial and executive components also seems to have been productive, in particular combined with the series of methods based on similarity effects and dual task methodology that make the approach readily applicable to new areas of investigation. The suggestion that these subsystems are themselves complex and fractionable has allowed the model to serve as a broad framework within which much more detailed and sophisticated investigation and modelling could proceed, again as illustrated by the chapters that follow.

*What did we get wrong?*

This can be divided into two sections: general limitations of the model, and specific studies that we wish we had done differently.

*General limitations:* The lack of specificity that is a strength in allowing new developments within a broad framework is of course also a limitation. Our model of the phonological loop for example did not even have a mechanism for explaining how serial order was retained. Nevertheless, the model provided a framework incorporating a rich array of empirical constraints that has led to considerable and successful activity in the modelling area, as reflected in the chapter by **Page and Henson** (chapter 8).

A particular problem with the model is the underspecification of the central executive. In the initial stages of development, the neglect of the executive was intentional since we suspected, correctly, that its investigation presented a particularly difficult problem. It is, however, essential that progress is made on tackling the central executive, and in recent years we have been making consistent attempts to tackle this area (Baddeley, 1996), resulting as mentioned below in the proposal for a fourth component of the model.

*Specific problems:* We now suspect that the relatively simple story of the role of subvocal rehearsal in the phonological loop is in fact over simple, and may also be atypical of rehearsal elsewhere within working memory. Attempts to find an equivalent rehearsal mechanism to subvocal articulation in the visuo-spatial sketchpad, for example, have proved fruitless, while it seems likely that, in young children at least, rehearsal probably involves a more basic and automatic process (Gathercole & Hitch, 1993). We also probably over-emphasised the importance of rehearsal during maintenance within the loop and neglected the equally important issue of forgetting during recall, as very clearly demonstrated by Cowan et al. (1992). It seems likely that the word-length effect, for example, operates through both rehearsal and output delay, a state of affairs that is implied by the initial model but not explicitly discussed.

A related issue is our assumption of trace decay within the phonological store, justified principally in terms of the study indicating that word duration rather than complexity is the principal determinant of forgetting (Baddeley, Thomson & Buchanan, 1975). However, as the chapter by **Lovatt and Avons** points out, although our findings are replicable using our set of words, they do not generalise to other sets of words. We had clearly committed the 'language-as-fixed-effect fallacy' (Clark, 1973) in not attempting to replicate and extend our findings using new sets of material. Even without this result, however, we might well have opted for a trace decay mechanism on the grounds of simplicity, and of the great difficulty,

then as now, of deciding between a whole range of potential mechanisms underpinning short-term forgetting (see Cowan, Nugent, Elliot & Gear, 2000) for a useful discussion of this point). Fortunately, the model is not greatly affected by changing from a simple decay to a rather general interference model, although we would not wish to opt for the specific stimulus-response associative interference theory (Melton, 1963) that was still active at the time we developed the model.

*Relationship to other models?*

Miyake and Shah (1999) recently published a book based on a workshop in which about 10 different theorists discussed the way in which their models of working memory would handle a series of standard questions. Despite what appeared to be enormous differences in theoretical style, the meeting ended with a remarkable degree of unanimity as to the broad characteristics of working memory, the issues we understood and those to be tackled. The most obvious distinction was between our own model, with much of the work focusing on the subsidiary systems, and the approach more characteristic of North America in which the emphasis is on executive processing, often based on studies employing individual difference measures. There was however a general acceptance of the need to assume both a general executive system and specific verbal and visual subsystems. Very recently, one of us (ADB) has proposed a new component, the episodic buffer, specifically to give an account of the interface between the slave systems, the central executive and long-term memory (Baddeley, 2000). The aim is to provide a theoretical mechanism for considering a whole range of important phenomena involving the role of chunking in complex cognition that were comparatively neglected by the existing framework. The buffer is assumed to have a limited capacity and to be responsible for optimising this capacity by integrating information from slave systems and long-term memory into coherent episodes. As such it is not dissimilar to Cowan's concept of short-term memory (Cowan, 1995, 2001). Cowan is, however, relatively non-committal about the number and nature of lower level or slave systems feeding into the store, an important aspect of our own model. He also regards short-term memory as simply reflecting activated portions of long-term memory. We prefer to regard working memory as a separate system albeit one that utilises much of the apparatus that evolved for perception and action. We make this assumption, not on any a priori grounds, but simply because the neuropsychological evidence appears to point to clearly separable systems (Jonides et al., 1996). In general, however, we believe, with Miyake and Shah, that various models of working memory are gradually becoming increasingly similar, although there will continue to be important differences resulting from the concern to emphasise different empirical problems, and to use different theoretical tools.

*Where next?*

In the case of one of us (ADB), having proposed a new component to working memory, the episodic buffer, I intend to attempt to develop techniques based on both normal subjects and neuropsychological patients that will allow the concept to be specified more precisely and manipulated systematically. This immediately raises the challenging question of whether it is possible to disrupt storage within the episodic buffer without simultaneously disrupting the two slave systems and/or the attention control processes of the central executive. In the case of the other (GJH), I intend to follow up a theoretical proposal arising from modelling the phonological loop, namely that an internal timing signal is responsible for encoding and retrieving serial order information (Burgess & Hitch, 1999). Such a proposal raises the general question of whether there is a single system for serial ordering or whether there are a number of different ordering systems, and suggests it will be interesting to study serial order in visuo-spatial working memory. Ideas about serial ordering also have implications for item learning and chunk formation in long-term memory, and it will be interesting to explore these too.

So much then for our own view of how the model has fared over the last 25 years. How it will fare in the future depends ultimately on our younger colleagues, so read on!

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