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CHAPTER

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Commentary: Dividing Attention to Study the Resource Demands of Memory Processes

How can we determine the processing demands of different component processes involved in remembering? This is a huge question, but certainly one that is critical to address in developing a full understanding of memory. It has long been one of the central questions motivating the research of Fergus Craik, so it is fitting that the three preceding chapters by his frequent collaborators take on one central aspect of this question: How do resource demands, in the form of attentional requirements, influence encoding versus retrieval? The answer offered in all three chapters is that resource demands ordinarily are considerably greater at encoding than at retrieval, but that the picture is not simple and that the exceptions are particularly informative.

The conclusion that retrieval is less resource demanding than encoding derives largely from research contrasting full attention, where there is no secondary task to distract from the primary memory task, to divided attention, where a secondary task must be performed in conjunction with the primary memory task. Thus, the resource in question seems closely related to attention. The research technique is referred to as the divided attention paradigm, an instance of a broader category of situations–dual task or secondary task methodologies (see Pashler, 1994a, 1994b)–where participants must cope with two tasks. Because these procedures require the coordination of two tasks, this research is necessarily quite complex, as indeed is the underlying concept of resources. With this complexity, however, comes a richness that has the potential to provide us with insight into the demands made by different memory tasks in a way that other standard cognitive procedures cannot readily do.

In this brief commentary, I will consider what has been learned from divided attention studies of memory, a domain of research in which Fergus Craik and his collaborators continue to be leaders. The domain has a long association with the University of Toronto, both through Craik himself (Anderson & Craik, 1974) and through his colleagues (e.g., Murdock, 1965). For much of the recent past, Craik and his colleagues have used the divided attention procedure to explore the encoding–retrieval contrast as part of Craik's ongoing program of memory research, which emphasizes encoding–retrieval interactions. Craik has long been interested in encoding processes (Craik & Lockhart, 1972) and in

retrieval processes (see Gardiner, Craik, & Birtwistle, 1972) from the standpoint of basic processes. And uniquely, because of his "parallel career" as a leader in the study of cognitive aging, Craik has used the aging work to inform his basic work and vice versa. Thus, his notion of environmental support in the cognitive aging literature (Craik, 1986) also highlights encoding–retrieval interactions, emphasizing the degree to which different remembering situations provide different types of cues to assist in remembering.

In these three chapters, emphasis shifts from encoding (Naveh-Benjamin, chapter 15), to the relation between encoding and retrieval (Anderson, chapter 16), to retrieval (Moscovitch, Fernandes, & Troyer, chapter 14), providing nice coverage of the whole sequence involved in remembering. Emphasis also shifts from behavioral data (Naveh-Benjamin), to models and brain imaging (Anderson), to neuropsychological evidence and theory (Moscovitch, Fernandes, & Troyer), providing a broad perspective on the domains in which these ideas have been considered. There is a wealth of information here, and I certainly cannot do it justice in these comments. But let us consider some of what is known and some of what needs to be addressed, working our way from encoding to retrieval.

Divided Attention at Encoding

In centering his attention on encoding, Naveh-Benjamin carefully evaluates a number of possible bases for the cost to encoding of a secondary task, from the methodological to the theoretical. An intuitively appealing basis is that dividing attention at encoding reduces the time available for encoding, but he argues that this can account for only part of the cost of dividing attention, based on his collaborative work with Craik (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Naveh-Benjamin, Craik, Gavrilescu, & Anderson, 2000; Naveh-Benjamin, Craik, Perretta, & Tonev, 2000).

Accepting that the problem at encoding is not solely insufficient time, Naveh-Benjamin considers other more qualitative reasons, working through the most likely suspects. Intriguingly, he is forced by the existing data to discard all of them. He initially considers that divided attention may reduce effortful, strategic processing that results in well-elaborated encoding–an instance of which would be reflected in the work of another of Craik's longstanding University of Toronto colleagues, Norman Slamecka, on the "generation effect" (Slamecka & Graf, 1978). But Naveh-Benjamin concludes after an extended examination of the literature that divided attention "may affect types of processing other than strategic-effortful ones," basing this on careful attempts to equate strategy under full and divided attention and also to minimize strategy via incidental learning.

If the problem is not with strategic processing, then it makes sense to turn to automatic processing, which Naveh-Benjamin does next. Once again, however, he rejects this as the answer: "The results described here do not provide support for the claim that the effects of DA [divided attention] at encoding on memory performance are mediated by the interruption of automatic nonstrategic processes." He bases this on attempts to examine both initial perceptual registration of information and its consolidation, neither of which appears differentially influenced by the division of attention. This results in something of a conundrum, given that his analysis would appear to eliminate the entire continuum from strategic through automatic as underlying the divided attention cost in encoding.

Naveh-Benjamin considers, however, that the automatic–strategic distinction may not be valuable in this context and turns instead to a distinction that relies more on the nature of the material to be remembered. Could it be that dividing attention impairs associative encoding as opposed to item encoding? This distinction, long a central emphasis in the theorizing of Craik's colleague at the University of Toronto, Bennet Murdock (1982), also

provides a plausible way to explain why the disruption of encoding leads to poorer retention. The idea is that associative encoding leads to better memory than item encoding, so being forced to rely more on item encoding due to divided attention would reduce memory. But Naveh-Benjamin eventually rejects this possibility as well: "Such results are not consistent with the notion that an associative deficit is the locus of the DA effects [on memory performance at encoding]." In so doing, he emphasizes association within items (e.g., between two words of a pair); I wondered whether deficits in associations across all of the items thoughout the entire encoding experience would be a good place to look for costs due to divided attention.

In discarding all of these possible accounts, Naveh-Benjamin reaches the conclusion that "the results convey a complex picture with no one specific mechanism implicated as the sole mediator of these DA effects." He is, nevertheless, optimistic that we can still discover the causes(s) of the harm done to encoding by dividing attention. One factor that I would point to is rehearsal or elaboration. Once an item is encoded, given that a memory test is usually expected, subjects are likely to rehearse or in some way further elaborate the encoded item. The presence of the secondary task, and the requirement to respond to it even *subsequent* to encoding, may also disrupt later memory. Indeed, Posner and Boies (1971) demonstrated this 30 years ago using a secondary probe task to estimate demands of various processing components. They concluded that rehearsal and response production or decision were most taxing. Thus, it may be postencoding processes like rehearsal that are most attention demanding. Interestingly, this would parallel the conclusion that Moscovitch, Fernandes, and Troyer offer with regard to retrieval—that it is not the retrieval itself but the postretrieval processes that are most vulnerable to disruption by dividing attention. I will return to this important point.

☐ Divided Attention at Retrieval

Anderson does a very good job of defining the terms and the fundamental issues in the domain of divided attention and memory, considering task effects, material effects, and even subject effects (aging differences). Indeed, one virtue of her chapter is the bringing together of pointers to so many of the relevant issues, particularly notable in the three tables that roughly correspond to the beginnings of a meta-analysis, an endeavour well worth pursuing. She also adds discussion of new work on brain imaging to the standard behavioral data on the effects of divided attention on memory (Iidaka, Anderson, Kapur, Cabeza, & Craik, 2000; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994). In the context of Tulving's HERA model in which the left prefrontal cortex is associated more with encoding and the right prefrontal cortex more with retrieval, she describes the complex pattern of brain activity as a function of aging.

Picking up the encoding thread from Naveh-Benjamin, Anderson argues that "divided attention during encoding interferes with deep, semantic processing," an argument also put forth by Moscovitch, Fernandes, and Troyer. For me, there is a paradox in this conclusion, resting on the episodic-semantic distinction (Tulving, 1972). It would seem that deep semantic encoding would necessitate the retrieval of related information from semantic memory, otherwise it is hard to see how elaboration of the input could occur. Does this not suggest that retrieval from *semantic* memory is therefore affected by divided attention? Or is it the postretrieval *use* of this retrieved information that is disrupted? This distinction between, on the one hand, encoding or retrieval itself, and on the other hand, the processes surrounding (particularly following) encoding and retrieval is one that is certainly recognized in all three chapters. Indeed, Craik et al. (1996) raised this issue and

suggested that retrieval itself—what Tulving (1991) called *ecphory*—does not demand attention, but that maintenance of retrieval mode and other retrieval-related activities does require attention. Breaking down encoding and retrieval into their component parts is without question an important direction for this research to pursue, as all of these chapters readily acknowledge.

Anderson proposes a model along the lines of a Pashler (1994a, 1994b) bottleneck model in which retrieval and the response to the secondary task cannot occur in parallel. By "retrieval" here, she means something more akin to ecphory—just the accessing of memory, not the use of what is recovered from memory. It will be important in future to discriminate between these two uses of "retrieval." She makes the reasonable prediction that if ecphory and secondary task response cannot co-occur, then a continuous secondary task might reveal this, whereas a discrete-response secondary task might not. This is an interesting observation in that secondary tasks always require responses and so does memory retrieval in a test phase, but encoding in a study phase does not. Could it be that retrieval is more able to accommodate an interruption than is encoding because of this difference in response conflict? (Indeed, it might even be the case that retrieval would occasionally *benefit* from interruption, if this causes the subject to shift from an unsuccessful to a more successful retrieval path.) On accuracy measures at the time of test, this may mean that memory will suffer more when encoding as opposed to retrieval has been disrupted. Classical memory research tends not to rely on retrieval latency as a dependent measure, but it is possible that latency would be useful in addressing this concern, as might the techniques of cognitive neuroscience, such as evoked response potentials (ERPs) or the like.

In keeping with Roediger's (2000) argument that retrieval is the "critical mystery" of memory, Moscovitch, Fernandes, and Troyer emphasize retrieval and the relevant neuropsychological evidence in the context of Moscovitch's component process model (see, e.g., Moscovitch, 1994; Moscovitch & Winocur, 1992). The essence of the model is that the medial temporal lobes are a kind of modular slave system that necessarily encodes inputs and then retrieves these encoded representations in a rather ballistic manner. In contrast, the frontal lobes are "intelligent" and nonmodular, having as one responsibility the task of working on the products of the medial temporal lobes in strategic ways: directing attention, organizing, searching, monitoring, and verifying. Under this view, the medial temporal lobes require little attention, whereas the frontal lobes make extensive demands on attention. Moscovitch, Fernandes, and Troyer point out the possibility of mapping this account onto Craik's environmental support account of aging, with resource depletion corresponding to the deterioration of frontal lobe function with age.

In their chapter, Moscovitch, Fernandes, and Troyer raise the interesting puzzle that we experience retrieval as difficult despite the evidence presented in all three chapters that retrieval requires little in the way of attentional resources. Once again, I see the distinction between "pure" retrieval and the other processes also occurring at the time of test as critical here. A great deal goes on at the time of test other than retrieval, and the effort we experience in retrieval may actually derive from these other processes. Moscovitch, Fernandes, and Troyer recognize this by saying that "retrieval itself consists of a number of component processes," but I would suggest that, despite their admirably pointing out the problem, it is still conceptually ambiguous. We must either reserve "retrieval" for the pure act of recovery from memory and then refer to the collection of processes surrounding this pure retrieval as "test-related processes" (or the like) or we must adopt a new term for the pure act of retrieval (as Tulving suggests with ecphory) and preserve the more common usage of "retrieval" as coincident with test-related processes. My vote is for the second option because it highlights the component processes.

There are two further ideas in the Moscovitch, Fernandes, and Troyer chapter that par-

ticularly caught my interest, one in a positive way and one in a negative way. On the positive side, they say that "At retrieval, it is competition for memory or representational systems, rather than for cognitive resources, that leads to memory decrement." I very much prefer this perspective. My sense is that the concept of resources is overly flexible, a problem discussed by Kahneman (1973) in his excellent and still very relevant treatment of the issues. He described how task demands potentially influence allocation of resources to a task. Once resources are seen as expandable in a given setting, measuring or manipulating them becomes much more complicated. How are we to differentiate when further resources *cannot* be allocated from when further resources simply *are not* allocated? But competition for memories or for memory systems, as an explanatory idea, holds the potential for keeping the explanation based firmly in the domain of memory.

The idea with which I disagree is their statement that "Because divided attention had different effects on encoding and retrieval, retrieval cannot simply be a reinstatement of the processes that occurred at encoding." This directly challenges the view of memory championed by another of Craik's long-time University of Toronto colleagues, Paul Kolers (Kolers, 1976; Kolers & Roediger, 1984), a view that has clearly influenced Craik's own thinking (e.g., Tardif & Craik, 1989). For Kolers, all events that constitute memory are processing or reprocessing events. Thus, to encode is to engage a set of processes, the actions of which are then themselves retained in memory. To retrieve is again to engage a set of processes, the actions of which may lead to "remembering." To the degree that the encoding-retrieval match is a good one, remembering will be good as well. This view remains very influential today in the transfer-appropriate processing framework (e.g., Roediger, Weldon, & Challis, 1989). Moscovitch, Fernandes, and Troyer contest this view. As they argue themselves, however, both encoding and retrieval consist of multiple processes. Moreover, we do not yet know which processes are affected and which are not affected by dividing attention. Different constellations of processes will always be invoked at study and test, such that the encoding–retrieval match will never be perfect. Therefore, that divided attention apparently influences encoding differently from retrieval cannot be diagnostic concerning whether retrieval consists of the *attempted* reinstatement of processes engaged during encoding.

The most intriguing idea put forth by Moscovitch, Fernandes, and Troyer is that there may be two quite different kinds of retrieval, retrieval that is strategic and heavily involves the frontal lobes, and retrieval that is quite ballistic and relies on the medial temporal lobes. This leads to the nice prediction that the former kind of retrieval should indeed require resources and hence be affected by divided attention, whereas the latter should not. They also present some evidence that is consistent with this view. This is clearly a direction that should be pursued, given its potential for drawing together the cognitive, cognitive neuropsychology, and cognitive neuroscience empirical and theoretical work.

☐ Memory Processes and Divided Attention

As Craik and all of the authors of these chapters have increasingly emphasized, encoding and retrieval are not themselves processes but rather collections of processes assembled for a particular memory-related task. It is for this reason that I find the Kolers perspective a particularly compelling one: Memory is not trying to match encoding and retrieval, but rather it is trying to deploy suitable processes to perform the task at hand (be it encoding or retrieval). To the extent that similar constellations of processes are deployed at encoding and retrieval, remembering will be more successful. Retrieval is not a weaker reinstatement of encoding; rather, retrieval is a new situation that can put into play some of

the same processes as encoding, but the degree of overlap is subject to a great many influences.

Under such a view, how do we deal with the results of divided attention manipulations at encoding versus retrieval? It may be that the pure act of retrieval does not require attention, or even that the pure acts of both encoding and retrieval do not require attention, though the literature on indirect, implicit tests of memory indicates that this is not a straightforward issue and that subtle changes in attention can have dramatic effects on memory (see, e.g., MacDonald & MacLeod, 1998; Szymanski & MacLeod, 1996). In contrast, it may be that the "supporting players" that surround encoding at the time of study and retrieval at the time of test do require much more in the way of attention. Rehearsing an already encoded item would appear to be very attention demanding, as would making a decision or producing a response (see Posner & Boies, 1971). For this reason, it is crucial to break down the activities at the time of study and at the time of test into their component processes and not to equate encoding with study and retrieval with test. This is where the research must go and, to their credit, like Craik himself, this is very evidently where the authors of these three chapters are taking their research.

Research must also put the divided attention technique itself under scrutiny, as the authors of these chapters are well aware. As always, we must be critical not just of our theories but also of the methods that we use to evaluate those theories. Very recent work indicates that dual task situations are remarkably complex. Thus, Rah, Reber, and Hsiao (2000) suggest that secondary tasks do not stay independent from primary tasks but rather that the two tasks become intertwined with each other, complicating analysis. In addition, Hegarty, Shah, and Miyake (2000) sound a cautionary note. They observed the counterintuitive result that secondary tasks considered on the basis of psychometric work to make the greatest resource demands (i.e., to most heavily tax the central executive) exerted less effect on primary tasks than did secondary tasks associated with lower resource demands. On this basis, they argued that there is a considerable problem of tradeoff between the two tasks. We must thoroughly understand the procedure if we are to be able to unambiguously interpret results derived from it.

☐ Concluding Comments

In her chapter, Anderson cites a recent article by Naveh-Benjamin and Guez (2000) wherein the secondary task indicated increased attentional demands during the period between the presentation of a retrieval cue and recall. She rightly notes how increasingly complex the patterns are becoming as researchers delve deeper into the attentional requirements of encoding and retrieval with both standard chronometric approaches and the new imaging approaches of cognitive neuroscience. Naveh-Benjamin raises the problems of binding and of intra-item association as important, correctly recognizing that we must go beneath the global domains of encoding and retrieval to unpack the processes that compose them. Moscovitch, Fernandes, and Troyer (see Fernandes & Moscovitch, 2000) point to the exceptions where retrieval clearly does make resource demands as being particularly informative and consistent with neuropsychological findings about the roles of various brain areas in encoding versus retrieval.

All three of these chapters are state-of-the-art statements of where we have come from and where we are now in terms of understanding the complex nature of attentional demands in remembering. Most importantly, all three chapters point to the path we must take to understand the resource demands of memory processes, a topic to which Fergus Craik has devoted so much of his incisive research throughout his career. As such, these

chapters are a fitting tribute to one of the most influential of memory researchers, and to the profound impact that he and his University of Toronto colleagues have had in moving encoding–retrieval interactions to center stage in the study of human memory.

References

Anderson, C. M., & Craik, F. I. M. (1974). The effect of a concurrent task on recall from primary memory. *Journal of Verbal Learning & Verbal Behavior, 13*, 107–113.

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.), *Human memory and cognitive capabilities, mechanisms, and performances* (pp. 409–422). North Holland: Elsevier.

Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General, 125*, 159–180.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning & Verbal Behavior, 11*, 671–684.

Fernandes, M. A., & Moscovitch, M. (2000). Divided attention and memory: Evidence of substantial interference effects at retrieval and encoding. *Journal of Experimental Psychology: General, 129*, 155–176.

Gardiner, J. M., Craik, F. I. M., & Birtwistle, J. (1972). Retrieval cues and release from proactive inhibition. *Journal of Verbal Learning & Verbal Behavior, 11*, 778–783.

Hegarty, M., Shah, P., & Miyake, A. (2000). Constraints on using the dual-task methodology to specify the degree of central executive involvement in cognitive tasks. *Memory & Cognition, 28*, 376–385.

Iidaka, T., Anderson, N. D., Kapur, S., Cabeza, R., & Craik, F. I. M. (2000). The Effect of divided attention on encoding and retrieval in episodic memory revealed by positron emission tomography. *Journal of Cognitive Neuroscience, 12*, 267–280.

Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.

Kolers, P. A. (1976). Reading a year later. *Journal of Experimental Psychology: Human Learning & Memory, 2*, 554–565.

Kolers, P. A., & Roediger, H. L., III (1984). Procedures of mind. *Journal of Verbal Learning & Verbal Behavior, 23*, 425–449.

MacDonald, P. A., & MacLeod, C. M. (1998). The influence of attention at encoding on direct and indirect remembering. *Acta Psychologica, 98*, 291–310.

Moscovitch, M. (1994). Cognitive resources and dual-task interference effects at retrieval in normal people: The role of the frontal lobes and medial temporal cortex. *Neuropsychology, 8*, 524–534.

Moscovitch, M., & Winocur, G. (1992). The neuropsychology of memory and aging. In F. I. M. Craik and T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 315–372). Hillsdale, NJ: Erlbaum.

Murdock, B. B., Jr. (1965). Effects of a subsidiary task on short-term memory. *British Journal of Psychology, 56*, 413–419.

Murdock, B. B. (1982). A theory for the storage and retrieval of item and associative information. *Psychological Review, 89*, 609–626.

Naveh-Benjamin, M., & Guez, J. (2000). Effects of divided attention on encoding and retrieval processes: Assessment of attentional costs and a componential analysis. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 26*, 1461–1482.

Naveh-Benjamin, M., Craik, F. I. M., Gavrilescu, D., & Anderson, N. D. (2000). Asymmetry between encoding and retrieval processes: Evidence from divided attention and a calibration analysis. *Memory & Cognition, 28*, 965–976.

Naveh-Benjamin, M., Craik, F. I. M., Perretta, J. G., & Tonev, S. T. (2000). The effects of divided attention on encoding and retrieval processes: The resiliency of retrieval processes. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 53A*, 609–625.

Pashler, H. (1994a). Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin, 116*, 220–244.

Pashler, H. (1994b). Graded capacity-sharing in dual-task interference? *Journal of Experimental Psychology: Human Perception & Performance, 20*, 330–342.

Posner, M. I., & Boies, S. J. (1971). Components of attention. *Psychological Review, 78*, 391–408.

Rah, S. K.-Y., Reber, A. S., & Hsiao, A. T. (2000). Another wrinkle on the dual-task SRT experiment: It's probably not dual-task. *Psychonomic Bulletin & Review, 7*, 309–313.

Roediger, H. L., III (2000). Why retrieval is the key process in understanding human memory. In E. Tulving (Ed.), *Memory, consciousness, and the brain: The Tallinn conference* (pp. 52–75). Philadelphia: Psychology Press.

Roediger, H. L., III, Weldon, M. S., & Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger, III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 3–41). Hillsdale, NJ: Erlbaum.

Slamecka, N. J., & Graf, P. (1978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory, 4*, 592–604.

Szymanski, K. F., & MacLeod, C. M. (1996). Manipulation of attention at study affects an explicit but not an implicit test of memory. *Consciousness & Cognition, 5*, 165–175.

Tardif, T., & Craik, F. I. M. (1989). Reading a week later: Perceptual and conceptual factors. *Journal of Memory & Language, 28*, 107–125.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*. New York: Academic Press.

Tulving, E. (1991). Concepts of human memory. In L. R. Squire, N. M. Weinberger et al. (Eds.), *Memory: Organization and locus of change* (pp. 3–32). New York: Oxford University Press.

Tulving, E., Kapur, S., Craik, F. I. M., Moscovitch, M., & Houle, S. (1994). Hemispheric encoding/retrieval asymmetry in episodic memory: Positron emission tomography findings. *Proceedings of the National Academy of Sciences (USA), 91*, 2016–2020.