23

Encoding: A cognitive perspective

Fergus I. M. Craik

The group of scientists given the task of defining and analyzing the concept of encoding at the Palisades meeting agreed that encoding refers to 'the set of processes involved in transforming external events and internal thoughts into both temporary and long-lasting neural representations'. This pithy definition raises an immediate host of questions, however, including: How are the 'cognitive' processes we experience during encoding related to the 'physiological' processes that are presumed to occur after the person's attention has turned to other matters? Are different encoding operations required for the optimal encoding of procedures, facts and events into different memory systems? What roles do both *attention* and *intention* play in the encoding process? What other factors affect encoding in a lawful fashion? What is the relationship of encoding to the later retrieval of the same event? What can we learn about encoding, storage and retrieval processes from clinical cases of impaired memory? Finally, can we construct a viable science of memory that must presumably give plausible accounts of the facts at the levels of experience, cognitive models, dynamic neural processes, biochemistry, pharmacology, etc., *and* provide mapping rules that connect these very disparate levels of description?

To provide some organization and coherence to these many different questions, and as a starting point for answering some of them, I will first describe the levels of processing (LOP) framework proposed by Craik and Lockhart (1972) and elaborated in later articles by Craik and Tulving (1975) and Craik (1983, 2002*b*). One major assumption embodied in the LOP perspective is that memory is not a separate faculty in either cognitive or neurological terms, but rather is one aspect of the overall cognitive system whose structures and processes are also involved in attention, perception, comprehension and action. Lockhart and I also stressed the idea (following Bartlett 1932) that human memory is an *activity* of mind, i.e. both encoding and retrieval processes are represented as dynamic patterns of neural firing.

Clearly there must also be structural changes in the nervous system to enable retention of learned information, but the only phases of memory and learning that have cognitive correlates are encoding and retrieval, and these appear to be neurophysiological processes rather than neuroanatomical structures. Just as perceiving reflects the dynamic interaction of processes invoked by the stimulus and processes associated with innate and learned schemas, so retrieval processes reflect the interaction of a stimulus (which may be a retrieval cue, a memory query, an environmental event or a transient thought) with pre-existing representations to give rise to the experience of recollection. We further suggested that the primary concerns of the cognitive system are perception and comprehension (as humans we need these abilities crucially to navigate the environment successfully and to know which aspects to approach and which to avoid), and that these processes of perception and comprehension also serve as 'memory encoding processes'. That is, there are no separate cognitive processes that constitute encoding; memory representations are created automatically in the course of perceiving and understanding the world around us.

The main line of evidence for this assertion comes from studies in which memory performance is assessed following either incidental or intentional learning. The experiments reported by Craik and Tulving (1975) in conjunction with those cited by Craik and Lockhart (1972) make it clear that memory performance, both qualitatively and quantitatively, reflects the processing operations that were carried out when the item or event was initially studied. In general, 'deeper' semantic processing is associated with higher levels of subsequent memory than is the relatively 'shallow' processing associated with sensory, structural or phonological processing. The effects are dramatically large. When single words were tested following positive answers to initial questions about case ('is the word in lower case?'), rhyme (e.g. 'does the word rhyme with BRAIN?') or meaning (e.g. 'does the word fit the sentence: The girl placed the—on the table?'), the probabilities of later recognition were 0.15, 0.48 and 0.81, respectively (Craik and Tulving 1975, Exp. 2). When the experiment was repeated under intentional learning conditions, so that participants knew there would be a later memory test, the corresponding recognition scores were 0.23, 0.59 and 0.81 (Craik and Tulving 1975, Exp. 9). It is worth stressing that the *same words* occurred in the three different conditions, counterbalanced over subjects: all that changed was the qualitative nature of the initial encoding, which increased memory by a factor of five from structural to semantic processing. The LOP effect can be obtained reliably in a single subject, and it has therefore proved useful in neuroimaging experiments on memory encoding (Kapur *et al.* 1994). One main conclusion from the Craik and Tulving studies was that intentionality is not necessary for good memory and learning; performance is a function of the type of encoding operation carried out initially, regardless of the original motivation for that processing. Of course, intention to learn material will typically boost performance, because the participant will carry out further processes such as rehearsal, organization, associative learning, and so on, but the point remains that later performance reflects the operations carried out during initial encoding, for whatever reason. Thus *intention* plays no special role in encoding, but *attention* is of the essence. It is not simply a question of 'paying attention', however; it is also necessary to specify both the amount of attentional resources devoted to processing an event and the qualitative nature of the processing operations involved.

Many experiments on human memory are carried out using verbal materials, and in this case deep processing implies retrieving the semantic/conceptual aspects of words, sentences or stories. However, deep processing can be carried out on any type of material; the general principle is that the new information is related conceptually to relevant pre-existing schematic knowledge. Thus familiar odors, pictures, melodies and actions are all well remembered if related to existing bases of meaning at the time of encoding. On the other hand, stimuli that lack an appropriate schematic knowledge base (e.g. words in an unknown foreign language, locations in a strange city, faces from a different racial group, snowflake patterns) are extremely difficult to remember.

Why exactly do deeper levels of processing result in higher levels of remembering? Our assumption is that schematic knowledge representations are highly organized and differentiated (like a well-ordered library), so that incoming events processed in terms of such knowledge bases will result in a processed record that is *distinctive* relative to many other encoded representations. At the time of remembering, the framework provided by schematic knowledge also facilitates efficient retrieval. A library analogy may again be helpful; if a new acquisition is 'encoded deeply' it will be shelved precisely in terms of its topic, author, date, etc., and the structure of the library catalog will later enable precise location of the book. If the new book was simply categorized in terms of its surface features ('blue cover, 8″ × 10″, weighs about a pound'), it would be stored with many similar items and be difficult or impossible to retrieve later. The ability to process deeply is thus a function of a person's *expertise* in some domain—it could be mathematics, French poetry, rock music, wine tasting, tennis or a multitude of other types of knowledge. Perceived information in the relevant domain will be analyzed and categorized precisely using existing schemas, and the new information added to these schemas. Distinctiveness is a function of the richness of analysis of the resulting analyzed differences between the present event and other similar stored events. An expert wine taster may identify a wine as being from a specific region of Burgundy and encode it as such, whereas another person may simply register 'a red wine with a slightly musty taste'. Successful retrieval of the event at some later time will again make use of available schemas and would thus enable correct recognition of the wine by the expert but not by the novice.

The LOP framework thus postulates no special 'store' or 'faculty' of memory—or even special memory processes. Encoding processes are simply those processing operations carried out primarily for the purposes of perceiving, understanding and acting; retrieval processes ('remembering') represent an attempt on the cognitive system's part to re-enact encoding processes as completely as possible. However, what happens in between the dynamic activities of encoding and retrieval? Presumably there must be some mechanism, some structural change, enabling the cognitive system to recapitulate (to some extent) the pattern of activity that occurred during initial encoding? My suggestion here (Craik 2002*a*) is that schematic knowledge representations are organized hierarchically, with specific instances (episodic events) represented at the branch terminals, and increasingly general, abstract, context-free knowledge represented as higher order nodes (see Fig. 23.1).

In the scheme shown in Fig. 23.1, there is no clearcut distinction between episodic and semantic memory—they are not different systems, but more simply levels of specificity in complex representations of knowledge. The scheme also renders unnecessary any suggestion that different types of encoding might be necessary to encode events into different memory stores or systems. By the present view, there *are* no different stores or systems, only different processing operations, representing sensory, phonological, visuospatial,

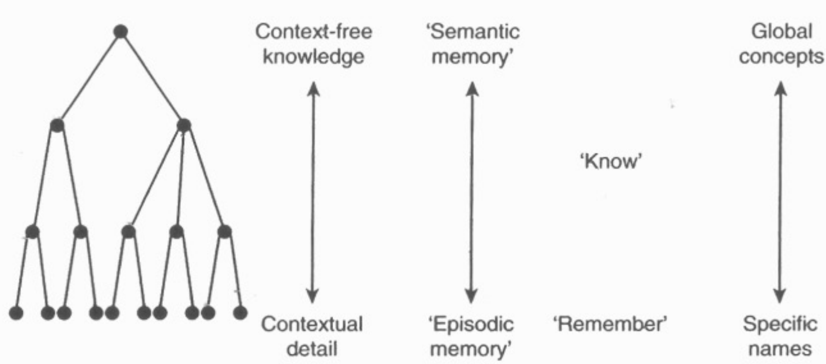

Fig. 23.1 A schematic model of knowledge representations. The suggested hierarchical organization with specific episodic records in lower nodes and general abstract knowledge occupying higher nodes. 'Remember' and 'Know' judgments reflect access to lower and higher nodes respectively.

conceptual or other types of information, which act to modify relevant existing representational schemes, in part by adding episodic records to appropriate representations. From this perspective, fleeting 'sensory memories' are not rapidly decaying traces but the ongoing processing of sensory information. Encoding 'into long-term memory' involves modification of representational systems, detectable later as recollection of the learning episode, as modifications of relevant knowledge or as more fluent processing of some perceptual–motor sequence observed in one of several 'implicit memory' tasks. Encoding for short-term or working memory involves ongoing processing activities as with sensory memories, but in this case the processing operations draw on more stable learned routines such as strings of articulation or visuospatial images (the articulatory loop and visuospatial sketchpad proposed by Baddeley and Hitch 1974). It also seems necessary to assume that processing in working memory involves long-term knowledge representations and makes use of their structure in order to deal with information as organized 'chunks' rather than as individual elements. This assumption of long-term memory involvement in working memory also explains the large increase in memory span for words if the words are presented as a meaningful sentence rather than as a random string. The ongoing processing activities that constitute working memory may draw on several different representational systems, resulting in a richly elaborated multidimensional experience. This appears to be the situation captured by Baddeley's (2000) recent suggestion of an 'episodic buffer'.

Encoding processes can be modified by a large number of factors. Some of these (such as expectations, set, goals and context) will bias processing towards relevant or salient aspects of the attended event. Other factors will reduce the amount of available attentional resources—dual-task situations, increased rate of presentation, fatigue, sleep deprivation, aging, intoxication and benzodiazepines are among the possibilities here. In these latter cases, the reduction in processing resources will result in encoding operations that are shallower, less elaborated and less effective in forging associative and organizational connections (see Fig. 23.2). In turn, these less efficient encoding operations are associated with lower levels of subsequent recollection.

This account of encoding processes has been couched in purely cognitive terms, but it has clear implications for corresponding neural activities. First, memory-encoding processes should be indistinguishable from the neural activities associated with attending, perceiving and comprehending. Secondly, the correlates of retrieval processes should overlap those occurring during encoding, in part at least. Thirdly, some neural activations may be specific to either encoding or retrieval; the HERA (hemispheric encoding/retrieval asymmetry) model proposed by Tulving and colleagues (1994) is one case in point.

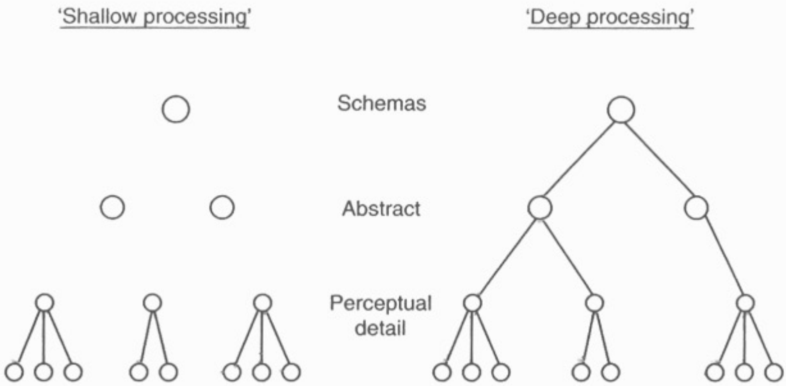

Fig. 23.2 A schematic model of knowledge representations. Deep semantic processing appears to entail integration of episodic records with pre-existing knowledge, whereas shallow processing lacks such integration.

Such process-specific activations may reflect control processes rather than the qualitative content of memories, however. Alternatively, the marked activation of the left inferior prefrontal gyrus observed during deep processing of verbal material (Kapur *et al.* 1994) may be associated with the retrieval of meaning from long-term conceptual representations ('semantic memory'). It is relevant to note that this left frontal activation occurs more strongly in verb generation (hear 'paper', say 'write') than in noun repetition (hear 'paper', say 'paper') in a purely word-processing context where memory encoding is not mentioned (Raichle *et al.* 1994). Yet when Tulving and colleagues (1994) followed these word-processing tasks with an unexpected recognition task 5 days later, recognition levels for noun repetition and verb generation were 0.26 and 0.50, respectively, again illustrating that intention to learn is unnecessary for effective encoding. It is also noteworthy that the left prefrontal activation associated with deep semantic processing is greatly attenuated when attention is divided during encoding (Shallice *et al.* 1994) and also in older adults (Grady *et al.* 1995); both cases are associated with a reduction in processing resources and with reduced levels of memory.

Finally, it is clear that a full account of memory encoding must include a host of neurophysiological processes that occur *after* cognitive processing has ceased. These neural activities constitute the processes of consolidation, discussed in the accompanying chapters by Hasselmo and Davachi. Consolidation has no apparent cognitive correlates, but various manipulations following cognitive encoding have been shown to affect subsequent recollection (Frankland and Bontempi 2005). Perhaps the most dramatic evidence for such post-perceptual effects comes from cases of amnesia following hippocampal damage. Such amnesic patients can perceive and comprehend normally, yet have little or no subsequent recollection (see Tulving 2001, for discussion). The relationships between the cognitive and neurobiological aspects of encoding thus provide a rich set of related research questions. What are the neural correlates of encoding at the cognitive level? What neurobiological mechanisms constitute the processes of consolidation, and do they have any cognitive or experiential counterparts? Finally, how do cognitive manipulations affect the nature and effectiveness of consolidation processes, and can such manipulations continue to influence consolidation *after* the event has been perceived, comprehended and dropped from conscious awareness?

Science of Memory: Concepts

Edited by

Henry L. Roediger III
James S. McDonnell Distinguished University Professor
at Washington University in St. Louis

Yadin Dudai
Sela Professor of Neurobiology at the Weizmann Institute
of Science, Rehovot, Israel

and

Susan M. Fitzpatrick
Vice President of the James S. McDonnell Foundation

OXFORD
UNIVERSITY PRESS

OXFORD
UNIVERSITY PRESS

Oxford University Press, Inc., publishes works that further
Oxford University's objective of excellence
in research, scholarship, and education.

Oxford New York

Auckland Cape Town Dar es Salaam Hong Kong Karachi
Kuala Lumpur Madrid Melbourne Mexico City Nairobi
New Delhi Shanghai Taipei Toronto

With offices in

Argentina Austria Brazil Chile Czech Republic France Greece
Guatemala Hungary Italy Japan Poland Portugal Singapore
South Korea Switzerland Thailand Turkey Ukraine Vietnam

Published by Oxford University Press, Inc.
198 Madison Avenue, New York, New York 10016
www.oup.com

Library of Congress Cataloging-in-Publication Data

Science of memory: concepts / [edited by] Henry L. Roediger III, Yadin Dudai, and Susan M. Fitzpatrick.

p. cm. -- (Science of memory)

Includes bibliographical references and index.

ISBN-13: 978-0-19-531044-3 (pbk.)

1. Memory. I. Roediger, Henry L. II. Dudai, Yadin. III. Fitzpatrick, Susan M., 1956-
BF371.S45 2007
153.1'2--dc22
2006029621

Typeset in Minion by
Cepha Imaging Private Ltd., Bangalore, India

Printed in Great Britain
on acid-free paper by Ashford Colour Press Ltd., Gosport, Hampshire

10 9 8 7 6 5 4 3 2 1