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Levels of processing: Past, present . . . and future?

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In this article I first briefly survey some enduring legacies of the Craik and Lockhart (1972) article on levels of processing (LOP) and address some common criticisms. In the next section I discuss whether memory can be regarded as "pure processing", the role of short-term memory in an LOP framework, measurement of "depth" in LOP, encoding–retrieval interactions, the concept of consolidation, and the reality of "levels" of processing. In the final section I offer some speculations on future directions, discussing the notion of levels of representation and a possible continuing role for LOP in memory research.

To start with some personal history, I spent a stimulating and productive year (1968–69) in the Psychology Department at the University of Toronto, imbibing the wisdom dispensed by Ben Murdock and Endel Tulving, and interacting with a lively group of graduate students and post-docs. The focus of my research was short-term memory, and this broadened out during the year to a consideration of encoding and retrieval processes in long-term or secondary memory. When I returned to Birkbeck College in London, I was intrigued and influenced by the work on selective attention being carried out by Donald Broadbent, Anne Treisman, and Neville Moray. In particular, Treisman's (1964) theory of selective attention combined aspects of previous knowledge with perception and attention; it was an exciting possibility that memory encoding and retrieval processes could also be brought into the mix, in the spirit of Neisser's (1967) call for an integrated theory of cognitive functions.

Treisman (1964, 1979) proposed that perceptual processing could be envisaged as a hierarchy of "levels of analysis" running from early sensory analyses to later analyses concerned with object properties and identification of words, pictures, and objects. In this scheme, identification and meaning may be regarded as occurring later (and thus in some sense "deeper") in the sequence of analyses than the analysis of sensory and surface features. From contemporary work on dichotic listening it also seemed that such deeper analysis of meaning required more attention than did the analysis of sensory features. Subjects were able to identify a speaker's voice as male or female on the unattended channel, but were unable to understand the meaning of the utterance. It also seemed reasonable to assume that analysis of a particular feature corresponded to conscious awareness of that feature.

In order to account for the phenomena of selective attention, Treisman also proposed that incoming information is subjected to a series of "tests" at each level of analysis, and only those dimensions of the incoming signal passing each test proceed to the next level of analysis. The tests are thought of as signal-detection problems, with signal strength a function of such data-driven variables as loudness and brightness, and criterion placement a function of such top-down variables as meaningfulness, contextual relevance, and recent experience. Early sensory analyses are carried out on virtually all incoming signals, but later analyses are progressively more

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selective so that we are consciously aware of the physical features of unattended signals (e.g., a woman's voice) but generally unaware of their meaning. It seemed possible that the strength and longevity of the memory of the signal, as well as its qualitative nature, depended on its depth of processing in this hierarchy of analyses. One striking observation in favour of this speculation was Treisman's (1964) experiment in which identical speech messages were played to the two ears in a dichotic listening paradigm, but with the messages staggered in time. The question was: How close in time must the messages be brought for the listener to realise that they are the same? The answer depended on whether the attended ear message preceded or followed the unattended ear. In the first case subjects recognised the identity at an interval of 5 seconds, but in the second case the messages had to be as close as $1\frac{1}{2}$ seconds in time before subjects realised they were the same. That is, identification of the sounds as particular words roughly tripled their survival time in memory.

I returned to Toronto in 1971 with plans to test the idea that memory is a function of the degree to which a stimulus is analysed; more specifically that "deeper" semantic analysis is associated with higher levels of retention and longer-lasting traces. I was delighted to find that my friend Bob Lockhart had been thinking along very similar lines, so we decided to join forces to write a theoretical article invited by Endel Tulving, who was the editor of the *Journal of Verbal Learning and Verbal Behavior* at that time. Tulving alternately praised, criticized, encouraged, and berated us, effortlessly combining the roles of the 'guard with the club' and the 'guard with the cigarette' in one person, until we finished the piece in the summer of 1972. The Craik and Lockhart article appeared in the December 1972 issue of *JVLVB*. Actually, it is very pleasant to put on record our gratitude to Endel Tulving who made many constructive suggestions, and whose skilful editing improved the final version immensely.

As I see it now, one of the main contributions of the levels-of-processing (LOP) article was to reinforce the idea of *remembering* as processing, as an activity of mind, as opposed to structural ideas of memory traces as entities that must be searched for, "found", and reactivated. In particular, we suggested that memory-encoding operations should be conceptualised as the *processes* underlying perception and comprehension, and that retrieval was the corollary of encoding. In the same vein, we argued against the notion of structural memory stores, although not against the distinction between primary and secondary memory in some form (see later). We also suggested of course that remembering reflected the qualitative types of analysis that had been performed during initial encoding processes of perception and comprehension, and that deeper processing was associated with higher levels of subsequent remembering.

These rather general ideas were backed up by the results of a series of experiments reported by Craik and Tulving (1975). Words were presented, preceded by orienting questions (e.g., "Does the word rhyme with train?", "Is the word a type of flower?") that were intended to control the depth to which the word was processed. Later unexpected memory tests showed that the level of recollection varied substantially (e.g., between 0.14 and 0.96; Craik & Tulving, 1975, Exp. 1) simply as a function of the type of question asked. At first I took the idea of "levels" rather literally, thinking that the processing was actually halted at different levels of perceptual–conceptual analysis; for that reason each word was exposed tachistoscopically for 200 ms and participants were not informed of the later memory test. Endel was sceptical of this line of thinking, however, and carried out a version of the experiment in which participants were told that there would be a later memory test, and each word was exposed for 1 second followed by a 5-second interword interval. Despite these radical changes the results were essentially the same as before; recognition varied between 0.23 and 0.81. I have a flashbulb memory of Endel phoning me from his bridge club one evening with these findings!

One unexpected result was that words that were congruent with their orienting question (e.g., "Rhymes with Spain?" TRAIN; "A type of flower?" DAISY) were better encoded and recognised than words that were not congruent (e.g., "Rhymes with Spain?" TIGER; "A type of flower?" CHAIR). Our suggestion was that congruent question–word combinations yielded an encoding that was richer and more elaborate, and that this enriched encoding in turn supported higher levels of recollection. Why should greater trace elaboration support good retention? Two possibilities are, first that a richly elaborate trace will be more differentiated from other episodic records—this greater *distinctiveness* in turn will support more effective recollection in an analogous way to distinctive objects being more discriminable in the visual field. A second (complementary) possibility is that elaborate traces are more integrated with organised knowledge structures which, in turn, serve as effective frameworks for reconstructive retrieval processes (Moscovitch & Craik, 1976). A number of theorists have emphasised the importance of differentiation or trace distinctiveness in memory (Hunt & Einstein, 1981; Klein & Saltz, 1976; Murdock, 1960; Nairne, 2002; Nelson, 1979; Stein, 1978) and I share their view. But I do not believe that the concept of distinctiveness eliminates the need for the concepts of depth and elaboration of processing. From my perspective, depth refers to the qualitative type of processing carried out on the stimulus, and elaboration refers to the degree to which each type of processing has been enriched during encoding. These two aspects of processing, along with the congruity of the stimulus to its context of presentation, combine to yield an encoded record of the event that is more or less distinctive from other encoded records. That is, depth, elaboration, and congruity describe aspects of the encoding process, whereas distinctiveness describes the eventual product of these processes (Craik, 1977).

In the Craik and Lockhart paper we made no attempt to provide an account of retrieval processes. Morris Moscovitch and I conducted some experiments a few years later to fill this gap, and demonstrated the importance of a unique linkage between the retrieval cue and the memory trace. The initial encoding operations determined the *potential* for later retrieval, and factors such as similarity of cue and trace information, and the specificity of the cue–trace linkage determined the degree to which that potential was realised (Moscovitch & Craik, 1976). In later papers (e.g., Craik, 1983) I stressed the notion that retrieval processes were similar to encoding processes (see also Kolers, 1973, 1979), essentially serving to recapitulate the original experience as closely as possible.

ISSUES: PAST AND PRESENT

In this section I will touch on some issues that have been the subject of comment and criticism over the past 30 years. Fuller comments and some answers to our critics are provided elsewhere (Craik, 1979; Lockhart & Craik, 1990).

Memory as "pure processing"

Is it reasonable to characterise remembering as involving only processes or activities of mind? Surely there must be some record of the initial event that is compared with present processing to yield a match that underlies the experience of remembering? My view is that certainly something must change in the brain as a result of the initial experience, and this change must persist until remembering occurs. But the change in question is not simply a snapshot of the original event; it may rather be a modification of the cognitive system so that when the event recurs, the consequent processing operations are interpreted both in terms of the current event and in terms of the brain changes caused by its original occurrence. Just as perceptual learning changes the perceptual system so that subsequent stimulus patterns are processed and experienced differently, so memory encoding changes the cognitive system in such a way as to change the interpretation of a repeated event. Just as the neural correlate of perceiving is the pattern of cortical activity that occurs while we are perceiving, so the correlate of remembering is the pattern of neural activity that accompanies the experience of remembering. By this view, cognitive neuroscientists should be attempting to map patterns of neural activity to recollective experience rather than be searching for "engrams" defined as stored records of experienced events.

The STM/LTM distinction

The Craik and Lockhart article is often regarded as the paper that attacked the distinction between short-term memory (STM) and long-term memory (LTM), but this is an overstatement. We criticised the notion of memory stores, including the concept of a separate capacity-limited STM in which incoming information was held before being "transferred" to LTM (Atkinson & Shiffrin, 1968, 1971). But we retained the STM/LTM distinction, recasting the concept of STM as a temporary activation of processes representing perceptual and conceptual aspects of incoming (or recently retrieved) stimuli. So in a sense STM was thought of as a temporary activation of parts of LTM (see also Cowan, 1999; Engle, Kane, & Tuholski, 1999; Shiffrin, 1975), but the short-term activity presumably also involves perceptual aspects of the input. Lockhart and I preferred the

Jamesian term "primary memory" (PM) to capture this account of STM phenomena.

By this view, PM is not a store in any sense, and is not located in one fixed place in either the cognitive system or the brain. Rather, PM involves activation of representations that correlate with present experience—the contents of consciousness—and thus PM activity can be located in many different brain locations depending on the type of information "held in mind". An alternative description is that "maintaining an item in PM" is equivalent to "continuing to pay attention to the item" (Cowan, 1988; Craik, 1971). This account of STM solves the riddle of how one memory store could hold a variety of different types of information—visual, auditory, articulatory, semantic—although other solutions have also been proposed (Baddeley & Hitch, 1974). Many experiments are conducted using verbal materials, and perhaps the greatest use of STM in real life is to hear and rehearse names, numbers, and other verbal materials. In such cases the contents of mind will reflect activations of cortical areas concerned with phonological and articulatory processing, and lesions of such areas will produce patients with "STM deficits" (e.g., Warrington & Shallice, 1969). Such clinical findings fit perfectly well with the present account of PM/STM; my only comment is that additional cortical areas may also be involved in short-term retention and rehearsal—if we maintain an image in mind, for example, think of a face, or rehearse a melody. As one final speculation, some phenomena of short-term retention may reflect recent activation of LTM structures rather than necessarily reflecting current "in mind" activations. Thus names, directions, and solutions to problems may be particularly accessible if we have recently thought of them. It seems possible that Baddeley's recent description (2000) of an "episodic buffer" may reflect this type of "primed" LTM activation, although Baddeley himself considers and rejects this view.

The elusive index of depth

One major criticism of the LOP framework is the absence of an objective index of depth of processing. Lacking such an index, it is all too easy to claim that any well-remembered event must therefore have been deeply processed (Baddeley, 1978). The concept of depth of processing is not hard to grasp—"deeper" refers to the analysis of meaning, inference, and implication, in contrast to "shallow" analyses such as surface form, colour, loudness, and brightness. It also turns out that experimental participants agree well about the relative depth of encoding operations, and these ratings predict later memory performance (Seamon & Virostek, 1978). Nevertheless it would be much more satisfactory to have an objective index, preferably one with a decent scale of measurement.

Our first attempt was to measure the time it took to decide whether a word was or was not congruent with the orienting question (e.g., "Rhymes with Spain?" TRAIN "yes"; TIGER "no"). In the second experiment reported by Craik and Tulving (1975), yes and no decisions took about the same time as each other at each level of analysis (case, rhyme, and sentence processing), yet words associated with positive rhyme and sentence decisions were better recognised than words associated with negative decisions. It seemed therefore that processing time by itself was insufficient. When decision times were plotted against later recognition levels a strikingly regular pattern emerged (Figure 1). The finding that yes and no initial decision times lie on different functions relating decision time to later recognition may mean that both depth (the qualitative type of information processed) and elaboration (the degree to which this type of information is enriched) must be considered before memory can be predicted. That is, for congruous ("yes") decisions, the extra time needed for deeper processing operations buys better recognition performance. Unfortunately this

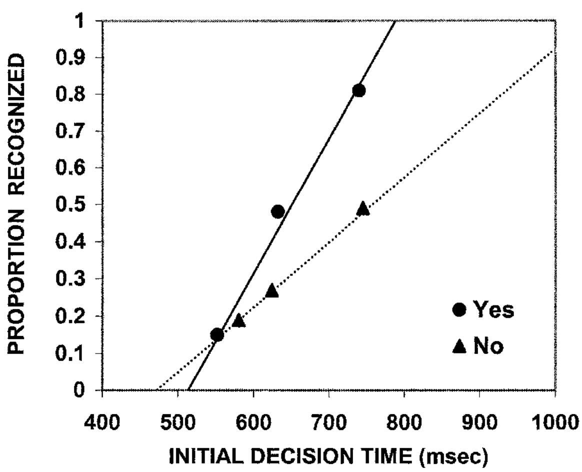

Figure 1. Proportions of words recognised as a function of initial decision time and compatibility with the encoding question (Craik & Tulving, 1975, p. 275).

account suggests the necessity for *two* different indices of processing—depth and elaboration.

A further problem for time as an index is that access time is also a function of practice and expertise. Highly familiar, well-practised stimuli (e.g., pictures) are identified and interpreted very rapidly, yet are also very well recognised in a subsequent test (Paivio, 1971). The same is likely true of specific domains of individual expertise; an expert can rapidly form a highly meaningful and elaborate encoding of a stimulus in his or her field of expertise, yet again this rapidly processed information will be well remembered (Bransford, Franks, Morris, & Stein, 1979). Clearly time cannot serve as an absolute index of depth across different types of material, although it seems possible that for a given individual and a given type of material, deeper processing will take longer to accomplish. Thus, processing time may serve as in index of depth if defined *relatively* with respect to a specific set of circumstances. The same arguments apply to the amount of attention ("processing resources") required to carry out a processing task. That is, deeper analyses generally require more attention (Craik & Byrd, 1982; Treisman, 1964) and diversion of attention to a secondary task results in shallower encoding of events processed in the primary task (Naveh-Benjamin, Craik, Gavrilescu, & Anderson, 2000), but again these relationships will be modulated by the meaningfulness of stimuli and the expertise of the person doing the processing.

Any valid index of depth must therefore measure the meaningfulness and elaboration of the final encoded representation, and not simply the ease or difficulty of achieving that representation. Unfortunately there does not appear to be a relevant psycholinguistic theory of meaning that we can buy into, so at the psychological level we are stuck for the moment with such unsatisfactory methods as agreement among judges. There are some other possibilities at the physiological and neurological levels, however. Evoked potentials signal the type of processing that is being carried out (Sanquist, Rohrbaugh, Syndulko, & Lindsley, 1980) and it seems possible that recent developments in ERP analysis can provide information both about the brain regions involved in various types of encoding processes and about the time course of the spread of activation between regions (Mangels, Picton, & Craik, 2001). Other promising leads include work on eye movements discussed in the articles by Velichkovsky (2002) and Reingold (2002), and the finding that heart-rate variability is reduced when deeply encoded words are retrieved (Vincent, Craik, & Furedy, 1996). Finally, the functional neuroimaging data provided by PET, fMRI, and MEG may help to solve the problem, although again ways must be found to distinguish differences in access time and effort on the one hand from differences in the meaningfulness and elaboration of the encoded representation on the other (see Treisman, 1979, for a useful discussion).

Encoding-retrieval interactions

As mentioned earlier, the Craik and Lockhart (1972) article dealt with problems of encoding rather than retrieval, although later publications discussed retrieval in an LOP framework (Craik, 1983; Lockhart & Craik, 1990; Moscovitch & Craik, 1976). The major idea in this area is the notion of encoding specificity (Tulving & Thomson, 1973) or transfer-appropriate processing (TAP) (Morris, Bransford, & Franks, 1977; Roediger, Weldon, & Challis, 1989). To me, the concepts of LOP and TAP have always seemed complementary rather than antagonistic; initial processing determines the qualitative nature of the encoded trace, deeper encodings are associated with a greater potential for retrieval, and this potential is realised by the provision of a retrieval environment (which may include a specific retrieval cue), compatible qualitatively with the trace information. The influential paper by Morris et al. (1977) made a stronger claim, however. They demonstrated that rhyme-related encoding was superior to semantic encoding when the retrieval test was one of rhyme recognition, and concluded that "deep" semantic processing was therefore not necessarily the most beneficial for later memory. It all depends on the retrieval test, they argued, and semantic encoding is typically very effective simply because the usual retrieval processes of recall and recognition also involve semantic processing. It is an ingenious argument and a compelling case! On the other hand, the Morris et al. data showed that the combination of semantic encoding and semantic retrieval yielded a substantially higher level of recognition than the rhyme–rhyme combination (0.68 vs 0.40 averaged over Experiments 1 and 2). My conclusion is therefore that any final theory must involve some account of encoding processes and the representations they create, as well as some factor capturing the relations between encoding and retrieval. That is, deeper encoding processes result in encoded traces that are *potentially* very memorable, provided that an appropriate cue is available at the time of retrieval. The article by Lockhart (2002) provides further useful discussion of this point.

Is consolidation necessary?

In the Craik and Lockhart (1972) paper, we suggested that the encoded version of an event—the memory trace—was simply the record of those processing operations that had been carried out essentially for the purposes of perception and comprehension. That is, there were no special memory encoding operations as such, and the memory trace could therefore be regarded as an automatic byproduct of initial processing. The evidence for these statements came from the results of studies in which encoding was "incidental" in the sense that participants were unaware of the subsequent memory test. Using orienting tasks that induced the participants to process words in a deep semantic fashion, it was easy to demonstrate that incidental encoding can yield levels of memory performance that are at least as good as those obtained after intentional learning (Challis, Velichkovsky, & Craik, 1996; Craik, 1977). Efficient rehearsal techniques and good intentional learning were assumed to represent self-initiated processes that consciously involved elaborate semantic processing.

From this perspective, impaired memory performance was seen as reflecting impoverished encoding operations, in the case of normal ageing, for example (Craik, 1983; Craik & Simon, 1980). My party line was that various conditions and situations were associated with a reduction in processing resources, and that this in turn resulted in a failure to carry out deep elaborate processing. As well as ageing, I argued that this pattern described divided attention (Craik, 1983; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996) and perhaps also fatigue and sleep deprivation. One condition that is clearly *not* well described by this account is that of organic amnesia (Cermak, 1979). Amnesic patients perceive and understand communications and other events perfectly well, but do not remember them. It therefore seemed necessary to concede that some further step is necessary—beyond perception and comprehension—for events to be encoded in a way that would support retrieval minutes, days, and years later. At first I was reluctant to acknowledge the necessity of this extra step ("consolidation"?) in conditions such as normal ageing and divided attention (Craik, 1983), but more recently I have bowed to the superior wisdom of colleagues (e.g., Tulving, 2001) and agreed that "deep processing is necessary but not sufficient for later episodic memory" (Craik, 1999, p. 102). Two pieces of evidence have pushed me in this direction; the first is some experiments from my lab that showed a decrement in memory following division of attention during encoding even when depth and elaboration were apparently equated between full and divided attention (Craik & Kester, 1999). Division of attention may well attenuate deeper levels of processing, but it also appears to affect some later processes in such a way that limits or even eliminates the formation of a permanent record. The second piece of evidence is more subjective and personal. In my middle sixties I do not feel that my intellectual processes are *too* depleted (although how could I tell if they were?!), but my memory abilities are certainly poorer than they were. Speculatively, normal ageing appears to attenuate the consolidation of cognitive operations, so that the relations between depth of processing and later memory are modulated by the effects of ageing.

The animal and neuropsychological literatures are replete with experiments and theories of consolidation which I will not comment on here, apart from saying that consolidation does not appear to have any experiential or "psychological" correlates. That is, it appears to comprise a set of neurological processes that run off outside awareness and outwith cognitive control. The processes are obviously no less interesting and important for that difference from other memory processes, but the absence of cognitive correlates (if that proves to be the case) provides an interesting challenge to studying the effects of ageing, division of attention, and other variables on the factors governing the effectiveness of consolidation.

The reality of "levels"

In the Craik and Lockhart (1972) article our notion of "levels" followed rather directly from Anne Treisman's (1964, 1979) work on selective attention. Some forms of representation, namely those concerned with meaning and implication, seemed to require more attention than those reflecting sensory and surface aspects of objects and events. We also assumed that perception proceeded from early analysis of sensory features to later analysis of conceptual features, and that changes associated with these later, deeper analyses formed the basis for good subsequent memory. This set of ideas suggested a fixed set of stages of analysis, with the output from one stage acting as the input for the next. However, in later papers, we acknowledged that a fixed progression from shallow to deep was unlikely, and that a more plausible scenario was one in which processing unfolded in an interactive manner involving both stimulus-driven bottom-up processing and conceptually driven top-down processing (Craik & Tulving, 1975). Nonetheless, performance still reflected the final depth and elaboration achieved.

The term ''levels of processing'' does suggest a continuum of processing, however, despite the fact that the qualitative nature of the processing operations clearly changes from early sensory analyses to later conceptual analyses. Deeper processing is not simply an extension or prolongation of shallow processing. For these reasons, Lockhart, Craik, and Jacoby (1976) suggested the notion of ''domains of processing'' to capture the idea that visual word processing, for example, proceeds through stages of visual and print analysis before undergoing analyses at articulatory, phonological, lexical, and conceptual stages. But are these qualitatively different types of analysis at least always carried out in the same sequence? Even this would seem doubtful. Beginning readers sound out letters, from which they assemble words and finally the meaning of a sentence; but fluent readers appear to bypass the phonological stage, and processing now moves directly from print to meaning (Coltheart, 1985). Similarly, Velichkovsky (2002) acknowledges that the sequence of events in his six-stage version of Bernstein's (1947) model of skilled action may not always run from 1 to 6. The order of processing, and the interactions between levels, will depend on the task at hand. Thus Velichkovsky concludes that he is describing a *heterarchy* of processing (Turvey, Shaw, & Mace, 1978) rather than a true hierarchy, although he also argues that there is a natural progression (reflecting both evolutionary and developmental trends) from stages concerned with muscle tone and sensory integration to stages concerned with the purposes and implications of actions.

In her excellent review of hierarchical models in cognition, Cohen (2000) distinguishes truly hierarchical models in which one level controls processing operations in the level below, from forms in which ''there is simply a transfer of information from one stage to another'' (Cohen, 2000, p.2). In this view she follows Broadbent's (1977) analysis of control processes in action and decision making in which control necessarily reflects top-down processing. However, during encoding, data-driven bottom-up processes also determine the nature of the representation at the next stage—visual analysis of a printed word determines which lexical representation is activated, for example, and this activation in turn determines the concept that is brought to mind. The processing modules at various levels of analysis are necessarily sequential in nature, although the specific sequence may be altered from time to time depending on the task, the subject's purposes, and his or her level of practice. Processing in this sequence of levels can also operate in a top-down fashion, reflecting expectations, context, and set, and also reflecting the likelihood that partial analysis at a higher (or deeper) level can affect attention and thus further processing at lower levels. Treisman's (1964, 1969) model of selective attention incorporates both sets of influences. In summary, it seems to me that the ''levels of processing'' discussed by Craik and Lockhart *do* constitute a somewhat flexible hierarchy of processing, and are not simply a set of independent modules. It is also true, however, that the present levels of encoding are not the same as the levels of control described by Broadbent (1977) and Cohen (2000).

As a final question, what about levels *within* qualitatively coherent domains of processing? Experiments by Craik and Tulving (1975) and by Johnson-Laird, Gibbs, and de Mowbray (1978) showed that recollection improves as further meaningful processing is performed at the time of encoding. In similar demonstrations Bransford and his colleagues showed convincingly that greater degrees of semantic elaboration, greater precision and specificity of encoding, and a better fit with subjects' expertise all led to improved memory performance (Bransford et al., 1979). All of these demonstrations seem better described as greater degrees of elaboration and enrichment of the encoded representation than as ''levels'' in any sense. It is worth remembering, however, that to be effective for later memory, further processing must enrich the representation ''meaningfully'' in the broadest sense. Further processing at shallow levels of analysis does not lead to better memory

(Craik & Watkins, 1973). Similarly, "distinctiveness" by itself is not sufficient. Goldstein and Chance (1971) showed subjects snowflake patterns; later recognition performance was poor despite the fact that each pattern was "unique". Performance was poor because the subjects lacked the rich semantic knowledge to classify and differentiate the stimuli in a meaningful way. Presumably a specialist in crystallography with an interest in snowflake formation *could* differentiate and categorise the stimuli, and would perform well on a later memory test. In line with Bransford's analysis, I would therefore say that good memory performance depends on the person possessing expert knowledge of the stimuli in question, and processing the stimuli in a differentiated meaningful way in relation to this knowledge. Finally, the processing necessary to achieve this detailed semantic representation typically involves a set of hierarchically ordered levels of analysis.

FUTURE DIRECTIONS

The Craik and Lockhart article was written 30 years ago, so it would be curious indeed if many researchers (including Craik and Lockhart!) still held exactly the same views expressed at the time, or regarded the article as a blueprint for future research plans in 2002. Nevertheless, there may be some ideas and points of view that are still valid and that can be used to guide future endeavours. Some of the ideas we proposed or endorsed are very much alive in current cognitive psychology. The close interactions among attention, perception, and memory have been stressed by some theorists (e.g., Cowan, 1988). The notion that primary memory or working memory reflects the temporary activation of relatively permanent long-term memory structures is also endorsed by some current theorists (e.g., Cowan, 1999; Engle et al., 1999) as it was by Craik and Lockhart (1972) and Shiffrin (1975) among others. The proposition that good explicit memory performance is related to deep semantic processing is undeniable, although hardly original with the LOP framework (see, for example, Bartlett, 1932; James, 1890; and Smirnov, 1973). Smirnov's book, published in Russian in 1966, is quite explicit in linking comprehension and understanding to good levels of retention. Craik and Lockhart's (1972) identification of remembering as processing (as opposed to thinking of memory as a structure) was emphasised strongly by Kolers (1973; Kolers & Roediger, 1984), and is discussed persuasively by Rosenfield (1988). Finally, the central notion of "levels" as a hierarchy of processing activities still seems viable in some form, bearing in mind the qualifications raised in the preceding section. A somewhat different type of hierarchy is discussed next.

Levels of representation: General to specific

Older adults typically experience two main types of difficulty with their memory; the first is memory for names, and the second is memory for details of occurrences. The difficulty with names sometimes generalises to infrequently used words and to names of objects, but is most evident in names of people. The second difficulty shows itself in forgetting where a possession was left, in the source of newly acquired information, and in "telling the same tale (at least!) twice" (Koriat, Ben-Zur, & Sheffer, 1988). Do these difficulties reflect some common failure? The second set are clearly problems of episodic memory—the individual forgets details of specific past episodes. But forgetting names, often of people we have known for many years, is a failure of retrieval from semantic memory in memory systems terms (Tulving & Schacter, 1990). Despite their different origins, the commonality may arise because both types of information are quite *specific*, and refer either to unique persons in the case of names, or unique events in the case of forgetting source or context.

Knowledge may be represented as a hierarchy of levels of representation, in which higher levels represent greater degrees of generality and abstraction, and the lowest levels represent labels for specific people or objects, or represent specific details of an experienced event (Cohen, 2000; Conway, 1992). In a recent chapter (Craik, 2002) I suggested that older adults may experience difficulty in accessing and retrieving information from these lowest levels, almost as if they lacked the necessary "resolving power" to discriminate such specific details, although higher levels of generality *are* still easily accessed and retrieved. The suggestion is supported by similar reports from researchers studying retrieval failures in depression (Williams, 1996) and in semantic dementia (Hodges, 2000) as well as in normal ageing (Burke, MacKay, Worthley, & Wade, 1991; Holland & Rabbitt, 1990; Levine, Svoboda, Moscovitch, & Hay, in press). A useful review of hierarchical models in cognition with supporting evidence is provided by Cohen (2000).

My version of the concept is illustrated in Figure 2. With regard to autobiographical memory, the idea is that commonalities among individual instances are represented as higher-order nodes, so that there is essentially a continuum between the "episodic memory" of specific occasions and the "semantic memory" of knowledge abstracted from such specific experiences. The distinction between "remember" and "know" judgements (e.g., Gardiner & Richardson-Klavehn, 2000) may be conceptualised as reflecting access to different levels of this hierarchy. Why should it be more difficult to access lower levels? One possibility is that representations at higher levels are more interconnected and networked, thereby providing more access routes for retrieval processes; another is that the general knowledge represented by higher levels is used to interpret new events or plan new actions, and is therefore accessed more frequently than is specific event information represented by lower levels.

Future research from this perspective could profitably explore the degree to which the relative difficulty of retrieving specific types of information (both "episodic" and "semantic") holds across a wide variety of conditions associated with memory impairment. Does the generality hold for all types of organically based memory deficits for example (e.g., traumatic brain injury, lesions in frontal, temporal, and subcortical regions), and does it hold for more "functionally based" decrements such as those associated with divided attention, fatigue, and sleep deprivation? A second set of questions concerns the neurological reality of these various hypothesised hierarchies of representation. Are different levels of representation detectable and discriminable by neuroimaging techniques for instance? One intriguing question in this regard is whether higher levels of abstraction are represented as such (as suggested in Figure 2) or are computed online from representations of individual instances, which are the only forms of experience actually represented neurologically (Logan, 1988). Optimistically, if neuroimaging methods permit a distinction between the retrieval of individual episodes and semantic abstractions (as preliminary work suggests they can) are the regions associated with episodes also involved in the activation of relevant abstractions from these episodes? It seems that they should be from the perspective of instance theory. Finally is it possible to improve access to specific representations? If successful retrieval of episodes is associated with higher levels of arousal (Williams, 1996) and adequate availability of processing resources (Craik & Byrd, 1982) is it possible to boost retrieval success by temporarily and selectively boosting attention and arousal? And given the involvement of the prefrontal cortex in retrieval processes (Tulving, Kapur, Craik, Moscovitch, &

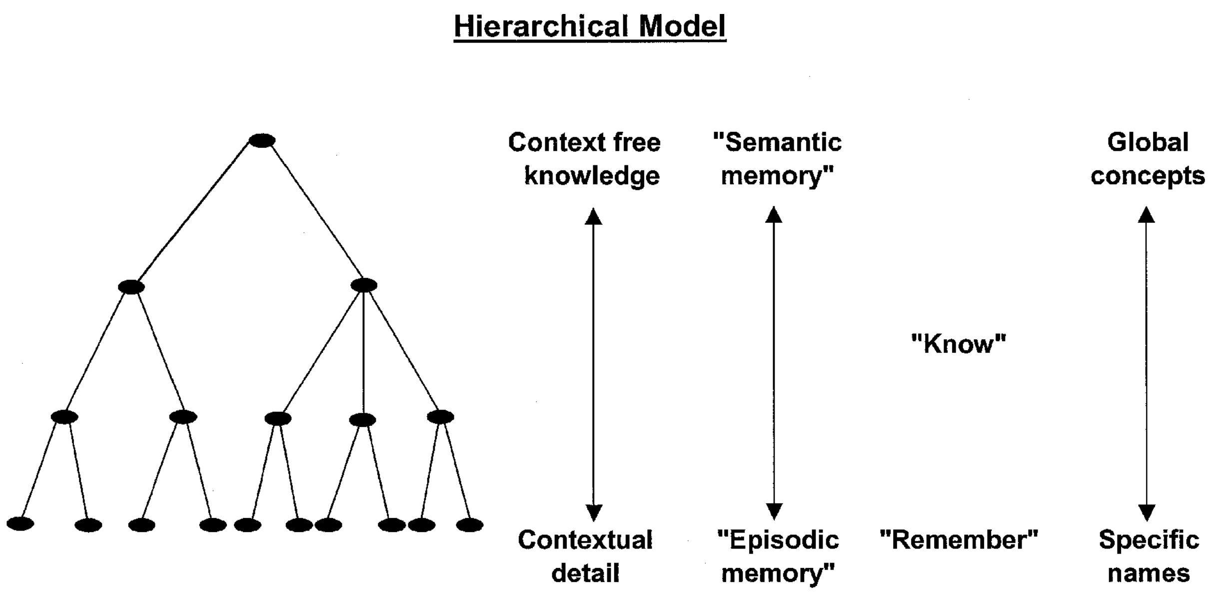

Figure 2. A hierarchical view of cognitive representations.

Houle, 1994; Wheeler, Stuss, & Tulving, 1997) and in ‘‘resolving power’’ (Fuster, 2002), is it possible to increase the efficiency of frontal functioning and thereby enhance the ability to retrieve specific types of information?

How does the notion of levels of representation fit with the original LOP ideas? Craik and Lockhart’s (1972) position suggested that good memory performance reflected *deeper* processing in the sense of more abstract semantic analysis, so what are the conditions for excellent encoding and recollection of specific detailed information in this framework? The answer may be that deep semantic analysis is necessary to provide a rich, organised schematic framework within which specific ‘‘surface’’ details are given meaning and significance. So it is not really the case that specific details are “processed deeply”, but rather that deep processing provides the schematic context within which episodic details are related to each other and to more abstract representations of significance and purpose.

Levels of processing revisited

Although it now seems highly unlikely that ongoing cognitive activity proceeds in a fixed series of stages, we nevertheless must still understand the sequence of events that transpire between reception of a stimulus and the experience of perceiving, and between the activation of the memory trace (whatever that turns out to mean) and the experience of remembering. Central to this understanding are the concepts of regulation and control—how are incoming stimuli and activated memory traces guided towards interpretation, decision, and action? The linked notions of working memory and central executive (e.g., Baddeley, 2000) are invoked by many theorists at present, but what is the nature of this reclusive autocrat (lurking in the capacious folds of the prefrontal cortex perhaps?) who controls our destinies?

Bressler and Kelso (2001) suggest that control is not exerted top-down by some neural homunculus, but should be thought of, rather, as an emergent property of interacting subsystems (see also Barnard, 1985; Teasdale & Barnard, 1993). Bressler and Kelso further propose that coordination, interpretation, and control are also mediated by the context provided by the next level up in a hierarchy of processing levels. That is, components at one level combine to represent higher-order units, but the interpretation and significance of the higher unit will depend on the prevailing context at that higher level; that context, in turn, is often imposed by top-down influences from pre-existing stable networks representing schematic knowledge. They propose, for example, that ‘‘coordination in any complex system is an emergent property of groups of components’’ and that coordinates at lower levels are set in the context of adjustments of the overall system: ‘‘In walking, for example, not only the muscles of the legs, but also muscle groups throughout the entire body, must be coordinated” (Bressler & Kelso, 2001, p.30).

In the case of lexical processing, local cortical areas may represent specific features which then combine in a way that satisfies mutual constraints, with ‘‘comprehension’’ represented by a coordinated cortical network ‘‘in which each system provides constraints that jointly determine lexical meaning by causing convergence to a single interpretation’’ (Bressler & Kelso, 2001, p.34). Thus local cortical networks come to represent lower-order features though learning, and these combine in an interactive way in response to a specific input to form a higher-order coordinated network. Other networks at this higher level (some activated by the current input and some representing previous learning at that higher level) then combine interactively in turn to form dynamic representations at the new level. Speculatively, this process continues until interpretation is represented by a very widespread pattern of activation throughout many cortical areas. It seems to me that this set of suggestions is quite compatible with Treisman’s (1964, 1969) account of attention and perceptual processing, although Bressler and Kelso are understandably more specific about possible underlying mechanisms.

Another interesting parallel is with current theories of genetics (see Keller, 2000, for an excellent overview). According to Keller, the idea of a linear fixed series of stages from gene to protein to structure and function has been abandoned in favour of a hierarchy of stages in which ‘‘control’’ is again a function of interactions among local representations and computations. The regulatory circuitry governing gene expression is dynamic rather than static, and this set of dynamic processes itself changes over the course of development. She writes, ‘‘I argue that an understanding of its dynamics needs to be sought at least as much in the interactions of its many components as in the structure or behavior of the components themselves” (Keller, 2000, p.100).

In the case of gene expression, one major top-down influence is provided by the external environment, thereby providing a mechanism for adaptation. In the case of memory retrieval, we may perhaps think of the neural changes corresponding to the memory trace as being analogous to the gene and that ''memory expression'' will therefore again depend on interactions at local levels forming higher-order dynamic networks whose interpretation is modulated by top-down influences including that of the external environment. That is, the current environmental context (including ''retrieval cues'') will shape the neurocognitive contexts at various levels in a top-down manner, thereby helping to construct the interpretation of the dynamic set of activities corresponding to retrieval of the encoded trace. To the extent that the current environment corresponds to the environment that existed during encoding, retrieval processes will yield the same conscious percept experienced on the initial occasion. Obviously this account describes the pattern of results known variously as encoding specificity, transfer-appropriate processing, or repetition of operations.

FINAL QUESTIONS AND CONCLUSIONS

One major change in my own viewpoint since 1972 concerns the necessity for consolidation as an encoding step *beyond* the ''psychological'' levels of perception and comprehension. Further research should explore such issues as whether consolidation *does* after all have psychological correlates or is cognitively silent, and whether the same variables that enhance memory performance at the cognitive level also affect consolidation. That is, are there variables that affect consolidation differently *after* given levels of depth and elaboration have been achieved, or do consolidation processes simply accept and consolidate the representations encoded at the cognitive level (Moscovitch, 1992)? In the latter case, do such variables as depth and elaboration affect the rate or effectiveness of consolidation?

With respect to encoding processes, the concept of depth clearly requires much greater specification. Experimental subjects agree on the relative depth of orienting tasks, and these tasks do result in levels of memory performance that reflect subjectively judged depth (Seamon & Virostek, 1978), but a more objective, and *measurable*, index is required. The notion of relative *distinctiveness* of encodings (Nairne, 2002) may provide a way forward. With respect to retrieval processes, models of the type proposed by Bressler and Kelso (2001) may provide some guidelines for new research; can retrieval be usefully conceptualised as a set of interactions (taking place at different levels of representation) between bottom-up processes stemming from the retrieval environment, modulated by expectations, context, and prior knowledge?

A final set of questions concerns the relations between encoding and retrieval processes. One attractive notion is that retrieval essentially recapitulates encoding (Kolers, 1973, 1979) so that the same percept or thought is experienced on the two occasions, and this equivalence is reflected in the activation of the same processing operations. Two problems with this view are, first, at the neurological level, substantially *different* areas of the prefrontal cortex are activated at encoding and retrieval (Tulving et al., 1994); second, at the psychological level, if retrieval processes are simply a repetition of encoding processes, what is it about retrieval processing that yields the experience of *remembering* as opposed to perceiving or thinking? A tentative answer to the second question is that retrieval processing activates representations that go beyond the current context and evoke details of the previous event, via pattern completion mechanisms. If we are set to remember (in ''retrieval mode'', Tulving, 1983) we focus on and amplify these aspects, as opposed to the operations that represent the current environment. With regard to the neurological problem, it is possible that the different prefrontal areas activated during encoding and retrieval respectively are activated by *control* processes (such as effort after meaning and comprehension during encoding, and efforts to recollect during retrieval) rather than by representational processes as such. The activations associated with the representations themselves may be located in more posterior areas of the cortex (Kapur et al., 1995). The challenge now (as in 1972) is to refine and specify such concepts as depth, elaboration, and distinctiveness.

In conclusion, I am suggesting that the idea of ''levels of processing'' still provides a useful framework in which to develop specific models of memory and cognition. Perhaps the most enduring legacy of the Craik and Lockhart (1972) paper is the greater emphasis on memory as processing in current theories. The similarity (at least) between encoding processes and the processes involved in the normal course of perceiving, attending, and thinking, is still valid today. We know more about the component processes of perception than we did 30 years ago, but I have seen no evidence against the propositions that the memory trace reflects those processes carried out primarily for the purposes of perception and comprehension, and that more meaningful processing is usually associated with higher levels of recollection. My optimistic hope is that findings and ideas from cognitive neuroscience may combine with findings and ideas from experimental cognitive psychology over the course of the *next* 30 years to provide us with a deeper understanding of what memory is, and how it works.

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