Memory and Aging: The Role of Retrieval Processes

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Older adults have consistently been found to perform more poorly on memory tasks than young adults. This review demonstrates that production deficiency hypotheses are unable to account fully for this fact. We explore the possibility that age-related differences are due to changes in fundamental processes involved in retrieval of information from memory, namely, (a) utilization of contextual information and (b) activation processes occurring in semantic memory. Automatic as well as intentional processes are examined.

People who have passed their 60th birthday often complain of memory problems. They also perform more poorly than young adults in their twenties and thirties on a wide variety of memory tasks in the laboratory. This deterioration of memory with advancing age has been subject to a variety of interpretations, both cognitive and noncognitive. Among the noncognitive explanations are the hypotheses that age differences found in the laboratory are artifacts of differences between young and old adults in formal education, expectations about cognitive abilities, anxiety about performance in the laboratory, or motivation to perform well in the laboratory (Baltes & Schaie, 1976; Langer, Rodin, Beck, Weinman, & Spitzer, 1979; Perlmutter, 1978). These noncognitive accounts all have the same flaw. They predict age differences across the board and cannot readily accommodate findings of small age differences in some types of memory tasks and larger differences in others; an outcome that is not uncommon in the memory and aging literature. For this reason, our review deals only with cognitive explanations, which do not, as a class, have this difficulty.

The most popular explanation of memory problems in old age is that older adults suffer from some species of “production deficiency” (Kausler, 1970). The claim is that they are less likely than young adults to spontaneously use those strategies that are most efficient for encoding and retrieving new information even though these strategies may be known to them. According to this view, age-related differences in memory should disappear if older adults can be induced to use these encoding and retrieval strategies or if memory tasks are used that are not too dependent on retrieval strategies.

We have two goals in this article. The first is to examine two versions of the production deficiency hypothesis and show that each is inadequate as an account of age-related changes in memory on empirical grounds. We demonstrate that even when encoding strategies are nominally equated across adult age groups and retrieval demands are minimized, older adults remember less well than younger ones. Our second goal is to propose an alternative approach to the study of memory and aging that we believe will provide

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1 Cognitive psychologists who have studied memory and aging generally organize research findings in terms of the multi-score model of Atkinson and Shiffrin (1968), who postulate that the memory system consists of three storage structures, each corresponding to a stage of processing: sensory registers, short-term memory, and long-term memory (Craik, 1977; Fozard, 1980). Here we do not evaluate this approach and are concerned only with processes that cut across all three stores, but our review is concerned primarily with studies of long-term memory.
a useful heuristic for future research. Our review shows that memory declines in old age may well derive from age-related changes in operations involved in the encoding and retrieval of information. However, the focus on strategies in many investigations has led to an overly narrow interpretation of what is involved in retrieval to the neglect of two fundamental processes, namely, (a) utilization of contextual information and (b) semantic activation. The focus on strategy-dependent processes also fails to take into account the possibility that there are age-related changes in automatic processes that are not under conscious control. It is our aim to show that decrements in recall and recognition with increasing age cannot be properly understood without taking into consideration the role of contextual and semantic processes, both strategy-dependent and automatic.

Because both our critique of past work and our own approach stem from a particular theoretical orientation, we begin with a brief overview of our theoretical perspective. The remainder of the article is divided into two major sections. The first is a selective review in which we evaluate two versions of the production deficiency hypothesis. In the second we discuss the role of contextual and semantic information processes in greater detail and examine evidence that changes in these processes may be implicated in the memory impairment associated with old age.

Theoretical Overview

Most of the research we discuss is concerned with recall and recognition of verbal material. In the typical experiment, people see or hear some to-be-remembered material and are subsequently asked to recall the items or, in recognition, to select them from a larger set of items. Some theorists (e.g., Kintsch, 1970) have held that recall requires an active search through long-term memory to retrieve items that may be recalled, while recognition does not require search because the items to be remembered are physically presented on the recognition test. Anderson and Bower (1972, 1974) have pointed out that this view of retrieval as involving only memory search is overly simplistic and that four different types of retrieval processes must be distinguished. These are as follows: (a) search of long-term memory during recall to find word meanings that should be checked to see whether they have occurred in some particular context of interest; (b) examination of contextual information associated with word meanings to determine whether the meanings did occur in the context of interest; (c) generation of words corresponding to meanings; and (d) access to meanings (concepts or senses) from words.

Anderson and Bower (1974) claim that recall involves memory search, examination of contextual information, and generation of words corresponding to meanings (in that order), while recognition involves access to word meanings from words followed by examination of contextual information. Although we are in basic agreement with Anderson and Bower’s position, we do differ on a number of points. First, Light, Kimble, and Pellegrino (1975) and Mandler (1980; Mandler & Boeck, 1974) have pointed out that the search process may also be important for recognition. Mandler has discussed the concept of a “retrieval check” in recognition, by which subjects decide whether a test item is old by trying to retrieve it through a search of memory. Thus, retrieval demands in recognition are of at least three types: memory search, access to meaning, and examination of contextual information. Second, Anderson and Bower assume that the processes that deal with the relation between meanings and their lexical realizations are basically infallible. We do not make this assumption; rather, we believe that it is an important developmental question whether there are changes in adulthood in the efficiency of these processes. Third, although we are concerned here with retrieval processes, we believe that they are implicated in the initial encoding of information as well as in subsequent attempts at recall and recognition. For example, the nature of the encoding of new information clearly depends on the degree to which its meaning in long-term memory is accessed and associated with the present context (cf. Craik & Simon, 1980, for a related position).

Research on memory problems in the elderly has focused heavily on memory search.
We will demonstrate the need to consider the remaining three contextual and semantic retrieval processes in any account of age-related changes in adult memory.

Production Deficiency Hypotheses

Two approaches to the study of memory and aging have in common the notion that the elderly are less likely to spontaneously engage in certain strategies that improve memory. The first of these production deficiency approaches posits that the elderly perform less well on memory tasks because they fail either to formulate good retrieval plans as they are studying new information or to use such plans for memory search when they are later tested. We call this the search deficit hypothesis. The second—the depth-of-processing approach—is based on the levels-of-processing framework of Craik and Lockhart (1972). It claims that the elderly do not encode the meaning of new information as thoroughly as the young and that this is the source of their memory difficulties. In general, these two approaches share the assumption that there are no qualitative changes in the nature of cognitive operations as a function of age. Thus, any memory impairment seen in old age is simply the result of failure to use certain strategies that improve memory.

The Search Deficit Hypothesis

The search deficit hypothesis has been investigated in several experimental paradigms. One examines the use of organizational strategies for grouping together to-be-remembered items on the basis of common physical or conceptual properties or on the basis of a rule (Bower, 1970). These strategies are developed during the initial processing of to-be-learned material, but the locus of their effect is thought to be at recall. The common association or link among items allows more efficient search of memory. A number of studies have investigated whether older adults are less likely than younger ones to spontaneously use organizational strategies and whether this could account for their poorer recall performance. A second, related, approach involves comparison of old and young adults’ use of mnemonic strategies in paired-associates (P-A) learning. These strategies link pairs of words so that one word may be retrieved easily when the other is presented. The question investigated here is whether failure to use imagery or verbal mediators to link word pairs is the source of poor P-A learning in older adults. A third approach is to compare performance of young and old adults on tasks that purportedly reduce the necessity for using search strategies, namely, recognition tasks. Recognition generally yields more accurate memory performance than recall, and this difference has been attributed to the elimination of memory search requirements in recognition. Thus, a number of studies have investigated whether older adults have reduced performance in recall tasks, which rely heavily on memory search, but not in recognition, which does not. We examine each of these three approaches in detail.

Age-related changes in organizational strategies. One of the most popular paradigms used in the study of organization and memory is the free-recall task. The subject is given a series of items to remember and is subsequently asked to recall them in any order. A particular list can be presented and tested once in a single trial or repeatedly over multiple trials. The degree to which subjects engage in organization has been assessed by examining their responses for clusters of items whose order differs from the presentation order and that seem to be grouped on the basis of common properties, as with, for example, instances of a common taxonomic category. More idiosyncratic grouping, called subjective organization, can be detected by consistencies in order of recall over multiple trials, even when the basis for the grouping is not apparent. Clustering and subjective organization are thought to represent the subject’s attempts to structure the list and, in general, are correlated positively with recall (Klaczynski, 1980).

If older adults do not spontaneously engage in organizational strategies, their recall performance should be poorer than that of young people, and their response protocols should show less evidence of structuring. Sanders, Murphy, Schmitt, and Walsh
(1980) found that older adults had poorer free recall of lists consisting of four words from each of four categories and also showed less clustering in their responses. Decreases in subjective organization with age have been found in free recall of unrelated words (Hultsch, 1974) and lists of synonym pairs (Denney, 1974); both studies also report poorer recall performance for older adults. On the other hand, Laurence (1966) found no age differences in subjective organization but significant differences in amount recalled; Hultsch (1974) suggested that Laurence's index of subjective organization penalized recall of new words, an occurrence more common for the young. Taub and Kline (1978) found that age differences in recall of prose increased over four trials with the same passage, reaching significance on the third and fourth trials. One possible explanation for these results is that the young were better at developing memory search strategies for increasing recall, but the analyses of subjective organization necessary for confirming this were not carried out. Thus, there is some evidence that older adults spontaneously organize lists less, at least as measured at recall, but it is not clear that this is the cause of their poorer recall.

Another technique for assessing the use of organizational strategies is to increase or decrease the opportunity for using such strategies. If older adults have poorer recall because they fail to spontaneously organize material, age differences should be eliminated under conditions that allow little opportunity for the use of organizational strategies. Indeed, Craik (1977) argues that age differences in short-term memory span are "slight" because organizational strategies can have little effect, given the conditions under which span is typically measured: The stimuli consist of short lists of digits, which presumably are not amenable to organization; the presentation rate is relatively fast, so there is little time for organization; and digits must be recalled in the order of presentation, eliminating organization requiring reordering. Nonetheless, some investigators have argued that memory span can be increased by organizational strategies (Simon, 1974). In any case, although age differences in span may be "slight" in absolute units, the percent decline from young to older adults is in fact sizable; furthermore, age differences are statistically reliable in some studies (e.g., Botwinick & Storandt, 1974; Gilbert & Levee, 1971; Parkinson, Lindholm, & Urell, 1980; Taub, 1975) though not in others (e.g., Drachman & Leavitt, 1972).

Other studies have compared age differences in recall of material that is amenable to organization (e.g., words in sentences) and material that is less easy to organize (e.g., randomly selected words). The prediction that age differences should be greater with material that is more amenable to organization is not consistently supported in studies using supraspan lists (e.g., Craik & Masani, 1967, 1969; Talland, 1968), but there is some supporting evidence from span tasks (cf. Craik, 1977; Craik & Masani, 1967; Heron & Craik, 1964). There is therefore insufficient evidence to warrant any conclusion that age differences will disappear when there is little opportunity for organization in a memory task.

Other studies have investigated the prediction from the production deficiency hypothesis that age differences in recall will disappear when the experimenter imposes organization on the material or instructs subjects to organize the material. This result should be found if older adults are not organizing spontaneously but are capable of doing so and if this lack of organization contributes to their poorer memory. Thus, older adults would be expected to improve more than young adults if lists are presented with items already grouped according to some principle because the young, but not the old, are presumably organizing the lists spontaneously in the ungrouped conditions. Contrary to this prediction, Waugh and Barr (1980) found that younger adults increased their ordered recall of 9-digit lists more than older adults when the lists were temporally grouped into three groups of three digits. Furthermore, examination of the pattern of errors by position in the list suggested that both young and old adults were spontaneously organizing ungrouped lists into three groups of three digits, and age differences were actually greater in the grouped than in the ungrouped condition. There is no anal-
ogous study of age difference in grouping on
the basis of a semantic rule (e.g., comparing
recall of lists in which words were grouped
by category with lists in which word order
was random). Age differences have been
found for free recall of lists of 12 unrelated
words but not for recall of a list of words
from a single category (Laurence, 1967a).
However, young subjects may have been at
ceiling in the categorized condition.
If older adults are not spontaneously or-
dzizing incoming items but are capable of
doing so, and if this lack of organization
contributes to their poorer memory, then in-
tuctions to organize should improve their
performance. Again, the production defi-
ciency hypothesis predicts greater improve-
ment for old than for young adults, who are
presumably organizing spontaneously. With
instructions simply to learn a word list,
Hultsch (1969) found no difference in free
recall for young and old adults who had
scored high on a measure of verbal skills,
and instructions to organize words alpha-
etically while learning them improved per-
formance at all ages. For adults of low verbal
ability, however, he found age differences
with instructions to learn and with instruc-
tions to organize while learning but none
with specific instructions to organize alpha-
betically while learning.
Organization has also been induced using
Mandler’s (1967) sorting technique, in which
people are asked to sort unrelated words into
piles on successive trials until they achieve
identical sorts. This is thought to indicate
that the person has achieved a stable orga-
nization that allows a consistent grouping
of the words. Inasmuch as this technique con-
trols organization across age, it should eli-
minate age differences in memory for the
sorted words, according to the production
deficiency hypothesis. Using this technique
Hultsch (1971) found significant age differ-
ences in a subsequent recall test, and elderly
subjects who sorted did not have improved
performance over those who did not sort.
The organization used in sorting did not dif-
fer with age, but there was no measure of
subjective organization in recall. One expla-
nation of the recall results is that the same
level of organization was achieved by young
and old during sorting, but the elderly did
not use the organization to guide memory
search during recall. The results of a study
by Gordon (1975), however, seem to reduce
the plausibility of this explanation. She
found no age differences in type or amount
of organization used in sorting sentences
prior to recall or in subjective organization
of recalled sentences. No final conclusions
can be drawn on the basis of these studies.
If older adults do not spontaneously pro-
duce retrieval cues to guide memory search
but are capable of using such cues, then the
search deficit hypothesis predicts that their
recall should improve more than that of
young adults when cues are supplied by the
experimenter. Here, too, the results are
mixed. Hultsch (1975) tested recall of four
words from each of 10 categories and at re-
call provided some subjects with the cate-
gory names. Contrary to prediction, there
were age differences in both the cued and
the uncued conditions, and providing cate-
gory names improved performance for both
young (18–34 years) and old (65–83 years)
adults but had no effect on middle-aged peo-
p le (50–64 years). Laurence (1967b) did
find that category-name retrieval cues im-
proved performance for elderly but not
young adults, but this result must be re-
garded cautiously because there were no sig-
nificant age differences in either this cued
condition or the no-cue control condition,
where one would expect to see them.
Effective retrieval cues appear to be ones
that are encoded with the target item during
initial study (e.g., Anderson & Ortony,
1975; Tulving & Thomson, 1973). In several
experiments, retrieval cues have been pro-
vided at study in an attempt to guarantee
that they will be encoded with the target
items. With long lists of words from several
categories and presentation of category-name
cues both at study and at recall, age differ-
ces in recall remained (Hultsch & Craig,
1976; Smith, 1974). Nevertheless, when cat-
egory names for 20 words each from a dif-
ferent category were provided at presenta-
tion, Smith (1977) found no age differences
in recall with or without presentation of the
category names as cues. The elderly, but not
the young, benefited from having the cues
at study. Without category cues at study,
retrieval cues facilitated recall across ages,
and age differences in performance remained. Smith’s data suggest that the important factor is not cueing at the time of test but rather the availability of cues at input.

In summary, older adults show less organization in free recall, but there is little evidence for the hypothesis that their poorer memory performance is because they do not spontaneously organize. Age differences do not disappear under conditions that encourage organization, namely, when organization is imposed by the experimenter or when specific instructions on how to organize are given. The poorer performance of older adults under these conditions is not due to failure to spontaneously use the organizational scheme at recall. That is, although they are often able to use organizational cues supplied by the experimenter at recall, age differences in performance remain.

Despite these results, it is still possible that a deficit in organization underlies older adults’ memory impairment in that they may be unable to use organization as effectively as the young, regardless of whether they generate it themselves or are given cues by the experimenter. That is, contrary to the production deficiency hypothesis, they may have a deficit in the retrieval processes that underlie effective use of organization. For example, in order to organize on the basis of conceptual similarity, those aspects of meaning shared by words on a list must be retrieved at presentation, and this meaning must be capable of accessing the words at recall. Thus, the ability to use at least some organizational strategies depends in part on basic semantic retrieval processes that might be impaired in old age. Another possibility is that older adults may have difficulty utilizing organization because of age-related changes in the nature of semantic processing. Denney (1974) found that middle-aged adults had higher recall for lists of words paired by similarity (e.g., crib–bed, ocean–sea) than for lists with words paired by complementarity (e.g., crib–baby), while older adults had higher recall for complementary than for similar pairs. With both types of lists older adults had poorer recall than middle-aged adults. These results suggest that the type of organization people can use may vary with age. We return to this issue later.

Age-related changes in mnemonic strategies in paired-associates learning. In paired-associates (P-A) learning, the goal is to produce one member of a pair of items when the other is offered as a cue. Young adults often spontaneously engage in a variety of strategies that link the pair members by imagery or by some verbal mediator. Such mediators integrate the two members of a pair into a whole so that minimal memory search is required for either of the pair members given the other. The poorer performance of older adults in P-A tasks has been attributed to their failure to spontaneously use such mnemonic strategies. Self-reports about imagery following a P-A task do confirm that older adults use linking imagery less often (Hulicka & Grossman, 1967; Nebes & Andrews-Kulis, 1976; Rowe & Schnore, 1971; Whitbourne & Slevin, 1978).

Nevertheless, the prediction from the production deficiency hypothesis—that instructions to use mediating techniques should eliminate age-related differences—is not supported. When explicit instructions to use mediators are given, all age groups benefit, but age differences remain. For instance, Hulicka and Grossman (1967) found that P-A learning by both high-school students and older adults improved when they were told to use their own images, were given linking words to image with the P-As, or were given linking words with no image instructions, but age differences in performance remained. Similar results were found by Canestrari (1968) when he gave young and old adults verbal or pictorial mediators. In both studies improvement was greater for the older adults, but this may have been the result of ceiling effects for young subjects. This interpretation is supported by the finding that in a study by Hulicka, Sterns, and Grossman (1967), younger people’s performance did not come close to ceiling, and the improvement from strategy instructions was about the same across ages.

It has been suggested that age differences are not eliminated by instruction in mnemonic strategies because central nervous sys-
tem slowing in the elderly results in a concomitant slowing of mental operations (Birren, Woods, & Williams, 1979; Waugh & Barr, 1980). Older adults might therefore not be able to use mnemonic strategies, even when instructed to do so, if presentation rates are very rapid or if response intervals are too short. The cognitive slowing position predicts that age differences should be eliminated by slow or self-paced learning conditions. The evidence is by no means unanimously in support of such a position. With self-paced learning, age differences in performance remain even after instructions about mediators (e.g., Canestrari, 1968; Hulicka et al., 1967; Smith & Mason, 1977).

In contrast, Treat and Reese (1976) did find that with a long response interval and explicit instructions to form interactive images, their older adults performed as well as their young subjects. The evidence also conflicts with a related prediction from the cognitive slowing hypothesis, namely, that older adults should require more time to produce verbal mediators or images. Nebes and Andrews-Kulis (1976) found that young and old adults took the same amount of time to make up sentence mediators for noun pairs but that the older adults were considerably worse on a surprise cued-recall task. Nebes (1976) found no difference in time to generate an image from a description in a matching task. All in all, the cognitive slowing position does not seem able to explain age-related differences in P-A learning.

The production deficiency approach predicts that mediators given by young and old adults should be qualitatively similar, with older adults simply failing to use mediators on a regular basis. However, the Treat and Reese (1976) study raises the possibility that older adults may not reach the same level of performance as young adults because the mediators they produce are qualitatively inferior. The importance of interactive imagery for effective retrieval is well known (e.g., Horowitz, Lampel, & Takanishi, 1969), and only Treat and Reese explicitly told their subjects to use this type of imagery. It is therefore conceivable that older adults are less apt to use interactive imagery spontaneously. Two studies have attempted qualitative evaluation of mediators without finding definitive support for the qualitative inferiority hypothesis (Marshall et al., 1978; Nebes & Andrews-Kulis, 1976). One finding of Nebes and Andrews-Kulis (1976) is, however, worth mentioning. These investigators analyzed the sentence mediators produced by their subjects in terms of length, grammatical construction, and rated imagery but found nothing that could fully account for the observed aging decrement in cued recall. They did find that older subjects had a tendency to produce mediators that were less integrative (for instance, the two nouns were in separate clauses), but reanalysis of the data taking this difference into account did not explain away the age difference.

Thus, the deficit of the elderly in P-A learning tasks cannot be fully explained by differential use of mnemonic strategies. Young adults do use these strategies spontaneously in laboratory situations much more often than do older adults. Indeed, older adults may fail to use particular mnemonics even after extensive practice unless they are reminded to do so (Robertson-Tchabo, Hausman, & Arenberg, 1976). However, older adults are able to use mnemonic techniques if instructed to do so, but this does not always boost their performance to the level of younger subjects. Both young and old subjects appear to benefit equally from mediation instructions. Older people do not require more time for either image or verbal mediator production, and there is no well-documented evidence that their mediators differ qualitatively from those of the young.

Age-related changes in recognition memory. It is widely believed (e.g., Kintsch, 1970) that recall entails retrieval processes while recognition requires only the judgment that an item is "old" (familiar or recent). As Bower, Clark, Lesgold, and Winzenz (1969) put it, "recognition tests which directly provide the test word, clearly bypass the search and retrieval processes by which S' generates his recall" (p. 329). Thus, if older adults suffer from a deficit in search, their recall performance should decline with age, while recognition performance stays
constant or shows less deterioration. Early work supported this position. For instance, Schonfield and Robertson (1966) presented people with lists of 24 monosyllabic nouns and adjectives and tested them for both recognition (using a multiple-choice test with five alternatives) and recall. Although recall declined systematically from age 20 onward, recognition performance was constant at about 80% correct.

Since publication of the Schonfield and Robertson (1966) article, other investigators have also reported lesser declines over the adult years in recognition than in recall (see Craik, 1977, for a review), but the finding of age-invariant recognition performance has not held up (see Schonfield & Stones, 1979, for a different conclusion). Most subsequent studies have reported a decline in recognition accuracy with increasing age across a wide variety of conditions, though the differences have not always been reliable. In this connection, it is important to note that some studies with findings of no reliable age differences in recognition lack power because of small sample size (Craik, 1971), overly simple tasks (Hartley & Marshall, 1967; Smith, 1975), or an insufficiently broad age range (Kausler, Kleim, & Overcast, 1975). In the remainder of this section we simply elaborate evidence for the conclusion that there are age-related declines in recognition memory. The reader who is already convinced of this point may wish to skip ahead to our summary of the research on the search deficit hypothesis.

Reliable age differences in recognition have been obtained with a variety of materials. Young adults perform better than older adults in tasks involving words (Botwinick & Storandt, 1974; Erber, 1974, 1978; Fozard & Waugh, 1969; Gordon & Clark, 1974a; Harkins, Chapman, & Eisendorfer, 1979; Kausler & Kleim, 1978; Rankin & Kausler, 1979), nonsense syllables (Gordon & Clark, 1974a), sentences (Fullerton & Smith, 1980), prose passages (Gordon & Clark, 1974b), pictures of objects (Harwood & Naylor, 1969; Howell, 1972), and photographs of faces (Ferris, Crook, Clark, McCarthy, & Rae, 1980; Smith & Winograd, 1978; but see Bahrick, Bahrick, & Wittlinger, 1975, for a somewhat different outcome).

The results from studies of memory for current and historical events have been mixed, with Warrington and Silberstein (1970) reporting no age decline in recognition, Squire (1974) and Warrington and Sanders (1971) reporting some age decline, and Perlmutter (1978) and Poon, Fozard, Paulshock, and Thomas (1979) reporting superior fact memory for older adults. Botwinick and Storandt (1980) found better recognition of socio-historic information in older adults but no consistent age pattern for information about the entertainment world. Such naturalistic studies are appealing because they seem to have more ecological validity than laboratory tasks, but interpreting their results is difficult because it is impossible to equate people of different ages on initial learning or exposure to the materials. For instance, efforts to isolate an optimal age for acquisition of information about contemporary events have been unsuccessful, perhaps because it is impossible to determine whether individuals learn about such events when they occur or at some later date.

Older adults might recall less well than younger ones not because they have failed to learn the material but because they are more cautious and less willing to produce items of which they are uncertain. In view of the considerable debate about whether the old are more cautious than the young (see Botwinick, 1978, for a review), it is important to note that the age decrement in recognition is not due to older adults' adoption of a more conservative criterion for saying that a test item is one of the ones they studied. The old do more poorly even on multiple-choice recognition tests (e.g., Erber, 1974), which should eliminate the effects of differential response criteria as a function of age by forcing subjects to choose one of several response alternatives. Also, studies using signal-detection theory methods to obtain estimates of response bias on recognition tests are not consistent: Some find older adults more conservative, others do not (e.g., Gordon & Clark, 1974a, 1974b; Harkins et al., 1979; Poon & Fozard, 1980). There is thus no compelling evidence that declines in
recognition memory with age are an artifact of increasing cautiousness.

It is also possible that the aging decrement could be due to cognitive slowing (Waugh & Barr, 1980). There is no evidence, however, to support such a position. Age-related declines in recognition have been found with presentation rates as slow as 8 sec/item (Rankin & Kausler, 1979; Smith & Winograd, 1978) as well as under self-paced presentation conditions (Erber, 1978; Gordon & Clark, 1974b; the intentional learning condition of Perlmuter, 1978). Furthermore, the old have not been penalized by too rapid a test rate, since in nearly all studies the recognition test has been self-paced.

To summarize, there appears to be a decline in recognition accuracy with increasing age that cannot be readily discounted. Theorists who maintain that recognition eliminates search through memory could argue that the problem is in one or more of the remaining retrieval processes we have outlined, some of which are operative during encoding, or in differences in rates of forgetting. Differential forgetting rates cannot be ruled out as an explanation because studies involving continuous recognition sometimes find no age differences in accuracy as a function of "lag," or number of items intervening between the first presentation of an item and its later repetition for test (Erber, 1978; Ferris et al., 1980; Wickelgren, 1975), but they sometimes do find greater declines in accuracy as a function of lag for the elderly (Poon & Fozard, 1980).

Several encoding deficit models have been proposed. For instance, according to the partial learning hypothesis (McNulty & Caird, 1966) the elderly may store less complete information about to-be-remembered items. They may therefore not be able to produce items in their entirety for recall but may be able to pick them out of a set containing both old and new items so long as the distractors are not too similar to the target items. We have found three studies that varied the difficulty of the recognition task by manipulating the similarity of the distractors to the target items and tested both old and young people. Smith (1975) reported that the elderly made more false alarms on semantically related distractors. However, this may simply mean that the elderly were more likely to say test items had been on the original list because an analysis using the signal detection measure of accuracy, $d'$, which is not affected by response criterion, caused the difference to evaporate. In any case, the number of errors for any group was very small. In Howell's (1972) study, the older subjects were worse than the younger in recognizing color patterns only when the distractors were rather similar to the items studied, but there was no overall interaction between distractor similarity for several types of stimulus material and age level. The only study to provide even moderate support for the partial learning hypothesis is that of Rankin and Kausler (1979), who found nearly twice as many false alarms on synonym and rhyme distractors (but not on unrelated lures) for their middle-aged and elderly subjects as for their young adult sample.

Evidence for the partial learning hypothesis is thus far from overwhelming. Part of the problem may be that the hypothesis did not specify the nature of the memory representation of "partially" learned items. Another encoding deficiency approach, that of the depth-of-processing framework, does not suffer from this shortcoming (Craik & Lockhart, 1972; Craik & Tulving, 1975). According to this approach the elderly do not carry out as complete a semantic analysis of new information as do the young, and this is the source of their memory problems. This hypothesis has led to a large number of studies. We shall defer further analysis of the importance of age-related differences in recognition until we have discussed those studies.

Summary. We have explored the search deficit explanation of memory decline in the context of studies of organization and recall, of strategy use in paired-associates learning, and of recognition. The outcome of research in these three areas has been the same. There is no consistent evidence that older people recall less well simply because they do not organize to-be-remembered material or simply because they do not engage in appropriate mnemonic techniques in paired-asso-
ciates learning. Nor do age differences disappear when recognition rather than recall is used to measure retention.

Depth-of-Processing Hypotheses

Perhaps the most popular current approach to memory decline in old age is derived from the levels-of-processing framework (Craik & Lockhart, 1972). In this view, incoming information can be encoded in different ways. For instance, a visually presented word can be encoded in terms of its appearance (e.g., whether it is printed in upper or lower case type), in terms of its acoustic properties (e.g., whether it rhymes with “frog”), in terms of its meaning (e.g., whether it is a member of the category “fruit”). These different ways of analyzing information are viewed as lying on a continuum from shallow to deep processing, with structural analyses at the shallow end and meaning analyses at the deep end. Deeper or more semantic analysis produces a richer or more elaborated memory trace (Craik & Tulving, 1975), which is more resistant to forgetting. Although the depth-of-processing hypothesis has undergone several revisions since its first formulation (e.g., Lockhart, Craik, & Jacoby, 1976), it is the earliest version that has been most influential in the area of memory and aging. According to this view, older adults may not spontaneously encode items semantically, and this would lead to poorer recall independent of other problems of retrieval (Craik & Simon, 1980). What seems to be suggested here, although the point does not appear to have been made explicitly, is that older adults are less likely to access conceptual information in semantic memory when processing new inputs; that is, they have a problem in accessing meaning, given a word.

It has been argued that the encoding of information may be controlled by the use of incidental orienting tasks. Subjects are not told to remember items but rather to perform some task that varies in whether it involves structural, acoustic, or semantic analysis of items (e.g., producing rhymes vs. synonyms). When a surprise recall test is given, performance in college students is typically better with more semantic orienting tasks. With such tasks, recall may not differ from intentional learning conditions in which people are told to memorize the material but are not told how to go about doing it (Craik & Lockhart, 1972).

There are two versions of the levels-of-processing hypothesis, which posit different reasons why old people do not encode meaning efficiently (Craik & Simon, 1980). The production deficiency hypothesis asserts that older people do not apply deep processing strategies spontaneously, but that they can utilize them when forced to do so. Under such conditions age differences should be eliminated. Note, however, that the production deficiency hypothesis can predict some residual age differences, even when semantic orienting tasks are used, because older adults may have deficiencies in memory search. Combining semantic orienting tasks with techniques of measuring retention that purportedly eliminate memory search (i.e., recognition) should, according to this view, eliminate age differences in memory.

Eysenck (1974) has suggested that older adults have a processing deficiency rather than a production deficiency; that is, they cannot perform deep semantic processing operations. Craik and Simon (1980) suggest that the reason for this inability to process deeply is that older adults have diminished processing resources and that deep semantic processing requires more attention. Thus, older adults should be especially penalized by deep processing tasks. They claim, nevertheless, that forcing older adults to engage in semantic processing and eliminating search requirements should bring their level of performance up to that of younger adults. Thus, in fact, Craik and Simon appear to espouse the production deficiency approach.

Free recall. There are a number of studies of free recall within the levels-of-processing framework. The pattern of results is quite complex, and we keep two issues separate for the sake of clarity. The first concerns the comparison between intentional and deep semantic processing conditions across ages. The second concerns the interaction between different types of incidental orienting tasks and age. We take these up in turn.

If old people do more poorly than young
people under intentional learning but not when deep semantic processing is imposed on them, this would suggest that the differences observed under intentional learning are due to lack of spontaneous deep processing in the elderly. On the other hand, if the elderly suffer from a processing deficit, semantic orienting tasks should not eliminate the age difference. The results of seven studies are inconsistent with the production deficiency hypothesis. Eysenck (1974) compared free recall in old and young adults following intentional learning and semantic orienting tasks (producing an appropriate adjective or image). He found age differences in the semantic orienting conditions as well as with intentional learning instructions, and semantic orienting tasks did not boost recall over that observed in the intentional condition for either age group. A similar outcome has been reported by Erber, Herman, and Botwinick (1980), with an orienting task involving pleasantness judgments of word meanings. White (cited in Craik, 1977) compared case, rhyme, and category judgment tasks with intentional learning. There were no differences in recall between the category judgment and the intentional learning conditions, and the size of the age difference was about the same for the two conditions. In two studies Perlmutter (1978, 1979a) obtained a similar result comparing intentional recall with recall of the stimulus words used in an incidental word association task. Mason (1979) used the same tasks as White did and found that category judgments and intentional learning instructions produced equivalent levels of recall, whether subjects were young, middle-aged, or older adults, but young and middle-aged adults recalled more than the oldest group under both conditions. Zelinski, Walsh, and Thompson (1978) compared recall following intentional learning and orienting tasks involving pleasantness judgments, determining whether a word contained certain letters, and passive listening. Although there were age differences such that young and young-old (aged 55–70) people recalled more than the old-old (aged 71–84), intentional learning and pleasantness judgments produced equally good recall.

Thus, in no study did deep semantic processing tasks eliminate the age differences in recall that were found with intentional learning. This result would seem to rule out the production deficiency hypothesis. Nevertheless, the belief persists that aging decrements in memory are due to strategic differences in initial depth of encoding. It is argued that the age differences observed when initial processing is controlled are due to other problems, namely, defects in the search processes involved in recall. The corollary to this, as we have mentioned, is that age differences should evaporate when initial processing is controlled and search requirements are eliminated. As we will show, however, age differences persist when recognition accuracy is the dependent variable.

Furthermore, a little thought reveals an even more serious problem. Applying the argument that under semantic processing conditions, residual recall differences are due to search problems, forces us to an unwanted conclusion. Remember that the difference between old and young people given semantic orienting tasks is of the same magnitude as the age difference observed in intentional learning. Because it is assumed that initial processing is controlled with semantic orienting tasks, the residual difference in recall must be due to age-related search differences. Nevertheless, because this difference is the same as that found with intentional learning, the age difference in intentional learning must also—by this argument—be attributed to memory search differences. The hitch is that we began with the assumption that age-related recall differences are attributable at least in part to encoding differences, but the data require the conclusion that the only differences are in memory search. Note that this conclusion is forced only for the production deficiency hypothesis, not for the processing deficiency hypothesis. The finding of equivalent age differences in intentional learning and in semantic orienting conditions could be interpreted as evidence that the elderly are spontaneously processing as deeply as they can in the intentional conditions of the studies reviewed above.

Let us now examine the Age × Orienting Task interaction, excluding intentional learning conditions. If we take seriously the notion
that orienting tasks control processing at input, then the view that age differences in memory are the result of a production deficiency in the elderly leads to the prediction that with any orienting task that predetermines subjects' responses (e.g., those used by White and by Mason), there should be no age differences, regardless of the hypothesized level of processing required. This result is never obtained with free recall, although it is sometimes found with recognition.

Even if we acknowledge that residual age differences in recall could be the result of the memory search requirements of this task, we cannot predict an interaction between orienting tasks and age. At most, we would expect an effect of orienting task on recall but a constant difference between ages for all orienting tasks, with performance favoring the young in all cases. This is just the pattern obtained by Zelinski et al. (1978), who found that pleasantness judgments produced better immediate recall than the other orienting tasks, with equivalent age differences in all conditions. The predominant pattern, however, is that semantic orienting tasks help at all ages, but that there is also an Age × Task interaction such that age differences are small and unreliable for shallow processing tasks and larger for deeper processing tasks (Erber et al., 1980; Eysenck, 1974; White, cited in Craik, 1977). Mason (1979) found that category judgments resulted in better recall than case and rhyme judgments for young and middle-aged adults but not for old adults. In these studies recall in the shallow processing conditions is at or near floor for all age groups. Thus, the meaning of the interaction is not clear. What is clear is that age differences in memory persist with semantic orienting tasks. The data support a processing deficiency hypothesis.

Recognition. Given the apparently clean picture in recall, it is unfortunate that studies of recognition memory provide at best mixed support for any version of the depth-of-processing position. The same two issues that we took up for recall can be addressed here. First, consider the comparison between performance with deep semantic orienting tasks and intentional learning. White (reported in Craik, 1977) found that with category judgments, old and young performed equally well, but that with intentional learning, the usual difference was found. Craik and Simon's (1980) replication of White's study also found smaller differences with category judgments than with intentional learning instructions, but age differences remained even when initial processing was controlled. Perlmuter (1978, 1979a) reports a similar finding of reliable age differences in recognition following intentional learning but not following a free-association task, although the performance of her older subjects was still slightly poorer than that of her younger ones.

Other patterns of results have also been reported. Mason (1979) found no difference in d' scores with intentional learning instructions, but the young outperformed the old with a category judgment task. Moreover, the young performed better with the category judgment tasks than with intentional learning instructions. Smith and Winograd (1978) had people view photographs of faces under one of three instructional sets: (a) intentional learning, (b) judging whether the face has a big nose (physical feature analysis), or (c) judging how friendly the person is. Although the “friendly” task improved performance over intentional learning instructions for both old and young subjects, the old performed more poorly on both tasks, and there was no interaction between age and orienting instructions. Finally, Erber et al. (1980) found better recognition for old and young subjects with intentional learning instructions than with a semantic orienting task involving pleasantness judgments and no Age × Instructions interaction.

The picture is also confused when we consider the Age × Task interaction for recognition, excluding the intentional learning condition. Remember that the processing deficiency hypothesis predicts that age differences should be exacerbated by deeper processing, while the production deficiency hypothesis predicts no age difference when processing is controlled with an orienting task and improved performance for all ages with tasks requiring deeper processing. White (cited in Craik, 1977) found no age differences for case, rhyme, or category judgment tasks and equal improvement for both age
groups when rhyme and category judgment tasks were compared. Similarly, both Erber et al. (1980) and Smith and Winograd (1978) found that deeper processing helped all age groups, but that there was no reliable Age \times Task interaction. Mason (1979) found no age differences within an orienting task except after category judgments; here the young were better than the oldest group. The young were helped more by deeper processing than the old, who did not benefit from deeper processing.

It is unclear why this miscellany of results should be obtained. Whatever the reasons for the inconsistency, we conclude that the recognition data do not, overall, unequivocally support any version of the depth-of-processing explanation for age-related differences in memory.

Cued recall. Cued recall may be considered intermediate between free recall and recognition in terms of memory search requirements. Age differences are not eliminated by supplying extralist retrieval cues at the time of test but not at input (e.g., Hultsch, 1975). It is not clear whether the remaining age difference is due to deficient initial encoding in the elderly, to a mismatch between the extralist cues and the subject’s own encodings, or to both factors. A number of studies have attempted to control initial encoding with orienting tasks and to ensure that the cues given at recall have been encoded with their corresponding list members. The predictions here parallel those for recognition. With a relevant orienting task, the production deficiency hypothesis predicts that the old should benefit more from retrieval cues than the young; the processing deficiency hypothesis predicts no diminution of the age differences.

Simon (1979) has recently argued that older adults encode information on a more superficial level and therefore should be less able to utilize semantic retrieval cues than younger adults. She attempted to influence depth of processing by telling subjects that they would be cued for recall with phonemic cues (the first two letters of the target words), semantic cues (synonyms), or no cues (free recall). In her first experiment, free recall decreased with age; all age groups (young, middle, old) were helped by phonemic cues, and only young subjects benefited from semantic cues. In her second experiment, semantic processing was encouraged by embedding the to-be-remembered words in sentences and asking subjects to read the sentences silently. Under these conditions, phonemic cues were beneficial for the two older groups but not reliably so for the youngest group, while synonym cues aided the two younger groups but not the oldest group. Simon suggests these results show that the old use more superficial memory codes than the young. However, this conclusion is suspect because neither Drachman and Leavitt (1972) nor Smith (1977) found greater benefits for old subjects than for young ones with first-letter cues. Simon’s results are also incompatible with Smith’s finding that category cues presented only at recall benefited all age groups equally; if Simon were correct, the old should benefit less or not at all because they do not encode semantically.

Simon’s (1979) results are also problematic in that there is no way of knowing whether her instructions actually influenced processing because no overt response was required during initial processing. We have found two other studies of cued recall that did require overt responses during the semantic orienting task. Till and Walsh (1980) found that age differences in recall of sentences could be eliminated by using cued recall following an acquisition task that required subjects to give a written response that was related to sentence meaning. They used implicational cues such as “television” for the sentence “The youngster watched the program.” Perlmutter (1979a) compared young and old adults in cued recall of words following both intentional and incidental learning instructions. In the incidental task, subjects gave free associates to words from the Palermo and Jenkins (1964) norms. The retrieval cues were either the most common associates of the words in the Palermo and Jenkins norms (for all of the intentionally learned words and half of the incidentally learned words) or the subjects’ own first response from the orienting task. Contrary to Till and Walsh’s study, older adults did not achieve the same level of performance as young adults with cued recall under either
intentional or incidental learning, though the difference between age groups was larger for intentional learning. The overall pattern of these results is not consistent with any version of the depth-of-processing approach.

**Summary.** Results from free-recall studies that have attempted to control initial processing are unanimous in reporting no reduction in the size of age differences with any type of deep orienting task. Even when memory search requirements are minimized by using recognition or retrieval cues, age differences are not always eliminated. The results are clearly inconsistent with the production deficiency version of the depth-of-processing hypothesis. The processing deficiency hypothesis is supported by the results of free-recall studies, but the outcomes from other tasks are inconsistent in this regard.

Two methodological problems are apparent in these studies. First, in several studies there have been no adequate checks on whether orienting tasks do produce similar initial encoding in young and old subjects. Although requiring an overt response at least guarantees that subjects are performing the orienting task, there must be a further check of determining whether the task is being performed in the same way across ages. Even in studies such as those by Mason and by White, in which the orienting task requires a very constrained response (e.g., Does this word belong to the category “fruit”?), there may be processing differences as a function of age. That is, different semantic information may be activated during retrieval of category information. Such age differences in the pattern or extent of semantic activation would not be apparent in performance on the orienting task, and this paradigm provides no way of monitoring semantic activation directly. Simon (1979) has made a related point, arguing that although orienting tasks may determine the nature of processing to a considerable extent, it cannot be assumed that particular orienting tasks produce the same underlying mental operations in normal and in memory-deficient populations. Given this problem, is the depth-of-processing hypothesis, or at least the production deficiency version of it, testable because the critical experiments cannot be performed without the assumption that orienting tasks control processing?

The second issue is the theoretical adequacy of the depth-of-processing approach. T. O. Nelson (1977) has pointed out a serious problem of circularity. The lack of a convenient way of measuring task “depth” independent of memory performance may lead to inconsistencies in research involving “deep” tasks. There is no way of comparing different orienting tasks across studies without a yardstick for measuring depth, nor is there any guarantee that the depth scale is the same for all age groups.

**Conclusions**

It is clear that the results of the studies on memory and aging that we have reviewed are inconsistent, at least when interpreted within the framework of the major hypotheses concerning memory declines in later adulthood. Neither version of the production deficiency hypothesis can fully account for the observed age differences in memory. A serious problem is that these hypotheses are based on overly simplistic analyses of cognitive operations in memory. It is thus no surprise that they do not allow specification of the mechanisms involved in age differences in free recall, cued recall, or recognition.

In free recall one focus has been on memory search, but when the literature is examined closely, we see that semantic processes involving the relation between words and their meanings may also be implicated. The depth-of-processing approach has emphasized semantic information processing, but there has been no in-depth consideration of the specific mechanisms involved. In addition, failure to recall may result from inadequate encoding or utilization of contextual information.

Another issue concerns the processes involved in cued recall. Retrieval cues may not automatically provide direct access to target items in memory, especially when they are related to targets inferentially (Till & Walsh, 1980). The effectiveness of retrieval cues may, in these cases, depend on the use of
strategies whereby the subject consciously generates words related to the cue and checks them for the relevant contextual tags. If older adults were less likely to use such a strategy spontaneously, age differences in cued recall would remain even after semantic orienting tasks. Attributing these differences to the inability of older adults to engage in deep processing would be an error. We are not suggesting that older adults are less likely to use such strategies, but only that the interpretation of cued-recall studies is in doubt.

There are also problems with the claim that recognition eliminates or minimizes retrieval. Even if memory search is eliminated by recognition, other retrieval processes (i.e., those involved in contextual and semantic information processing) are still important here. Furthermore, even the claim that recognition bypasses memory search is not universally accepted (Mandler & Boeck, 1974), but no effort has been made to determine whether age differences in recognition could be due to memory search problems in the elderly. Thus, a finding of age differences in recognition following either intentional or incidental learning instructions, with or without orienting tasks of various kinds, cannot be unambiguously assigned to encoding or to retrieval problems.

Contextual and Semantic Information Processing in Old Age

In contrast to the emphasis on strategies in production deficiency approaches, contextual and semantic information processing are thought to involve automatic as well as attentional, strategy-dependent components. According to recent formulations (e.g., Posner & Snyder, 1975), automatic processes occur without awareness, do not interfere with other ongoing cognitive processes, and are not susceptible to instructional variables or to conscious control.

Our review of the memory and aging literature leaves open the possibility that there may be age changes in what are thought to be automatic processes. We present specific evidence suggesting that this is the case.

Hasher and Zacks (1979) have argued that automatic processes remain unchanged throughout the life span and make lack of change with age another criterion for automaticity. We think, however, that this position is premature and that the first step is to determine whether any processes satisfy the other criteria for automaticity but fail the developmental one. Thus, in our review of contextual and semantic memory we consider both intentional and automatic processes in searching for the mechanisms that underlie memory deficits in old age.

The Role of Context in Recall and Recognition

The role of context in everyday life is clear. We frequently tell several of our friends the same story, put our keys in different places, or try to remember where we read a particular fact. Each of these commonplace activities requires that we remember contextual information if we are not to boringly repeat ourselves, spend a great deal of time in futile search of home or office, or hunt endlessly through books for information. In list-learning tasks, nothing new is learned because the items to be remembered are already part of the learner's vocabulary; what is required is that contextual information be stored to identify the circumstances surrounding acquisition (i.e., that I need to purchase laundry detergent on this particular trip to the supermarket). Retention of context may well be the basis for discriminating one memory from another (e.g., Hunt & Elliott, 1980). Schank and Abelson (1977) have discussed the concept of stereotyped action sequences or "scripts." Part of our knowledge about the world concerns these routine activities such as going to a restaurant, getting up in the morning, attending a movie, spending a day at the beach. Such activities are so stereotyped that we know which actions are likely to occur in a given script. We perform scripted activities so often that the only way to keep track of the particular actions performed on a given occasion (e.g., whether we left a tip) is through the storage of contextual infor-
information about each episode (Bower, Black, & Turner, 1979).

This view has motivated current theorizing about memory. For instance, Tulving and his associates (e.g., Thomson & Tulving, 1970; Tulving & Osler, 1968; Tulving & Pearlstone, 1966; Tulving & Thomson, 1973; Watkins & Tulving, 1975) have argued forcefully for the "encoding specificity principle," which asserts that the effectiveness of retrieval cues depends on whether they were also encoded as part of the input context; that is, only those cues that were part of the original encoding context can be effective retrieval aids in either recall or recognition. Although this strong view of encoding specificity has been challenged (e.g., Ehrlich & Philippe, 1976; Light, Kimble, & Pellegrino, 1975), a weaker version of the encoding specificity hypothesis seems unsailable, namely, that reinstatement of contextual information present during initial processing improves recall and recognition (Anderson & Bower, 1972; Bower, 1967; Estes, 1959). There is abundant evidence that reinstatement of internal and external contextual information does indeed improve recall and recognition performance (e.g., Geiselman & Glenny, 1977; Godden & Baddeley, 1975; Hintzman & Summers, 1973; Isen, Shaliker, Clark, & Karp, 1978; Light & Schurr, 1973; Smith, 1979; Thomson & Tulving, 1970).

Reinstatement may have its effects by improving the efficiency of the memory search process. It may also increase the likelihood that the test item is interpreted semantically the same way as it was during acquisition (Light & Carter-Sobell, 1970; Reder, Anderson, & Bjork, 1974). Judgments that a recognition test item is old are based on the overall similarity of the encoded test item to memories that are accessed during testing; both semantic and nonsemantic information (e.g., the location in which an event was experienced, the sound of the speaker's voice, mood or drug states) may be evaluated in arriving at final recognition judgments. Thus, if nonsemantic contextual information is not retained or utilized as well in the elderly as in the young, we would expect to see impairment in memory tasks in which contextual information plays a role. We consider two sources for decrements in processing of contextual information: (a) increase in interference with age and (b) decline in central processing capacity with age.

The view that the elderly are more susceptible to interference from both retroactive and proactive inhibition is common. Horn (1976) states this position as follows:

By virtue of having lived longer than younger persons, older persons tend to have been exposed to more opportunities to learn and therefore presumably (on the average) would have learned and stored more than younger persons. Thus, it is not unreasonable to suppose that learning and memory deficits associated with age are, at least in part, a result of interference of one form or another. (p. 469)

Having more experiences of a certain kind might increase the number of contextual associations that are similar to each other and thus hard to distinguish (Anderson & Bower, 1972), making recall less likely and recognition less efficient.

Research on interference effects as a function of age in adulthood does not, however, unambiguously support the notion of increased interference in the elderly and, moreover, has been beset with methodological problems (see reviews by Craik, 1977, and by Kausler, 1970), making firm conclusions difficult. For instance, if contextual information about list membership is less available to the elderly, they should exhibit a higher rate of first-list intrusions in second-list learning in the A–B, A–C paired-associates learning paradigm. Some workers find this effect (e.g., Lair, Moon, & Kausler, 1969); others find increased intrusions when first-list learning is not equated across age groups but not when level of first-list acquisition is the same (Hulicka, 1967). This suggests that interference in the elderly is the result of inadequate learning. Increased rates of intrusions in recall of categorized lists by the elderly (Smith, 1974) could, however, be interpreted as stemming from greater interference in the elderly.

A well-established finding in research on aging is that the elderly have diminished processing capacity in that they are less able than are the young to divide attention between two tasks to be performed simulta-
neously (Craik, 1977; Craik & Simon, 1980). This finding suggests either that they have less total processing capacity to allocate at a given moment, or that tasks that once required less capacity now require more attention, leaving less residual capacity for other activities even if total capacity remains the same. Certain kinds of contextual information may be stored in an obligatory fashion (i.e., without expenditure of effort) as a consequence of normal encoding operations, while other kinds of contextual information may be stored only if attention is directed to them during learning. Hasher and Zacks (1979) have argued that by virtue of the way in which human beings are "wired-up," event frequency as well as information about the temporal and spatial characteristics of information are stored effortlessly and automatically.

The automaticity issue is important for the study of memory decrements in later adulthood. If contextual information of various kinds is encoded only if attention is allocated to its processing, then we might predict that older adults will remember such information less well because of declining processing capacity. On the other hand, if storage of contextual information is an obligatory concomitant of normal encoding operations, we might not expect to see any change in memory for contextual information with increasing age. This is, in fact, the position adopted by Hasher and Zacks (1979).

Studies of Contextual Information Processing in Older Adults

Memory for contextual information. There is relatively little evidence relevant to the issue of whether there are age-related decrements in memory for contextual information. What evidence there is does suggest that older adults may not store or retrieve certain types of contextual information as efficiently as younger adults, but that there may be no age differences in memory for frequency information. The support for these conclusions comes from a variety of studies that provide either indirect or direct evidence on these points.

Let us first consider the indirect evidence from several sources. Kausler, Kleim, and Overcast (1975) examined item recognition in young and in middle-aged adults following a multiple-item study trial. They showed their subjects pairs of words with one member of each pair designated as "right," and they instructed the subjects to learn which item was "right." Though the two age groups did not differ on item recognition, the middle-aged subjects were considerably less accurate in remembering which items were "right" and which were "wrong." This could be interpreted as failure in a paired-associates task. It could also be interpreted as loss of contextual information.

Mergler, Dusek, and Hoyer (1977) used an incidental learning task in which subjects were asked to learn the serial order of objects. The objects consisted of cards, each containing a drawing of one animal and one household object. During the learning phase, the experimenter always asked the subjects about the location of the animals and never mentioned the household items. The incidental learning task required subjects to indicate which household item had been paired with which animal. Older adults performed more poorly on both the serial-order task and the incidental learning task. Although the authors do not report this, our calculations indicate that the young but not the old subjects exceeded chance levels of performance on the incidental task.

In a study of paired-associates learning, Kausler and Lair (1965) found no difference between young and old subjects in acquisition of responses for a 10-item paired-associates list, but the older subjects were far less likely to remember stimulus terms when tested with the response members of the pairs. If we consider stimulus members of paired-associates as contextual information, we see again that older adults do less well in remembering such information.

Rankin and Kausler's (1979) finding of increased false alarm rates for synonym and rhyme distractors but not for unrelated distractors in older adults may also be interpreted as support for lack of memory for contextual information. To the extent that subjects consciously think about related
events during initial processing or the related items are automatically activated in semantic memory during processing (Anisfeld & Knapp, 1968; Underwood, 1969), inability to discriminate whether events are externally produced or internally generated (Johnson, Raye, Wang, & Taylor, 1979; Johnson, Taylor, & Raye, 1977) would produce an increased tendency to make false alarms on recognition tests. There is a naturalistic observation that is related to this point: Older adults are more apt to say that they have trouble remembering whether they told someone something or only thought about telling her (Zelinski, Note 1).

More direct evidence comes from work by Zelinski and Light (Note 2), based on a study by Hintzman and Block (1971, Experiment 3). In Hintzman and Block's study, college students saw two lists of words (separated by a distractor task of about 5 minutes' duration) with a given word repeated 0, 2, or 5 times on each list. On a subsequent frequency-judgment task, students indicated how many times each word had occurred on each list. Zelinski and Light tested three groups of people: young, young-old, and old-old. Examination of frequency judgments for the conditions in which items occurred zero times on one list and either twice or five times on the other list indicated systematic declines in the proportion of correct list attributions with age. The youngest subjects correctly identified list membership of .40 of the items; the proportions for the two older groups were .31 and .25. These data demonstrate that older people may have difficulty in precise dating of temporal events. This conclusion, however, may need qualification, given the results of a study by Perlmutter, Metzger, Miller, and Nezworski (1980). These authors examined the ability of young and old adults to assign the correct date to historical events that took place between 1862–1877, 1922–1931, or 1962–1977, as well as the accuracy of their judgments as to which of two events from one of these periods was more recent. There were no reliable age differences on either of these tasks, though younger adults tended to perform better on the most recent events. This latter finding could be taken as support for the view that temporal judgments become less accurate with age, or it could mean simply that older adults do not attend to current events as much as younger adults.

The studies by Kausler and Lair (1965) and by Mergler, Dusek, and Hoyer (1977) may be interpreted as supporting the position that older adults are less likely to pick up or utilize contextual information, which was available during acquisition (but which subjects had no reason to suppose they would have to remember), because of diminished processing capacity.

Two interesting studies from Kausler's laboratory provide additional data that are relevant to this question. Kausler and Puckett (1980a) tested young and elderly adults on three tasks: recognition memory for words, memory for the case in which the words were printed, and recognition memory for both words and case. In the latter task, each test item consisted of four alternatives comprising an old word and a new word, each printed both in upper case and in lower case. The subject's task was to choose the alternative that duplicated an input item. The subjects were aware of the type of test to be administered. Although the Age X Task interaction was not reliable, further analyses showed no reliable age difference on content recognition, no doubt due to ceiling effects. The performance of both young and old adults was better than chance on the case test, but on this test and on the content plus-case test there were reliable age differences. If processing capacity is needed for storage of contextual information (i.e., if case information is not stored automatically), then asking people to remember this information should result in performance decrements in other memory tasks performed concurrently (Hasher & Zacks, 1979; Light, Berger, & Bardales, 1975). Regrettably, the authors do not report the proportion of correct word recognitions regardless of accuracy of case judgments in the content plus-case condition; this omission means that we cannot evaluate whether there was a tradeoff here between memory for case and content or whether this tradeoff, if it occurred, was larger for old than for young people. Nevertheless, these data do indicate
that memory for physical aspects of input is impaired in the elderly.

In a second article, Kausler and Puckett (1981) compared the performance of young and elderly adults in memory for voice of speaker under both incidental and intentional learning conditions. Twenty sentences were presented, half in a male voice and half in a female voice. Subjects were tested for cued recall of the two nouns in each sentence, and for the test on voice of speaker the subjects were given a list of the 20 input sentences and asked to specify the input voice. Recall of nouns was lower under intentional learning conditions when the older subjects were asked to remember the speakers’ voices; there was no reliable effect of learning condition for the young subjects. Voice recognition was better for young subjects than for older ones. Also, for young adults voice recognition exceeded chance under both incidental and intentional learning, but for older adults performance on this measure was above chance only under intentional conditions.

The same pattern of results was obtained in a second experiment comparing young and middle-aged adults. Thus, it appeared that instructions to remember speaker’s voice improve memory for this aspect of nonsemantic context for middle-aged and elderly adults but not for younger ones. There was also a trade-off between memory for sentence nouns and speaker’s voice for the two older age groups but not for the younger one. These results suggest that memory for speaker’s voice is not automatic and that the age-related decline in memory for this type of contextual information is the product of diminished processing capacity. Because the young do equally well in incidental and in intentional learning conditions, it would appear that they have sufficient capacity to allocate to both content and context memory, but that reduced capacity in the middle-aged and the elderly produces a tradeoff in memory for these types of information.

It has been argued that information about event frequency is stored automatically by young adults (Flexser & Bower, 1975; Hasher & Chromiak, 1977; Hintzman & Stern, 1978; Howell, 1973; Rose & Rowe, 1976, Experiment 1). Hasher and Zacks (1979) have suggested that if memory for event frequency does not require effort, there should be no age-related differences in this aspect of memory. They report (Experiment 2) that the frequency judgments of both young and old adults increased with true event frequency, but that those of the old did so at a slower rate (see also Warren & Mitchell, 1980). If this measure is used, the young appear to be more accurate than the old. This effect could be due to age differences in response bias, and when the correlation between actual and judged frequencies—a measure designed to eliminate differences in bias—was used, the age differences in frequency judgments disappeared. Neither age group’s judgments were affected by using incidental rather than intentional learning instructions for frequency information. Similarly, Attig and Hasher (1980) found no differences in frequency judgments as a function of either age or instructional conditions when response bias was eliminated by forcing subjects to choose which of two items had been presented more frequently. Kausler and Puckett (1980b) tested young and old subjects under both intentional and incidental frequency memory conditions using a forced-choice frequency-judgment test. Neither age nor instructions had any effect on performance, which was in any case very close to ceiling. Nevertheless, when the same subjects were tested on paired-associates learning, the old did not do as well as the young. Thus, these data are consistent with the view advanced by Hasher and Zacks that frequency judgments are based on automatic processes.

There are two problems, however, in interpreting the results of frequency-judgment tasks. First, performance on tests in which people must choose which of two items was presented more frequently is close to ceiling and may therefore be insensitive to true age differences. Also, successful performance on such forced-choice tests depends only on remembered frequency increasing monotonically with actual frequency for all age groups and not on the functions being identical across groups. Second, it is not clear whether the correlational measure used by Hasher
and Zacks (1979) is appropriate in developmental studies. Until there is actual evidence that older adults do tend to assign smaller numbers to event frequencies than younger adults, the use of correlational analyses that reduce the interaction of actual frequency with age must remain suspect. Also, in the Zelinski and Light (Note 2) study described earlier, age differences in the relation between judged and actual frequencies remained even when a correlational analysis was used. Finally, it has been claimed that frequency judgments are based on contextual information (e.g., Hintzman & Stern, 1978); it could therefore be predicted that if older people have problems in remembering context, they should show impaired frequency judgments. The final word on this issue is not yet in.

Use of contextual information. There is some evidence that the old may be less able to utilize contextual information in retrieval, which should come as no surprise given that they seem less likely to store such information. Simon (1979, Experiment 2) had young, middle-aged, and older adults read sentences silently. They were to remember the last word of each sentence and were tested by free recall or recall cued by phonemic cues (the first two letters of the to-be-remembered words) or semantic (synonym) cues. At the end of the session, they were cued with the sentence frames used at input. Reinstatement of the input context boosted performance well above free-recall levels for young adults but not for the two older age groups. Unfortunately, there is no guarantee that all subjects actually read the sentences at input, though they were instructed to do so.

A similar objection may apply to a study by Simon and Craik (cited in Craik & Simon, 1980) in which old and young subjects were given sentences containing a word to be learned, though we are not given details of the study procedure. Words were cued either by adjectives that had occurred in the sentence (context-specific cue) or by a general cue—that had not occurred in the sentence—as to the meaning of the word. For young adults, the context-specific cues were more effective, but for older adults the general cues were more effective. These results suggest that older adults may not encode context as effectively as younger ones (possibly because they do not comprehend the sentences as well) or that they cannot utilize contextual information as a retrieval cue as effectively, or both.

Two studies have examined the question of whether responses made by subjects during acquisition will be equally good retrieval cues for young and older adults. Perlmutter (1979a) found that reinstatement of the subjects' own associates as retrieval cues was helpful to young but not to older adults. She concludes that older adults have problems in using retrieval cues even when these are provided for them and that their failure to take advantage of their own associates as cues may be the result of more variable encoding of words, which makes it more difficult for them to retrieve the original stimulus terms. It is interesting that Till and Walsh (1980) reported a strong correlation (.82) between sentence recall and the similarity between the experimenter-provided retrieval cue and the older subjects' comprehension responses. The corresponding correlation for young subjects was only .15. This suggests that the more similar the experimenter's cue is to the subject's orienting response, the better the recall. This would predict that in Perlmutter's study the old should have benefited more from having their own associative responses as cues (rather than the most common associative responses from the norms), but in fact it was the young who benefited. The reason for this apparent discrepancy in results is not obvious.

In summary, it appears that older adults are less able to retain information about contextual information than younger adults and that it is effortful for them to remember nonsemantic contextual elements. (It is interesting to observe that this is the opposite of what might be anticipated from the depth-of-processing approach, which should predict that since older adults process less deeply it is precisely the nonsemantic contextual information that they should retain.) Although the evidence from studies of memory for event frequency is not altogether clear, it could be interpreted as indicating that frequency information is stored equally well by all age groups and that such information is stored in an obligatory fashion.
The evidence is also inconclusive as to the question of whether the elderly are unable to utilize the contextual information they have available in discriminating one memory from the next.

The Role of Semantic Processes in Memory

According to the retrieval framework we have been discussing, the processes involved in search of semantic memory to find specific information, access to a meaning given a word, and access to a word given a meaning, are all essential for recall and recognition. Here we review research that has investigated the nature of these semantic processes. Our goal is to consider the mechanisms involved in semantic information processing. This review sets the stage for the next section, which evaluates studies of age-related changes in semantic information processing in old age.

Recent theories have postulated that semantic processes involve both automatic and attentional, strategy-dependent components (e.g., Collins & Loftus, 1975; Posner & Snyder, 1975; Posner & Warren, 1972; Schneider & Shiffrin, 1977). The automatic processes occur at early stages of processing and include activation of words associated with a meaning or of semantic information associated with a word. Activation leads to retrieval of the information in memory, or makes it more available for retrieval, a process called priming. According to a popular model, activation spreads automatically through a semantic network to related concepts. The pattern of automatic activation depends on structural aspects of memory that reflect the nature of the organization of stored information (e.g., Collins & Loftus, 1975; Collins & Quillian, 1969; Posner & Snyder, 1975; Schvaneveldt & Meyer, 1973). The activation pattern may be influenced by context or directed by the subject’s conscious attention, but the pattern based on automatic processes is thought to be invariant, at least in young adults (e.g., Posner, 1978).

Evidence for semantic priming comes from a variety of studies showing that processing a target stimulus is faster when it is preceded by an identical stimulus (e.g., “A” . . . “A”; Posner & Snyder, 1975), a stimulus with the same name (e.g., “a” . . . “A”; Rabbitt, 1979), or a semantically associated word (e.g., “ARM” . . . “LEG”; Meyer & Schvaneveldt, 1971; Neely, 1977) or phrase (Schuberth & Eimas, 1977; Tyler & Marslen-Wilson, 1977). These priming effects appear to be attributable to both intentional and automatic processes (e.g., Fischler & Bloom, 1979; Neely, 1977; Posner & Snyder, 1975; Tweedy, Lapinski, & Schvaneveldt, 1977). That is, when successive stimuli are related in a particular way on a number of trials, subjects appear to expect this type of stimulus. This expectation reduces reaction time (RT) when the stimulus is compatible with expectation, but it increases RT when an unexpected stimulus is presented. The reduction in RT appears to be due to activation caused by a conscious shift of attention to the expected item prior to its presentation. The increase in RT appears to be due to the time required to shift attention to an unexpected item when it is presented (Posner & Snyder, 1975). Automatic semantic priming has been demonstrated with young adults when expectation was eliminated by presenting only one related word pair (Fischler, 1977) and when the priming effect for related words was not accompanied by an increase in RT for unrelated word pairs (Neely, 1977).

Let us consider how age-related changes in these semantic retrieval processes might affect memory performance. First, the way words are encoded during their initial presentation depends on semantic activation. That is, the features of meaning that are encoded are determined by the pattern of activation in semantic memory. For example, there would be age differences in encoding if there were an age-related shift in the nature of semantic memory organization so that the pattern of activation for a specific word varied across age. Similarly, a change in the strength of semantic activation might result in fewer semantic features being encoded. If fewer semantic features were activated, language comprehension might also be affected, and, indeed, comprehension deficits have been reported in older adults (e.g., Feier & Gerstman, 1980; Taub, 1979). Since material that is comprehensible is easier to remember (e.g., Bransford & Johnson, 1972), this problem might contribute to older adults’
poorer retention of prose (e.g., Cohen, 1979; Taub, 1979).

Second, semantic processes during encoding may also influence the use of organizational strategies that improve recall. When items can be organized into an interrelated structure on the basis of interim associations, categorical relations, and so forth, they are easier to remember. Semantic processes can facilitate the use of organizational strategies by activating features of meaning shared by two words (Huttenlocher & Newcombe, 1976). The duration of activation is important because the relatedness of items in a list will not affect recall if they are separated by too long an interval (Jacoby, 1974). Thus, the probability of subject-imposed organization and the type of organization that is imposed may depend, at least in part, on semantic activation processes.

Third, retrieval in the output phase of recall and recognition tasks may also be influenced by automatic activation processes. Correct recognition depends on the test item being interpreted semantically in the same way as it was at presentation (e.g., Light & Carter-Sobell, 1970). Variability in the pattern of semantic activation at initial presentation of a word and at test would reduce the probability of a consistent interpretation. In recall, spreading activation may be the basis for the improved performance found with the use of retrieval cues that are semantically related to list items. For example, effective use of a category name as a retrieval cue depends on a consistent activation pattern at input and recall. That is, if a category name activated different category members at input and recall, it would be of little use in improving retrieval. Of course, active search strategies might supplement such automatic operations.

Finally, in most experimental recall tasks, correct performance depends on remembering not only the meaning but the exact words that were presented. Since the connection between a word's meaning and its name may be automatically activated (e.g., Posner, 1978), an impairment in this activation could result in correct recall of the meanings of words on the list but an inability to recall the correct words. In a common analogue to this outside the laboratory, the so-called "tip of the tongue" phenomenon, a word whose meaning is thoroughly in mind cannot be retrieved (Brown & McNeill, 1966). Zelinski (Note 1) found an increase in self-reports of such word-finding difficulties in the elderly.

Studies of Semantic Information Processing in Older Adults

The popular view is that verbal ability is well maintained in old age relative to performance on nonverbal tasks. Indeed, this has been called a "classic aging pattern" (Botwinick, 1978). For example, performance of elderly subjects on the Wechsler Adult Intelligence Scale (WAIS) usually shows the least decline, or even none, on the vocabulary and information subtests (e.g., Botwinick, 1977; Goldstein & Shelly, 1975; Harwood & Naylor, 1969). Certainly, this suggests that retrieval of semantic information shows less impairment than retrieval of newly acquired information. But when quality of response on the vocabulary subtest was analyzed, an age decrement was found that was not reflected in the quantitative scores (Botwinick, West, & Storandt, 1975). Older adults also demonstrate poorer performance on some vocabulary tasks requiring production of a word specified by semantic or graphemic features than on traditional vocabulary tests. For example, teLinde, Schonfield, & Adam (cited in Schonfield & Stones, 1979) found that older adults had higher vocabulary scores than young adults on the usual test in which a word is presented and its meaning must be given, but their performance suffered more than did that of the young adults when asked to produce a word given a definition and a first-letter cue. Thus, there may be age-related changes in verbal processes that are not detected in traditional vocabulary tests.

The first issue we will pursue is whether elderly adults have an impairment in semantic retrieval processes—in particular, in the time required to retrieve semantic information. We consider whether a deficit in activation processes seems to be implicated. Then we consider whether the nature of semantic organization changes during adulthood.
Semantic retrieval time. Verbal fluency tests measure the number of words that can be written or spoken in a given time and begin with a specified letter or are instances of a specified category. Older adults give fewer responses than younger adults on fluency tests, suggesting that it takes them longer to retrieve particular words (Birren, Riegel, & Robbin, 1962; Howard, 1980; Riegel & Birren, 1966; Schaie & Parham, 1977; Schaie & Strother, 1968; Schonfeld & Stones, 1979; Stones, 1978; but see Drachman & Leavitt, 1972, and Eysenck, 1975, for no age differences in a similar task). Longer reaction times for the elderly are also found in word-association tests in which subjects give the first word they think of after hearing a stimulus word or syllable (Riegel, 1968; Riegel & Birren, 1966; Riegel & Riegel, 1964; Burke & Peters, Note 3).

The faster rate of output for younger subjects could be related to a faster writing or speaking rate or to greater cautiousness on the part of the elderly. Speaking rate for the elderly, however, appears to be faster than the rate of output in fluency studies and thus seems unlikely to be a limiting factor (Birren, Riegel, & Robbin, 1962).

These results from fluency and word-association tests suggest that under some conditions, retrieval of information from semantic memory may be a slower process for the elderly. Although this may reflect a general slowing in cognitive function (Birren, Woods, & Williams, 1979), we may speculate that it also reflects a greater use of intentional search processes rather than processes based on automatic activation. Intentional processes seem to result in slower retrieval than automatic processes (Neely, 1977). Of course, both fluency and word-association tasks are inadequate measures of semantic retrieval time because both allow the use of strategies for retrieving items. Thus, age differences on these measures could be the result of differences in use of strategies rather than differences in semantic activation.

Studies of naming latency should be less susceptible to strategy use, and they provide some evidence for age differences in semantic retrieval. Poon and Fozard (1978) found age differences in naming latency for pictures but claim that they are the result of cohort differences in the familiarity of the objects in the pictures. Older adults had longer latencies and more errors than did younger adults for rare contemporary objects (e.g., calculator, dune buggy), but younger adults had longer latencies and more errors on rare dated objects (e.g., spats, churn). Latencies and errors were smaller for all ages when common objects were selected, with young people slower than old people with dated objects and with no age differences with contemporary objects. However, the correlation between reaction time and error rate suggests that longer latencies may have been the result of guessing strategies, not retrieval time. Another problem is that common objects with the same name were used in the dated and contemporary conditions. Because older adults had more correct identifications of common dated objects, they may have been more prepared to name the equivalent contemporary objects, compensating for any retrieval time deficit. Indeed, the repetition of object names in the common condition could explain their faster reaction time for all ages. Thus, these results suggest that there are cohort differences in the familiarity of objects, but they do not allow the conclusion that age differences in naming latency are due to such cohort effects rather than to aging effects on cognitive processes.

Thomas, Fozard, and Waugh (1977) found that naming latency for pictures of objects increased with age, and they presented convincing evidence that retrieval time was involved in the age difference. When the picture was preceded by a word, latencies were reduced on trials when the word named the object (match trials), with a larger effect for older subjects. Thus, there was a smaller age difference in latency when the object name was “primed.” Since priming seems to facilitate retrieval time rather than sensory processing or motor response time (e.g., Posner & Snyder, 1975), at least some of the age difference in the no-prime condition would seem attributable to slower retrieval in the elderly. In addition, the priming effects seem to be based, at least in part, on automatic processes. Reaction time was slightly slower when an unexpected picture
was presented (i.e., when the picture did not match the preceding prime word) than in the no-prime condition, which suggests an expectation effect. But this slowing effect was small relative to the reduction in reaction time on match trials. Thus, although some of the priming effect may have been due to expectation, it seems likely that automatic activation contributed as well (see Posner & Snyder, 1975, for an exposition of this logic). The results of this study suggest that older adults have longer lexical access time but stronger facilitation of naming when a picture is preceded by its name.

A study using the Stroop task also suggests that older adults have automatic activation effects from reading a word. In this task, people must name the color of the ink in which a word is printed. Naming the color is slower if the word is a conflicting color name and easier if the word and ink share a common name (e.g., Dyer, 1973). This Stroop interference effect is attributed to the subject's automatically reading the base word and retrieving its name, even though this slows reaction time by creating response competition between vocal responses to the ink color and to the base word (Posner, 1978). Negligible age differences in this task have been reported in time to name the ink color of color patches or to read color words written in black ink, but elderly adults were much slower than young adults to name the ink color in which a conflicting color word was written (Comalli, Wapner, & Werner, 1962). This result and that of Thomas et al. (1977) demonstrate that when a word is presented, name codes are activated equally well in the old and in the young, but they tell us nothing about activation of meaning.

Several other studies have compared priming effects in young and old adults. Both young and old adults identified target stimuli faster when they were preceded by physically identical stimuli (Rabbitt, 1979). However, Rabbitt (1968, 1979) reports that young but not older adults had faster recognition of a letter target when it was preceded by a letter with the same name but in a different case (e.g., "a" . . . "A"). This differs from the priming effect of names on picture targets found by Thomas et al. (1977), but in the Thomas study the response was a name and in the Rabbitt study it was depression of a button to indicate detection. Thus, name codes may be activated automatically across age and facilitate name responses in young and old, but they facilitate perception of a different stimulus with the same name only in the young. Hines and Posner (Note 4) found faster same–different name judgments for letter pairs when they were preceded by a same name prime for both young and old adults. Reaction times for identical ("A" . . . "AA") and non-identical ("a" . . . "AA") primes were not presented separately, so we do not know whether this result is consistent with Rabbitt's.

Rabbitt (1979) also reports that young but not older adults had faster recognition of letter stimuli that were expected to follow the preceding stimulus rather than those that were unexpected. Rabbitt concludes that no age-related changes in priming effects occur when a physically identical stimulus is repeated, but that the elderly do not show priming effects when the relation between successive stimuli is based on information stored in memory (e.g., expectation or sharing the same name). Older adults, however, did show faster responses to expected stimuli in a simple binary-choice reaction-time task (Fozard, Thomas, & Waugh, 1976; Waugh, Fozard, Talland, & Erwin, 1973). The discrepancy between this and Rabbitt's results may be related to the longer interval between stimuli in the Fozard et al. and Waugh et al. studies, which would be critical if older adults require more time to shift attention to expected stimuli.

Two studies have investigated priming based on semantic relations between stimuli. Howard, Lasaga, and McAndrews (1980) demonstrated interference effects in a Stroop ink color naming task when the baseword was not a color name but appeared in a to-be-remembered word list presented just before the Stroop task. Reaction time also increased if the baseword was the category name for the list words. This effect is attributed to priming of the baseword by the prior list items, making it more available as a response so that it interferes with the color response (Warren, 1972). Howard, McAndrews, and Lasaga (Note 5) also dem-
onstrated that the time required to decide that a string of letters is a word (lexical decision) is faster for both young and old adults when the target stimuli were semantically related, specifically, instances of the same taxonomic category (e.g., NOSE-EYE) or an instance and a descriptive property (e.g., NOSE-SMELLS). The effects found in each study, one inhibitory and one facilitative, appear to be based on semantic relations among stimuli. Further research is necessary to determine whether these effects are based on automatic rather than on intentional processes because strong expectancy effects were possible in both studies. If these effects do reflect automatic activation of semantically related information in memory, it would suggest that organization of at least some information in semantic memory does not change with age. In the next section we consider other experimental results that are relevant to this issue.

In summary, older adults do seem to require more time to retrieve semantic information. With respect to semantic activation, presentation of a stimulus seems to produce activation that facilitates subsequent recognition of the same stimulus in both young and old adults. Presentation of a stimulus also seems to activate its name code so that both young and old adults are faster to name another stimulus with the same name, but only young adults seem to be faster to produce other responses to such a stimulus. Older adults seem to have expectancy-based activation under some conditions and not under others. Activation of semantically related information has been demonstrated in young and old adults, but it is not clear whether these effects would be found when expectation is eliminated.

Semantic organization. Although there has been considerable debate about whether semantic organization changes in the young child (e.g., Huttenlocher & Lui, 1979; K. Nelson, 1977), it seems to be assumed that development is complete by adolescence and stable through old age (Flavell, 1970). There is some evidence, however, that semantic organization may be less stable than previously thought. First, the responses of the elderly on word-association tests are more variable than those of younger adults; that is, they give more different words, so there is less overlap among subjects (Perlmutter, 1978; Riegel, 1968; Riegel & Birren, 1966; Riegel & Riegel, 1964). Inasmuch as word associations reflect the organization of semantic memory (e.g., K. Nelson, 1977), this greater variability might reflect a less stable organization in older adults. On the other hand, Howard (Note 6) found no age differences in number of different responses in a restricted word-association task in which subjects were asked to produce response words that were from the same category or that described the stimulus word. Howard argues that her findings are not necessarily inconsistent with previous findings of greater variability for the elderly in free associations. She suggests that the elderly have more variability in the kind of association they give, not in the specific word they give for a particular kind of association. Thus, greater variability for elderly adults is found when they are free to generate any type of word associate, not when they are restricted to associates of a particular type as was the case in her study. Consistent with this, Howard (1980) reports no age differences in variability of category instances generated in a fluency task with taxonomic category name cues.

Variability in word associations has also been investigated within subjects by examining the consistency of responses to the same word when it is repeated. Perlmutter (1979b) reports greater variability in the responses of older than younger adults when the same stimulus word was repeated in a single session. This result as well as the greater between-subject variability found in earlier studies could be due, of course, to a desire to give unusual or different responses. Indeed, Burke and Peters (Note 3) found that young and old adults were equally likely to give the same word-association response to a stimulus word presented in two sessions separated by a 6–7 week interval. This long interval between repeated presentations may have eliminated set effects as it is unlikely that participants could remember the responses they had given in the first session.

The nature of word associations has been used as a basis from which to infer the nature of organization of semantic memory. Re-
responses are commonly classified as "paradigmatic," that is, words that are in the same form class as the stimulus word (e.g., given "boy," a response of "girl"), or syntagmatic, that is, words that can co-occur with the stimulus word in a syntactic sequence (e.g., given "boy," a response of "run" or "bad"). An age-related change in the frequency of either type of response might reflect a change in semantic organization such that, for example, words that co-occur might become more strongly associated in memory than words sharing features of meaning. Of course such a change could also reflect an age-related change in strategy for producing a response and thus must be interpreted cautiously. The responses of both young and old adults tend to be paradigmatic (Riegel & Riegel, 1964; Burke & Peters, Note 3). Riegel and Riegel (1964) studied German speakers and reported an increase in syntagmatic responses with age, but Burke and Peters (Note 3) found no age-related difference in the proportion of syntagmatic responses of English speakers.

There is some evidence for age-related changes in semantic or conceptual organization from sorting tasks. The basis used for grouping objects appears to differ in young and old adults: Young adults group conceptually similar things, and old adults group complementary things. When asked to group forms varying in shape, color, and size by putting together the ones that are alike, old adults grouped by making a design with forms, while young adults grouped by similarity (Denney, 1974; Denney & Lennon, 1972). The old adults who did group by similarity used the dimensions of shape and size less, and color more, than did younger adults. Both design responses and color classification are used by young children and decrease during childhood (Inhelder & Piaget, 1964; Vygotsky, 1962). Sorting tasks that use line drawings of common objects show that old adults group objects less on the basis of taxonomic category (e.g., grouping bird with butterfly) and more on the basis of functional or contiguous relationships (e.g., grouping bird with tree; Annett, 1959; Cicirelli, 1976; Kogan, 1973) than young adults do. The use of taxonomic category grouping increases during childhood, and grouping based on function or contiguity decreases (Annett, 1959; Cicirelli, 1976).

Studies using other paradigms have demonstrated similarity in semantic encoding for young and old adults. Unlike the sorting and word-association tasks, these studies do not measure primary or predominant responses but only whether certain types of semantic encoding occur. Wickens, Born, and Allen (1963) demonstrated that proactive interference (PI) effects on recall of successive triads of items can be eliminated by a shift in type of item in a triad, for example, when triads of numbers are switched to triads of letters. Wickens (1972) claims that improvement in performance following a category shift (i.e., "release" from PI) indicates that a triad of items was encoded differently from earlier items, making it less similar to earlier items and thus less susceptible to interference from them. Release from PI is comparable for young and old adults with shifts in taxonomic category (Elias & Hirasuna, 1976; Puglisi, 1980), rhyme category (Elias & Hirasuna, 1976), or evaluative dimension on the semantic differential (Puglisi, 1980). Miskel-Lachman (1977) found release with shift from letters to numbers for elderly subjects, but this result is difficult to interpret because there was not a significant improvement in her study for young people on the shift trial. These results suggest that older adults semantically encoded items along the dimensions of the category shift. Even so, they had poorer recall of the triads.

In summary, the results of sorting studies suggest that there may be age-related changes in semantic organization, while word-association studies are less consistent on this issue. Greater between-subject variability in older adults' word associations suggests that they may have a less consistent pattern of semantic activation, although this finding could also result from differences in strategies used to generate responses (e.g., Burke & Peters, Note 3). Results from release from PI studies and from lexical decision and Stroop tasks suggest that at least some patterns of semantic activation do not change during adulthood. None of these paradigms, however, distinguishes between automatic and intentional semantic processes. Further research using techniques that are
capable of distinguishing between automatic and intentional effects (e.g., Neely, 1977; Posner & Snyder, 1975) is needed to clarify whether automatic activation and semantic organization are unchanged during adulthood.

**Language comprehension and memory.** The studies we have reviewed so far in this section have investigated semantic processing of single words. Studies with young adults have demonstrated that semantic processing during speech or prose occurs "on-line," that is, the meaning of successive words is retrieved as they are perceived (e.g., Blank & Foss, 1978; Marslen-Wilson, 1975; Marslen-Wilson & Welsh, 1978; Swinney, Onifer, Prather, & Hirschkovitz, 1979). These studies suggest that semantic activation occurs during language processing, making available the meaning of the perceived word and also facilitating processing of subsequent words through priming. There have been no studies of older adults' on-line semantic processes during speech or while reading, but there are reports that older adults have poorer comprehension. This finding suggests that they may have deficits in semantic processes.

Older adults performed more poorly when asked to manipulate objects to represent the action in a spoken sentence (Feier & Gerstman, 1980). Taub (1979) presented multiple-choice questions either with a to-be-learned prose passage or after it. Because the older adults did less well on the questions even when they had the prose available, he concluded that the poorer recall of older adults is due to comprehension problems. Cohen (1979) found that highly educated adults had no age difference on memory for facts from a previously presented story, but the older adults made more errors on inferences based on facts in the story. In a second experiment, Cohen found that older adults were less likely to detect anomalies in a paragraph. However, this could be the result of a deficit in memory rather than in semantic processing if older adults had forgotten information early in the paragraph when the contradictory information was presented later in the paragraph.

Walsh and his colleagues have argued that there are no age differences in integrating semantic information across sentences (Walsh & Baldwin, 1977; Walsh, Baldwin, & Finkle, 1980). These investigators used the Bransford and Franks (1971) paradigm in which related sentences about a single complex idea are presented. Each complex idea consists of four simple propositions, which are presented in sentences containing from one to four propositions. The typical finding is that people are much more likely to believe they have experienced test sentences that contain more of the propositions from one of the complex ideas, regardless of whether the test sentence is old or new. Walsh and his co-workers found this effect for both old and young adults, and the size of the effect was identical across age. They conclude that there is no age difference in integration of semantic information. This conclusion is probably premature, however, because the Bransford and Franks paradigm may tap confusion about which of many similar sentences were presented; it is thus not a good paradigm for studying semantic integration.

In conclusion, the elderly do have problems in language comprehension. These problems cannot be attributed entirely to their simply forgetting what they comprehended, since there are problems even when the linguistic material is present at the time of the test (Taub, 1979). This suggests that deficits in semantic processing contribute to comprehension problems.

**Conclusion**

We have discussed two contemporary production deficiency hypotheses about memory impairment in old age. The test of these hypotheses has typically involved either attempts to induce older people to use strategies they may not use spontaneously or the use of tasks (e.g., recognition) that do not require the critical strategies. The production deficiency hypothesis would be confirmed if age differences were eliminated under these circumstances. We have shown, however, that age differences in memory persist. The production deficiency hypothesis is therefore unable to account for age-related changes in memory. Of course, to the extent that experimenters have failed to monitor
whether people do engage in the strategies they are instructed to use, tests of the production deficiency hypothesis may have been inadequate. Also, in some cases (e.g., free recall, recognition) the analysis of retrieval mechanisms has not been specific enough to pinpoint the particular retrieval processes involved in a given task. As a consequence, these studies cannot be informative about the locus of age differences in memory. For instance, free recall of categorized lists surely involves both search and semantic activation, but only the former has been considered in previous analysis of this task.

Before leaving this topic we think it is important to note that versions of this production deficiency hypothesis have also been proposed to account for the poorer memory of young compared with older children or people of low intelligence compared with people of high intelligence (e.g., Belmont & Butterfield, 1971; Flavell, Friedrichs, & Hoyt, 1970). Here, too, the prediction that memory differences will disappear when the missing operation is imposed or is rendered unnecessary has not been supported in either case (Cohen & Sandberg, 1977; Huttenlocher & Burke, 1976). In general, then, this approach has had limited usefulness in understanding individual differences in memory.

Our review has made it clear that it is important to consider the role of both automatic and attentional aspects of contextual and semantic information processing. Older adults remember less contextual information than younger adults and find it effortful to store such information. They may also have difficulty in utilizing contextual cues in recall. Our analysis of the data on memory for frequency of occurrence, thought by some to be an automatic process, suggests that there may be age changes here as well. With respect to semantic information processing, older adults are slower than younger adults in retrieving semantic information, and they have comprehension deficits. Age differences in response variability and type of responses given in semantic tasks suggest that semantic organization may change with age. However, studies of semantic activation show similar effects in young and old adults. Because these studies, unfortunately, do not isolate automatic and intentional components of activation, no conclusion can be drawn regarding automatic semantic processes in the elderly. As it stands, the data are not incompatible with Hasher and Zacks' (1979) claim that automatic processes are age invariant. At this time, the appropriate experiments have not been performed, especially in the area of semantic information processing, and the issue therefore remains open.

We have tried to show that moving away from production deficiency hypotheses and toward a broader perspective on retrieval processes can help us to understand memory changes in adulthood. We believe that our approach helps to elucidate the specific mechanisms involved in these changes and that it will be a useful heuristic in further research.

Reference Notes


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