CHAPTER 11

Aging and Cognitive Deficits

The Role of Attentional Resources

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The general belief that cognitive abilities decline with age has been somewhat qualified in recent years. Many age-related effects previously demonstrated in studies using cross-sectional designs have been shown to be artifacts of sampling or of the different social and economic conditions experienced by different age cohorts (Schaie, 1973). In addition, older people tested in laboratory studies are usually further removed in time from formal education, and have not had so much recent practice at cognitive skills as their younger counterparts. Older experimental subjects *may* be less motivated to perform well on artificial laboratory tasks, they may have had less formal schooling and may be less healthy. As Avorn (Chapter 17) points out, these factors and others make interpretation of apparent age losses difficult and ought to induce substantial caution before observed deficits are attributed unequivocally to the aging process as such. On the other hand, it does not seem unreasonable to propose that genuine age-related deficits in cognitive functioning do occur. Physical strength, agility, and endurance clearly decline with age, and the various physiological systems of the body (respiratory, circulatory, digestive, excretory) also decline in efficiency as a person grows older (Finch & Hayflick, 1977). It would be rather extraordinary

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if the nervous system and its associated psychological functions were found to be immune to these otherwise widespread changes.

In the present chapter we examine the proposition that mental energy declines with age, as physical energy certainly does (Sacher & Duffy, 1978). By *mental energy* we mean the reservoir of psychological energy that enables cognitive operations to be performed. Presumably the psychological notion of mental energy has a physiological correlate, but we will not be concerned with that here. The concept of mental energy has not been much discussed in the literature although theorists have recently distinguished *automatic* from *controlled* (or *effortful*) processes (Shiffrin & Schneider, 1977). Automatic processes are those which run off involuntarily; they require little or no attention (and thus, presumably, consume little mental energy), interfere minimally with concurrent mental operations, and do not necessarily involve conscious awareness. In contrast, controlled operations typically involve a greater degree of conscious awareness, are voluntary and optional, and require the allocation of attentional resources. That is, they *do* consume mental energy. Most complex tasks probably involve a combination of automatic and controlled processes, the overall degree of automaticity being heavily dependent on how practiced the person is at the task. That is, specific operations can change from *controlled* to *automatic* with practice and experience.

By this account, different mental operations and activities will require different amounts of mental energy or attentional resource (Norman & Bobrow, 1975). Also, the observation that human subjects can perform a strictly limited number of controlled operations at one time has led to the notion that the momentary availability of attentional resources is limited (Kahneman, 1973). This is one usage of the term *mental energy*, and it is the one discussed in the present chapter. A second sense in which the notion of a pool of mental energy might be used is the total reservoir which may be depleted in the course of extended strenuous mental activity, thereby leading to fatigue. It seems plausible that older people have fewer reserves of mental energy in this sense also, but the theme will not be pursued here.

In summary, it is postulated that mental energy is required for the effective functioning of certain mental operations. In general, the *controlled* operations that require allocation of mental energy (or attention or processing resources) are those which are unpracticed or those which require novel combinations of existing operations. It is speculated that the momentary amount of energy available to perform a given task at a given time declines with age. If this is so, it follows that older subjects should be more heavily penalized in tasks requiring novel controlled processing, and there is mounting evidence to this effect (Hasher & Zacks, 1979).

The present chapter focuses on the notion that a reduction in available mental energy is *one* of several major factors underlying declining cognitive efficiency in the elderly. We will deal largely with deficits in episodic and semantic memory, but the implications of the current view for other cognitive abilities will also be pointed out. Specifically, the chapter explores three main themes. The first is an account of age differences in memory and related abilities in terms of encoding and retrieval processes. The basic idea to be examined is that the deeper and more elaborate encoding processes associated with higher levels of retention require more attentional resource (Johnston & Heinz, 1978). If older subjects have a smaller pool of available mental energy (that is smaller reserves of attentional resource), it follows that their encoding, and perhaps retrieval, processes will be impaired whenever the limit of processing resources is exceeded. Even if the limit is not exceeded, it is possible that a smaller pool of resource is associated with impaired processing, although that is a matter for empirical exploration. It is also possible that older people do not differ in the amount of mental energy they have available, but are less willing to expend it. In either event, it would be expected that tasks tapping automatic processes would show a lesser age-related deficit than tasks requiring controlled processing.

The second theme is an examination of the parallel between the effects of aging and the effects of other variables on memory performance. There are interesting similarities in the pattern of memory deficits observed in old age, alcoholic intoxication, and fatigue (Craik, 1977b; Craik & Simon, 1980). Of particular interest is the observation that encoding under divided attention conditions also yields the same pattern of memory deficits as is observed with older and intoxicated people (Craik, 1982), leading to the speculative conclusion that division of attention diverts processing resources from relevant encoding processes in much the same way as encoding processes receive insufficient resources in aging, intoxication, and fatigue. That is, it is suggested that intoxication and fatigue, like old age, are conditions in which attentional resources are depleted and that all these conditions can be mimicked by division of attention in young, alert, sober subjects.

The third theme to be explored briefly is that the memory deficits observed in older subjects are "production deficiencies" in the sense that the subjects are *capable* of carrying out more effective encoding and retrieval operations but do not spontaneously do so (see also Chapter 7). This analysis leads to an interesting question, namely, *why* do older subjects not encode more efficiently if they are capable of doing so? The analysis also leads to the important conclusion that if older subjects still possess these capabilities, it is presumably possible to rectify their inefficient processing through procedures that constrain and guide the relevant mental operations.

Theoretical Background

In this section we outline the theoretical assumptions that underlie our approach to the study of age changes in memory and thereby set the scene for the subsequent description of some empirical studies.

The first and most general point is that few absolute statements can be made about age differences in memory performance. Rather, overall performance must be understood as a complex set of interactions between the subjects tested, the materials used, and the task or goal set by the experimenter (Jenkins, 1979). Thus, final statements about memory and aging are unlikely to take the simple form of "memory becomes 10% less efficient with each decade" and more likely to consist of conclusions such as "age-related losses in memory are minimized by using highly meaningful materials, an encoding task that induces semantic processing of these materials, and a retrieval test that reinstates the original learning context." That is, conclusions are likely to be relative, not absolute, in character.

The view of remembering adopted in the present chapter is the set of ideas characterized by Craik (1981) as a general processing view of human memory. This composite view stems from the theoretical notions of several researchers, notably Jacoby (Jacoby & Craik, 1979; Jacoby & Dallas, 1981), Kolers (1975, 1979) and Tulving (1974; Tulving & Thomson, 1973). In outline, the idea is that past experience in some organized form largely determines the analysis and interpretation of the incoming stimulus array. The specific analytic operations performed on a particular event are retained in the form of a record (the memory trace) or form an encoded "description" (Norman & Bobrow, 1979) of the event, although not all theorists (e.g., Kolers, 1979) share this view. Typically, only some aspects of the event are analyzed or encoded on any one occasion; the specific subset is determined by the subject's accumulated relevant past experience ("semantic memory" in Tulving's terms) and the subject's temporary goals, expectations, and mental set. For example, highly familiar events or well-practiced operations will require relatively little analysis, and such events are poorly remembered at a later time. Conversely, tasks or materials that lead to rich and extensive analysis (especially "deeper" semantic analysis) are typically well remembered subsequently (Craik & Tulving, 1975). Thus, memorial performance is apparently a function of the extensiveness of the initial analytic operations (Kolers, 1975, 1979). At the time of retrieval, the same processing operations must be reinvoked to give rise to the experience of remembering. This qualitative similarity between encoding and retrieval processes (the encoding specificity principle) may be shaped and guided by the materials themselves, by identical or similar contexts, by retrieval cues, and speculatively by reconstructive processes that involve interactions between general knowledge of the to-be-remembered event and information in the encoded memory record of the event.

In this scheme, memory deficits could arise in a number of ways. Most obviously, if deeper and more extensive encoding processes require greater amounts of attentional resource, a reduction in attentional resources would result in deficient encodings. Similarly, retrieval operations may also demand attentional resources, and their unavailability might result in less extensive and less efficient retrieval. This speculation may require qualification in that some part of the retrieval process may be relatively automatic and thus not require attention (Jacoby & Dallas, 1981; Mandler, 1980). According to these theorists, recognition consists of a familiarity judgment which is rapid and relatively effortless, augmented when necessary by an effortful reconstructive process—conceivably, it is only the latter process that is attention-demanding. Thus, a reduction in attentional resources would yield a decrement in retrieval only to the extent that reconstructive processes must be involved. Finally, memory deficits might arise from a mismatch of encoding and retrieval processes—that is, if the qualitative nature of the mental operations differed at encoding and retrieval, successful remembering would be less likely to occur. It should be stressed that these are the deficits that might occur as a function of the processing framework described in the preceding paragraphs; other memory deficits (amnesias, fugue, repression) might occur for quite different reasons.

In the following sections, various empirical results will be described in an attempt to illustrate the processing deficit viewpoint. First, some studies of memory for events (episodic memory) will be reported, followed by studies of semantic memory. Following a description of the results, the adequacy of the theoretical viewpoint will be evaluated.

Empirical Studies

Aging and Divided Attention

Before describing some new experiments from our own laboratory, we shall briefly review some of the work that suggests a parallel between the effects of aging and the effects of divided attention. First, it is well established that dividing the subject's attention during presentation of a word list leads to a decrement in subsequent free recall of the words. The decrement is not uniform, however, but is confined to the early (secondary memory) portion of the list (Anderson & Craik, 1974; Baddeley, Scott, Drynan, & Smith, 1969; Murdock, 1965). This same pattern has also been found in older subjects as opposed to young subjects (Craik, 1968; Raymond, 1971) and in intoxicated as opposed to sober subjects (Jones, 1973). It is not the case that *any* disruptive activity gives rise to this pattern, as a task interpolated between presentation and recall leads to a decrement in primary memory but not in secondary memory (Glanzer & Cunitz, 1966). A plausible explanation of the pattern observed under divided attention, aging, and intoxication is that a reduction in attentional resources reduces the subject's ability to carry out deep and elaborate processing—both within and between words—and that this reduction in semantic processing is more detrimental to secondary memory than to primary memory (e.g., Baddeley, 1966).

A further similarity between divided attention and aging is seen in the relation between list length and free recall. It has been known for some time that the number of words recalled from a list increases as the length of the list increases, and that the relation between list length and number of words recalled is approximately linear (Murdock, 1960). That is, the relation can be expressed as

$$R = a + bL$$

where R = the number of words recalled, L = list length, and a and b are constants. Craik (1968) suggested that the intercept constant a largely reflects a relatively stable primary memory component, whereas the slope constant b is an index of secondary memory efficiency. This suggestion was supported by empirical evidence showing that b increased as the lists were made more familiar and amenable to organization; for example, it was found that b increased progressively from lists of unrelated words and lists of animal names to lists of English country names (English subjects were used). Craik also found that $b = 0.15$ for young adult subjects, whereas $b = 0.03$ for a group of subjects whose average age was 65. Mandler and Worden (1973) reported a study in which subjects freely recalled words from lists of 30, 60, or 120 words. The words were presented either under a condition in which subjects paid full attention to the words or under a condition in which subjects performed a concurrent task. The slope constants were 0.37 and 0.05 under the full and divided attention conditions respectively. In a similar study carried out in our laboratory, young subjects listened to word lists of different lengths under full attention conditions, or under the constraint to classify each word as starting with a letter from A–L or from M–Z and as spoken by a male or a female speaker; all subjects knew that they were to recall the words later. The equations relating recall to list length were:

Full attention	$R = 4.95 + 0.22L$
Divided attention	$R = 4.30 + 0.10L$

Thus, divided attention had relatively little effect on the intercept but was again found to have a substantial effect on the slope. The similarity between the effects of aging and divided attention is attributed to a common decrement in the efficiency with which words are encoded and retrieved.

A third similarity to be mentioned briefly is that both under conditions of divided attention during learning (Mandler & Worden, 1973) and in a group of older subjects (Rankin & Kausler, 1979) the experimental groups made more semantic errors in a subsequent recognition memory test than did the young (full attention) control groups. That is, the experimental groups showed a substantially greater tendency than controls to select synonyms of presented words in the recognition test. This interesting result strongly implies that older people and *divided-attention* subjects do encode something of the meaning of the words learned but that the encoded meaning is less specific and precise. That is, enough of the word's meaning has been encoded to enable the subject to choose that general category at the time of recognition, but not enough to enable him to differentiate between the correct word and a semantically similar distractor item. These findings will be discussed again later in the chapter.

A fourth point relating divided attention to aging and to alcoholic intoxication is that these variables typically interact in their effects on memory performance. For example, old subjects are particularly penalized by tasks requiring divided attention (Inglis & Caird, 1963; Kirchner, 1958). Similarly, intoxicated subjects perform particularly poorly when their attention is divided between two tasks (Levine, Kramer, & Levine, 1975; Moskowitz & de Pry, 1968). Further, older subjects are more vulnerable to the detrimental effects of alcohol on performance (Parsons & Prigatano, 1977). The consistent presence of these interactive effects strongly suggests that some common process is being tapped in all cases. Our suggestion is that a common pool of attentional resource is depleted by aging, divided attention, and alcoholic intoxication.

It is worth pointing out that divided attention is used here simply as a technique for reducing the amount of resource available for a specific task and that, according to the present argument, as the demands of the secondary task increase, performance on the primary task should increasingly resemble that of the older or intoxicated subject. In addition, there may well be deleterious effects on performance arising from the requirement to organize the division of attention between the two tasks, but such specific effects of divided attention will not be addressed in the present chapter.

What factors underlie the poorer memory performance of subjects who are old or intoxicated, or whose attention is divided? The present suggestion is that encoding processes are less efficient under these conditions, and this suggestion is supported by a number of findings in the literature. Encoding processes for words may be broken down into intra-item and inter-item processes (Mandler, 1979); it appears to be inter-item processing that is principally affected. For example, several investigators have shown that the formation of inter-item organization is impaired in older subjects (Hultsch, 1969; Laurence, 1966) and this result has also been found with alcoholically intoxicated subjects (Parker, Alkana, Birnbaum, Hartley, & Noble, 1974; Rosen & Lee, 1976). Intra-item encodings may be less affected by the presumed withdrawal of attentional resources, as indicated by the finding that recognition is less impaired than is recall by the aging process (see Craik, 1977a). Plausibly, then, it is the formation of new connections between items that is impeded by a lack of attentional resource. Other deeper types of processing are also detrimentally affected by aging both in the processing of word lists (Eysenck, 1974, 1977) and with more complex verbal materials. In the latter category, for example, Cohen (1979) and Till and Walsh (1980) have shown that older subjects fail to draw inferences as readily as young people do from sentences and short segments of text. It is attractive to postulate a failure of deeper, more elaborate processing under intoxication and divided attention also, but so far the evidence is scanty. In the case of alcoholic intoxication, indeed, there is some evidence contrary to a processing deficit explanation (Hartley, Birnbaum, & Parker, 1978).

In summary, there is good evidence that aging and divided attention have similar effects on memory. Both sets of effects can be characterized as failures of adequate encoding, more specifically as failures to form new inter-item connections, and failures to engage in deeper processing. It might be expected that retrieval operations would be similarly impaired (e.g., Craik & Jacoby, 1979) but there is no compelling evidence to this effect, except perhaps that aging (Schonfield & Robertson, 1966) appears to impair recognition less than it impairs recall. It is also attractive to believe that alcoholic intoxication has effects on memory that are similar to the effects of aging (Craik, 1977b), but here also the evidence is less than complete. The basic decrement postulated to underlie these processing deficits is a lack of mental energy or attentional resource. The adequacy of this speculation will be reassessed after some new empirical studies are considered.

Depth of Processing and Aging

Eysenck (1974, 1977) has suggested a processing deficit hypothesis to account for age differences in memory performance. According to this view, deeper (that is, semantic, associative, and inferential) processes typically require more effort and attention to achieve, and it is these processes that older subjects fail to carry out—with a resulting impairment in memory performance. Eysenck's notion apparently predicts an interaction between age and type of processing, with older subjects showing the greatest decrement at deeper levels, and he did obtain this result (Eysenck, 1974). Another line of argument put forward by Craik (1977a) appears at first to lead to a different prediction. Craik suggested that the older person's processing was inefficient rather than truly defective and that if processing was guided by means of an orienting task, the older subject's memory decrement might be overcome. This reasoning suggests that whereas old subjects would show a decrement in a free learning situation (because they do not spontaneously carry out deeper processing), *no* age decrement might be found at any level of processing when orienting tasks are provided to guide processing. Implicit in this argument is the idea that sufficient attentional resources are potentially available to older subjects (contrary to earlier suggestions in the present chapter) but that for some reason these resources are not mobilized effectively.

A study by White (described by Craik, 1977a) found an interaction between age and level of processing (greater age decrement at deeper levels) in recall, even though orienting tasks were used. This result thus supports Eysenck's position. However, in a subsequent recognition task within the same experiment

White found no age decrement at any level of processing, although a substantial age decrement remained in the free learning condition; this second result fits Craik's position. A possible resolution of the two views is that older people are inefficient at both encoding and retrieval processing. It is not sufficient to "repair" only encoding (by means, say, of an orienting task) because older subjects still exhibit a decrement if retrieval is unguided, as it is in free recall. This is our account of White's free recall data. When both encoding and retrieval are "repaired"—as in the combination of orienting tasks at encoding with a recognition test at retrieval—the age decrement is minimized, or even eliminated as in White's recognition data. We argue that recognition repairs retrieval processing in older subjects, in the sense that recognition is typically much more effective than free recall in guiding the memory system to reconstruct the same traces (Tulving, 1974) or operations (Kolers, 1973) that were formed when the target items were initially encoded. In free recall, subjects must presumably rely more on self-initiated reconstructive operations, and it may be this part of the retrieval process that older subjects perform less efficiently.

Thus, whereas *typically* older subjects will show greater decrements at deeper levels of processing because such encodings usually demand more effort and attention (Eysenck & Eysenck, 1979; Johnston & Heinz, 1978), there is nothing absolute or inevitable about this position. If deeper processing is made easy or accessible by some means, then the older person will make use of the constraints provided by the task or the material to accomplish those deeper types of processing. If some nominally shallow level of processing is made particularly difficult or effortful to accomplish (e.g., Craik & Tulving, 1975, Exp. 5), then older subjects might well show a greater memory decrement at that level. *Depth* of processing is defined in terms of where the qualitative type of processing lies between sensory surface structure on the one hand and semantic, associative, inferential information on the other. However, access to a specific type of information will depend not only on its depth, but on the task, the materials, and the expertise of the subject (Jenkins, 1979). Deeper levels will *usually* require more effort and attention, but this usual state of affairs must be qualified by consideration of these other factors.

A recent study by Yokubynas (1979) nicely illustrates some of these points. Yokubynas utilized the paradigm devised by Craik and Tulving (1975) in which subjects are asked questions relating to a presented word's typescript, rhyming characteristics, or semantic characteristics, followed by recall and then recognition of the words. Figure 1 shows that in recall deeper processing was associated with larger age decrements both in the case where the initial question led to a positive response (e.g., to do with religion–*priest*) and where it led to a negative response (e.g., a piece of furniture–*leopard*). These recall results thus replicate the findings of Eysenck (1974) and White (cited by Craik, 1977a). In recognition, Yokubynas found very much the same pattern of results in the negative condition, but no interaction (and virtually no age decrement) in the positive

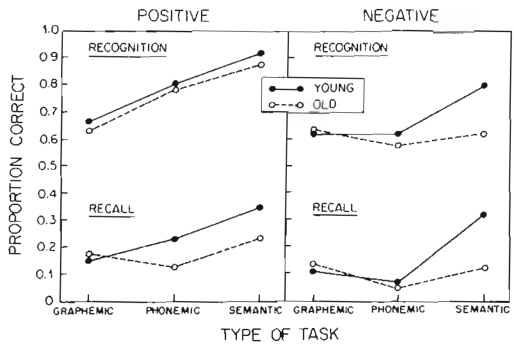

Fig. 1. Recall and recognition as a function of encoding condition and age (Yokubynas, 1979).

condition. Thus, the latter condition replicates the recognition findings in White's experiment. A plausible explanation of these results is that the age decrement is eliminated when a highly compatible encoding condition is combined with a retrieval condition that guides processing effectively.

In our own laboratory we had independently conducted an experiment that replicated Yokubynas's study, but with divided attention as the variable of interest rather than age. That is, subjects answered the orienting task questions about the visually presented words either under conditions of full attention or under conditions in which they had to perform a simultaneous auditory task. Figure 2 shows that the memory deficit normally found under divided attention conditions was eliminated in the conditions that combined positive responses to the orienting task with recognition testing. In other conditions, the divided attention group shows the greatest memory deficit at deeper levels of processing. All in all, the similarity of these results to those of Yokubynas is remarkable and adds further weight to the notion that the effects of aging and divided attention are very similar.

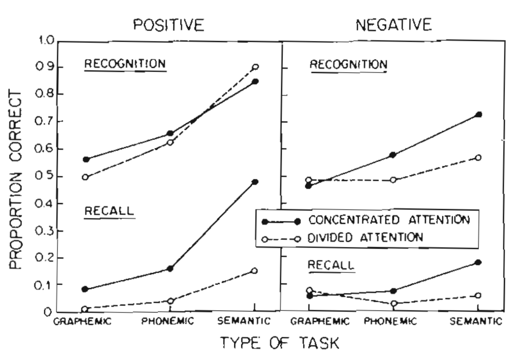

Fig. 2. Recall and recognition as a function of encoding condition and concentrated or divided attention.

The general notion that an age-related processing deficit at encoding and retrieval can be repaired by constraining and guiding the processes involved can also be demonstrated in other ways. It is known that pictures of objects are associated with higher retention levels than the corresponding names of the objects (Paivio, 1971). Paivio's account of this effect is that visual imagery is a particularly effective memory code and that pictures are more likely than words to evoke such imagery. If pictures facilitate these more effective encoding processes, it follows from the arguments made in the preceding paragraphs that older subjects should benefit more than younger subjects from pictorial presentation, especially if retrieval processes are also constrained by the use of recognition testing. By the same argument, age differences should be greatest when the names of objects are presented and retention is tested by free recall. This hypothesis was tested in a study by Rabinowitz, Ackerman, and Craik (unpublished). Lists of 32 objects were presented to young and older subjects, 16 of the objects as words and 16 as line drawings. After each of two such lists, subjects recalled as many as possible of the 32 items. Following the recall task for the second list, recognition tasks for both lists of items were administered; in all cases the recognition stimuli were words, even when the items were presented as drawings. The results are shown in Table 1.

The table shows substantial age decrements in free recall of both words and pictures, a reduced age decrement in word recognition, and essentially no age difference in picture recognition. We argue that pictures give relatively easy access to deep levels of processing, they "drive" the encoding processes to a much greater extent than do word stimuli, and the inefficient encoding processes of older subjects benefit particularly, especially when the pictorial stimuli are combined with a subsequent recognition test.

The same pattern of results was obtained in a further study by Rabinowitz, Ackerman, Craik, and Hinchley (1982) by manipulating encoding *instructions,* as opposed to varying the stimuli. In this second study, younger and older subjects were given lists of unassociated noun pairs to learn. Three different groups were instructed either (1) simply to learn the pairs as best they could, (2) to think of some commonality—some common property or characteristic of the two words in each pair, or (3) to form an interactive image of the two objects

Table 1. Age Difference in Recall and Recognition of Pictures and Words

	Recall		Recognition	
	Words	Pictures	Words	Pictures
Young	.33	.52	.73	.84
Old	.17	.36	.63	.83

Table 2. Proportions of Words Recalled after Different Encoding Instructions

	Learn	Commonality	Imagery
Young	.56	.89	.83
Old	.40	.75	.84

named in each word pair. The retention test was cued recall—one word from each pair was provided as a cue for the second word. Table 2 shows that subjects of both age groups benefited from the instructions to find a commonality or create an image but that the older group again showed a greater benefit. The age decrement fell from 16% in the case of free learning to zero in the case of interactive imagery. As in the previous study, the age decrement was eliminated by combining an encoding condition that induced effective processing with a retention test that induced effective retrieval processes.

To summarize, we have argued (with other authors, notably Eysenck, 1974, and Perlmutter & Mitchell, Chapter 7) that older subjects exhibit a processing deficit in that they often fail to carry out deeper, inferential processing at both encoding and retrieval. Our suggested reason for this failure is that deeper processing typically requires more attentional resources. However, older people are still capable of carrying out effective encoding and retrieval processes if their processing is constrained and guided by the materials and the task.

Age Differences in Semantic Memory

The experiments described in the preceding section involved memory for episodic events. Are there also age differences in retrieval of information from semantic memory, and do attentional resources play a similar role in this situation? Two recent experiments by Byrd explored these issues.

Byrd's first experiment contrasted generation and decision processes in semantic memory using a technique developed by Freedman and Loftus (1971). In the generation task, subjects were shown a category name followed after 2 seconds by a further presentation of the category name with an initial letter; the subject's task was to generate an exemplar of the category beginning with that letter. Thus, the stimulus *fruit–p* might yield the response *peach* or *plum*. In the decision version of the task, the subject was presented with the category name followed after 2 seconds by the category name and an exemplar; his task was to decide as rapidly as possible whether the exemplar belonged to the category—thus, *fruit–apple* should lead to a positive response and *fruit–chair* to a negative response. The generation and decision trials were either intermixed randomly or were blocked together; thus, only in the latter case did subjects know what type of trial would follow the first *category name only* slide. Loftus (1976) has demonstrated that blocking reduces response times in the *fruit–p* generation case, presumably by setting subjects to generate exemplars as soon as the first category name slide is shown. The present studies sought to ascertain whether blocking would have a similar effect on the decision task and a similar effect for old and young subjects.

Figure 3 shows that generation (*fruit–p*) took substantially longer than decision (*fruit–apple*), that old subjects were slower than young subjects, and that blocking speeded responses in all cases. Of greater interest is the finding that blocking speeded the generation task more than the decision task, but only for young subjects (the three-way interaction was reliable). Thus, in the generation task young subjects were able to take greater advantage of their knowledge of the type of trial coming up; presumably they marshalled their attentional resources to prepare to generate exemplars of the category shown on the first slide. Apparently older subjects did not "set" themselves to the same degree. The blocking manipulation was less effective in the decision task, perhaps because the stimulus drives processing to a greater extent. That is, the generation task requires a lot of self-initiated processing before a response can be made, whereas the decision task stimuli (*fruit–apple; animal–horse*) are more compatible with semantic memory structures and, speculatively, may drive the analysis and response in a somewhat more automatic way. If this account is correct, the present results again show that older subjects are at the greatest relative disadvantage to

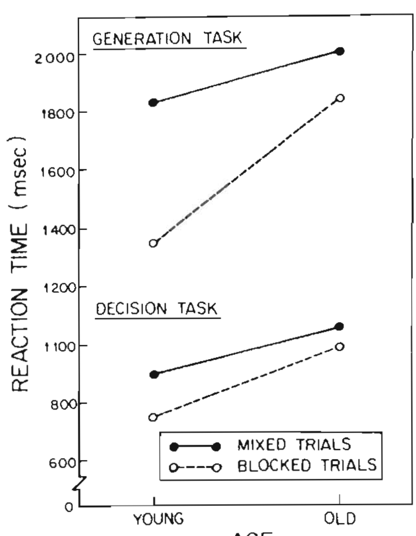

Fig. 3. Generation and decision times as a function of age and whether trials were mixed or blocked.

younger subjects when they must rely on self-initiated, conscious, controlled processes (Shiffrin & Schneider, 1977), and in this sense the present results resemble the findings from episodic memory studies.

If older subjects are relatively unimpaired in tasks utilizing automatic processes (Hasher & Zacks, 1979), it follows that they should show as great a priming effect as young subjects do in the decision task described above. The priming effect in this situation refers to the observation that response times are speeded when the same category is presented in successive trials. Loftus and Loftus (1974) demonstrated such a priming effect with the category–letter generation task; they also showed that the priming was relatively transient in that when questions from the same semantic category were separated by two trials using different categories, the reduction in generation time to the second question was virtually eliminated. The suggestion, then, is that the category priming effect reflects automatic processing and that there should be no age differences in the effect.

In Byrd's second experiment, subjects were shown a series of category–exemplar slides as in the decision task described above. In this study each decision slide appeared alone in the trial; it was not preceded by the relevant category name. Throughout the series of trials, categories were repeated (same category name but a different exemplar—e.g., *fruit–cherry, fruit–apple*) either with no further trials intervening (lag 0) or with one or two different-category trials intervening (lag 1 and lag 2, respectively). As in the previous experiment

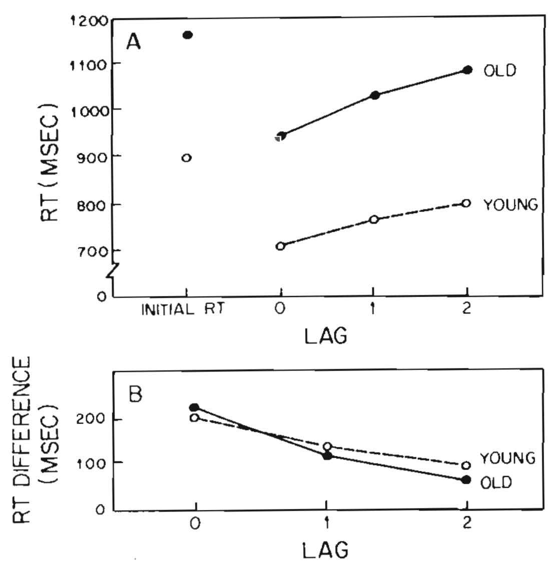

Fig. 4. Reaction times in a category-decision task as a function of age and lag.

the subject's task was to decide rapidly whether the exemplar was a member of the category name accompanying it on the slide.

The upper part of Figure 4 shows the absolute reaction times for old and young subjects. Both groups reacted more rapidly to repeated categories relative to the initial appearance of that category, but this priming effect declined from over 200 msec at lag 0 to 100 msec or less at lag 2. The interesting finding is that whereas older subjects took longer to respond in absolute terms (Figure 4A), there were no age differences in either the size of the priming effect or its decline over intervening trials (see Chapter 5 for a similar result). The implication of this finding is that there appear to be essentially no age differences in automatic processing even, as in this case, when the processing clearly involves semantic structures. Thus, the pattern of age decrements documented in this chapter cannot be described universally in terms of a greater decrement at deeper levels of processing; when deeper (semantic) processing involves automated procedures, age differences are minimal (Hasher & Zacks, 1979; Howard, Lasaga, & McAndrews, 1980). This conclusion adds further weight to our general position that age differences appear to the extent that effortful processing operations, requiring considerable attentional resources, are involved.

Summary of Empirical Results

The general position advocated in the present chapter is that age differences in memory performance can be attributed to inefficiencies in encoding processes and probably in retrieval processes also. We have suggested that the decreased availability of attentional resources in older people reduces the amount of spontaneously initiated deep, elaborate, and inferential processing carried out and that this reduction in turn is associated with lower levels of retention. We do not wish to imply that *no* semantic processing is carried out; rather, it seems that the semantic processing achieved is more general in character (Craik & Simon, 1980; Rabinowitz & Ackerman, Chapter 8). That is, older subjects may encode events in "the same old way" from one occasion to the next, rather than encoding each event distinctively in terms of its specific context. This postulated decreasing specificity of encoding may lie behind the observation that both older people and subjects under divided attention conditions make more false alarm responses to synonyms of target words in a recognition task (Mandler & Worden, 1973; Rankin & Kausler, 1979). Loss of contextual specificity in older people's encodings is also evident in the finding (Raymond, 1971) that older subjects import more intrusions from previous lists into their current list recall in a free recall test. It appears that older subjects do not delimit each item so precisely in terms of the temporal, semantic, and other factors specific to each list. A similar finding has been reported for amnesic patients (Huppert & Piercy, 1976) and for normal subjects under divided attention conditions (Allport, cited by Craik, 1977b). Generally, it appears that various abnormal conditions act to reduce the adequacy and extensiveness of an item's encoding. Some aspects of a perceived event—its basic physical attributes and its general meaning, for example—are encoded relatively easily and automatically, whereas further aspects such as inferential and contextually specific details of meaning appear to be more optional, and they may not be encoded unless guided by orienting tasks that facilitate such further processing.

A related point, which gains some support from the studies reviewed in previous sections, is that automatic aspects of information processing appear to remain essentially intact in older subjects (Hasher & Zacks, 1979; Howard *et al.*, 1980). It is the more effortful conscious processes that are impaired, and in this sense the results from older subjects are like findings with amnesic patients that conscious, episodic aspects of memory show large decrements, whereas less specific procedural aspects of memory (knowing how) show relatively little impairment (Cohen & Squire, 1980; Moscovitch, Chapter 4). Both Mandler (1980) and Jacoby and Dallas (1981) have recently suggested that recognition memory may be based on a relatively automatic judgment of familiarity plus a more effortful retrieval component. Putting these suggestions together with the preceding ideas, we may speculate that older subjects' recognition processes should be impaired only in the latter respect.

Finally, it may be worth stressing that it is not sufficient to characterize age losses in memory under the description "the harder the task, the greater the age decrement." A number of cases do fit that description; these are cases in which encoding or retrieval processes are repaired, and whereas all subjects benefit from the help provided, older subjects typically benefit more (e.g., Hulicka & Grossman, 1967; Schonfield & Robertson, 1966). This pattern of results occurs in our view because older subjects largely retain the ability to encode and retrieve effectively but do not carry out these effective operations unless constrained and guided by tasks or instructions. Younger subjects, on the other hand, carry out such operations spontaneously to a greater extent and thus their performance improves less markedly when guiding tasks or instructions are provided. But not all results show greater age decrements at lower levels of performance. For example, retention levels in the Peterson and Peterson short-term memory paradigm decline equally for old and young subjects as a function of retention interval (see Figure 6 in Craik, 1977a). Second, both Yokubynas's results (Figure 1) and White's data (Craik, 1977a) show an equivalent decline in recognition memory for young and old subjects as a function of shallower depths of processing. As a third example, Rabinowitz and Ackerman's data (Chapter 8, Experiment 2) show cases in which older subjects equal younger subjects' performance levels, both at high levels of retention (high associates, intra-list cues) and at relatively low levels of retention (high associates, extra-list cues), whereas at intermediate levels of retention, a large age decrement is found (low associates, intra list cues). It is not just difficulty level that determines the age decrement;

other *qualitative* aspects of encoding and retrieval processes must also be considered.

Conclusions: Possible Reasons for Age Decrements in Memory

In view of the emerging consensus that older people are able to carry out effective processing but do not do so spontaneously, it may reasonably be asked *why* older subjects exhibit such a production deficiency. One possible candidate is a failure of metamemory; perhaps older subjects have poorer insight into their own memory processes. At first sight this is an attractive hypothesis since it fits the production deficiency picture—older subjects do not realize that they should use associations or imagery to improve their performance. However, several studies have failed to find age differences in metamemorial knowledge (e.g., Lachman & Lachman, 1980; Perlmutter, 1978). It is certainly true that older people have poor insight into their memory processes, but so do young people, even bright young college students. It is apparently not the knowledge about memory that changes with age so much as the likelihood that an effective strategy will be used.

A second plausible candidate is that older people have had less recent practice at remembering, especially in dealing with the rather academic (and often meaningless) materials presented to them in verbal learning studies. Both Baltes and Willis (Chapter 19) and Rabbitt (Chapter 5) stress the important role of practice in ameliorating apparent age deficits. The lack of practice hypothesis does seem a very reasonable one and is particularly plausible if remembering is regarded as a set of skilled procedures (Bartlett, 1932; Kolers, 1979). However, lack of practice is unlikely to be the complete story in our view. Perlmutter (1978) has found "typical" patterns of age decrement with subjects who were younger and older university faculty members. Even allowing for some age-related drop off in intellectual activity, it seems probable that Perlmutter's older subjects continue to think, solve problems, and learn abstract verbal materials on a day-to-day basis. The converse case is that memory losses in the elderly are by no means restricted to artificial laboratory situations; older people typically complain of poorer memory for everyday incidents and events which they presumably continue to experience and thus "practice" as before.

Thus, whereas lack of practice may well underlie some memory decrements in older people, it is unlikely to be the only cause. In the present chapter we have argued that a decline in attentional resources (or mental energy) is a further major factor. This speculation is at least plausible from what we know of age changes in brain structure and function (e.g., Petit, Woodruff, Chapters 1 and 3) and from what we know of age-related declines in somatic energy levels (Sacher, 1978).

The speculation is given added credibility by a consideration of the strong parallels between the effects of aging, alcoholic intoxication, and divided attention, documented in the present chapter. We postulate that reduced attentional resources lead to an attenuation or shrinkage in the richness, extensiveness, and depth of processing operations at both encoding and retrieval. Automatic processes are left relatively unimpaired (because they require no attentional resources, by definition), whereas deliberate, effortful, and conscious processes are affected to the greatest extent. More specifically, older subjects' encodings will contain less associative and inferential information; their encodings go less beyond the information given. Similarly, we have suggested that an encoded event is less modified by the specific context in which it occurs for the older person and that this difference leads to a less distinctive (and thus less memorable) encoding of the event.

The hopeful aspect of this point of view is that if these postulated age changes are truly *inefficiencies* rather than absolute losses of function, the possibility of developing remedial procedures clearly exists. The work with orienting tasks and instructions that guide and constrain processing both during encoding and retrieval suggests techniques that might be tried and provides strong encouragement for their successful development.

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