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Human Memory

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Certain broad points of consensus are highlighted in previous reviews of the aging and memory literature (e.g., Craik, 1977; Craik, Anderson, Kerr, & Li, 1995; Craik & Jennings, 1992; Kausler, 1994; Light, 1991; A. D. Smith, 1996). For one, it is agreed that experimental and psychometric findings indicate age-related decrements in the ability to learn and remember. It is also agreed that not all types of memory show equal age deficits. Memories that were well established earlier in life and that are regularly retrieved (i.e., semantic memories and significant autobiographical memories) frequently show minimal decrease in retrieval probability or even in retrieval efficiency (speed) in old age. Even some forms of new memory formation (e.g., implicit learning and memory) are relatively spared from aging decrements. Furthermore, there is consensus that certain noncognitive and situational factors can modulate the degree to which age decrements are seen in particular memory tasks (see the section on memory and its moderators).

As a quick scan through aging journals and certain cognitive journals reveals, publications on aging and memory have been appearing at an accelerating rate over the past 10 to 15 years. In this work, aging and memory researchers have encompassed and built on theoretical concepts and methodologies that originate in cognitive gerontology, as well as in mainstream cognitive research, psychometric–individual difference work, and, increasingly, cognitive neuropsychology. Not surprisingly, this gives rise to diverse methods and to alternative explanatory frameworks. Although this is a sign of the health and vibrancy of the field, it means that it is not possible to attempt anything close to a comprehensive review of the literature. Nor is it necessary. Several excellent summaries of the literature have been published in recent years (see above citations). This chapter presents a selective review emphasizing recent work on topics of current major interest in the field. Our survey addresses age-related differences in memory performance in healthy individuals: Neuroimaging findings and patient data (e.g., from patients with Alzheimer's disease) are mentioned only as they might illuminate the "normal" aging of memory performance (discussions of neuroimaging findings and of findings on memory in brain-damaged older adults can be found, respectively, in chap. 1 and 2, this volume).

We begin with a brief overview of several important theoretical–methodological approaches to the study of aging and memory. The main section of the chapter is organized into sections on immediate and long-term memory, with the latter including subdivisions on unintentional remembering (implicit memory and learning) and deliberate remembering (episodic and prospective memory). Following the long-term memory section is one that addresses a number of biological and social factors that may have moderating influences on age differences in memory.

THEORETICAL ORIENTATIONS

Limited Resources and Self-Initiated Processing

One general approach to aging and memory proposes that age-related differences in memory are a consequence of age deficits in an essential processing resource, such as attentional or working memory capacity (e.g., Craik, 1986; Craik & Byrd, 1982; Hasher & Zacks, 1979; see Light, 1991, for a review). The viewpoint developed by Craik and colleagues (Craik, 1983, 1986; Craik et al., 1995; Craik & Byrd, 1982) has been especially influential in recent years, and we use it to represent theoretical approaches that formulate accounts of age differences in memory in terms of limited resources.[1] Craik's viewpoint is a functional account of memory that considers memory performance to result from an interaction between external and internal factors. The external factors include the amount of

[1]Speed of processing is sometimes considered a resource in the cognitive aging literature (e.g., Light, 1991). We treat speed-of-processing views separately from resource views because capacity-based and speed- or time-based constraints on performance seem quite different to us. For example, a capacity-based view suggests that decline in the capacity of working memory is a *direct* effect of aging, whereas a time-based view suggests that it is an *indirect* effect of slowed processing.

environmental support provided by the encoding and retrieval situations and by the form of the task. Environmental support is a broad notion that includes such dimensions as the amount of guidance provided as to how information should be encoded, the availability of relevant prior knowledge that might foster rich encoding of information, and the presence or absence at retrieval of external cues that might lead to direct access to memory traces. A major internal factor is the processing resources the person has available for memory encoding and retrieval. The presumed age-related decline in processing resources (e.g., Craik, 1983, 1986; Craik & Byrd, 1982; Hasher & Zacks, 1979) means that older adults are less able to carry out resource-demanding encoding and retrieval operations than are younger adults. The resource-demanding operations include *self-initiated* encoding and retrieval processes, such as the generation of novel connections among items or the construction of retrieval plans. These processes are most likely to come into play when materials are unfamiliar and thus are not readily interpreted or organized by the learner and when the environment provides few retrieval cues, as occurs when unrelated words are presented in the context of a free-recall task. On the other hand, strong environmental support in the form of familiar tasks and materials and the availability of external reminders and other cues for retrieval can compensate for the age-related reductions in the ability to carry out self-initiated processing.

Various types of findings from the aging and memory literature are consistent with this viewpoint. Among the strongest findings are those that relate to age effects on different types of memory tasks. In particular, in conformity with the differences among recognition, cued recall, and free-recall tasks in the cues that they provide for retrieval of target memories (and therefore in the demands they place on self-initiated processing), age differences are smallest in recognition tasks and largest in free-recall tasks, with cued recall falling in between (e.g., Craik, 1986; Craik & Anderson, 1999). Also, a study by Craik and McDowd (1987) that used secondary-task performance as a measure of the resource demands of recognition versus free recall found that the resource demands of the recall task as compared with the recognition task were differentially greater for older adults. These kinds of findings, and their general face validity, contribute to the continued viability of the Craik viewpoint and of reduced-resources views in general.

Speed of Processing

If there is any cognitive change with aging that is more apparent to casual observation than memory changes, it is the slowing of mental processing. That slowed processing might have a broad impact on the cognitive functioning of older adults has been proposed by a number of theorists, including Cerella (1985); Myerson, Hale, Wagstaff, Poon, and Smith (1990); and Salthouse (1991, 1996). For example, Salthouse and colleagues (e.g., Salthouse, 1991, 1992, 1996; Verhaeghen & Salthouse, 1997) have explored the implications of age-related slowing for working memory, episodic memory, and various fluid-intelligence functions, such as inferential reasoning.[2] This work has produced an impressive body of findings showing that (a) slowing of processing (as measured on simple perceptual tasks) accounts for a considerable portion of the age-related variance on a large number of cognitive tasks and (b) the amount of age-related variance accounted for by the speed factor is generally much greater than that accounted for by other possible mechanisms of age decline in cognitive function, in particular, working memory capacity (e.g., Park et al., 1996; Salthouse & Meinz, 1995; Verhaeghen & Salthouse, 1997). However, there are indications (Park et al., 1996) that working memory capacity increases in importance relative to speed as a predictor of cognitive performance as the memory task places greater demands on self-initiated processing (e.g., recognition vs. free recall).

In a recent article, Salthouse (1996) suggested that two mechanisms underlie the pattern of relations between speed and age-related changes in cognition. According to the *limited time mechanism*, the cognitive processes needed to complete tasks of any complexity may not occur when time is restricted because much of the available time is taken up with early processes. According to the *simultaneity mechanism*, the outcomes of early processes may be lost before they can be used by later processes. These are promising ideas that are likely to foster research examining the operation of the proposed mechanisms in the context of specific cognitive tasks.

Inhibitory Control

This view (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999; Zacks & Hasher, 1994, 1997; see also McDowd, Oseas-Kreger, & Filion, 1995) attributes age-related differences in memory and other cognitive functions to a decline in attentional inhibitory control over the contents of working memory. Hasher et al. (1999) proposed that there are three aspects to

[2]We note that there is a difference in typical research strategy between the work associated with the slowing approach versus other theoretical approaches to aging and cognition. Studies deriving from a slowing framework commonly administer a battery of cognitive tasks (often including a selection of standardized psychometric and neuropsychological measures) to a large sample of individuals from across the adult age range and make use of various regression and quantitative modeling techniques to analyze the data. By contrast, the typical research strategy used in the work associated with other approaches involves the administration of specially designed tasks to groups of younger and older adults (or sometimes also middle-aged adults) and the use of hypothesis-testing statistical techniques (e.g., analysis of variance) to analyze the data.

inhibitory control: access, deletion, and restraint. Working together, the *access* function, by hindering access to working memory of goal-irrelevant information that may be partially activated, and the *deletion* function, by suppressing the activation of any inadvertently activated extraneous and no-longer-relevant information, help ensure that the momentarily most active mental representations form a coherent set related only to the current goal(s) of cognitive function. The *restraint* function serves to prevent strong but situationally inappropriate responses from gaining control over thought and/or action, thereby allowing consideration of weaker but potentially more relevant responses.

When inhibitory control is deficient (as the Hasher–Zacks view suggests it is in older adults), the result is a kind of "mental clutter" in which extraneous thoughts and plans can interfere with, and possibly crowd out, goal-relevant thoughts and plans. This momentary increase in clutter is proposed to have subsequent consequences for long-term memory encoding and retrieval (e.g., Hasher et al., 1999; Zacks & Hasher, 1994; Zacks, Radvansky, & Hasher, 1996). Specifically, inhibitory failures to limit the presence of extraneous information in working memory during encoding results in the formation of associations between extraneous and goal-relevant thoughts. These "enriched" or "cluttered" memory structures will later result in slower and more error-prone retrieval of specific target information. One demonstration of this is the finding of age-related increases in the "fan effect" (Cohen, 1990; Gerard, Zacks, Hasher, & Radvansky, 1991), the finding that the more associations that are linked to a concept (the greater the "fan"), the slower and more error prone is the retrieval of any one of those associations. Also relevant are findings from "directed forgetting" tasks (Zacks et al., 1996) indicating that older adults are less able than younger adults to suppress the continued processing and retrieval of already-studied items cued as to be forgotten; these items can then produce more interference with the retrieval of to-be-remembered items than is true for younger adults. The retrieval problems of older adults may, in turn, promote increased reliance on schematic knowledge and other prepotent associations and responses to incoming information and retrieval cues. In general, this view suggests that an important consequence of increased mental clutter in working memory is an elevated sensitivity to potential sources of interference, both at encoding and retrieval. (For recent critiques of this view, see Burke, 1997; McDowd, 1997; for a rejoinder, see Zacks & Hasher, 1997).

Contextual Features and Source Memory

Relative to younger adults, older adults have been found to remember less about the contextual features of prior experiences (e.g., Spencer & Raz, 1995) and so less about the sources of their memories (e.g., Hashtroudi, Johnson, & Chrosniak, 1989; McIntyre & Craik, 1987). In addition, older adults have been found to make more memory errors of various sorts (see the section on memory errors). A theoretical approach that potentially accounts for all these trends is Johnson's source-monitoring framework (Johnson, Hashtroudi, & Lindsay, 1993; Johnson & Raye, 1981; see also Schacter, Norman, & Koutstaal, 1998). This framework proposes that memory for any given event consists of a bundle of attributes or features of that event (cf. Underwood, 1983). These attributes can be more cognitive in nature—for example, attributes that refer to the kinds of operations (e.g., imagining and inferring) that were used to think about an item, or to the meaning of the item and its relation to other ideas, or to other aspects of the environment. Or the attributes can be more perceptual and contextual in nature—for example, attributes that specify the color, shape, size, or sound of an object and its spatial and temporal location. Memory for such information is critical for determining the "source" of a memory: Did I read that fact, did I hear it, or did I make it up?

The perceptual and cognitive features encoded about an event can either be strongly or weakly encoded, and they can either be strongly or weakly "bound" or integrated with each other. Both these aspects of encoding are thought to be important for later accurate retrieval of source. Factors that promote weak feature encoding and binding, and that may play a role in the weaker integration of target and contextual memory in older adults (Chalfonte & Johnson, 1996; Henkel, Johnson, & De Leonardis, 1998), include distraction in the environment or in thought; a tendency to pay attention to the emotional, interpretive qualities of input rather than to factual qualities (e.g., Hashtroudi, Johnson, Vnek, & Ferguson, 1994); or a tendency to pay attention to one's own emotional responses rather than to events in the environment (Johnson, Nolde, & De Leonardis, 1996). At retrieval, other factors come into play: In particular, because retrieval is conceived of as a reconstructive process, changes in external cues and internal cues (goals) can influence what is reactivated. Additionally, whatever is reactivated at retrieval also goes through an evaluation process that can be set along a continuum from heuristic to systematic. When set toward the heuristic end, decisions about cues can be made quickly on the basis of rules about features that co-occur with different types of memories. For example, if a memory carries with it many perceptual features and few mental features (e.g., cognitive operations), it is likely to be the product of observation, whereas if it carries with it many mental features and few perceptual features, it is likely to be the product of thought. More systematic evaluation of memories may occur if, for example, the cost of an error in a given situation is high or if other related information is assessed about plausibility of source. Older adults may be less likely than young adults to engage in such systematic evaluation processes of retrieved information in making source attributions. This, in combination with weaker encoding of contextual attributes and weaker integration of those attributes that are encoded, could account for older adults' poorer source-monitoring performance.

Summary

This brief summary of theories is not exhaustive (e.g., minimal reference was made to frameworks that have a strong neurocognitive basis). Even so, it should be apparent that the theoretical ideas that motivate research on age differences in memory are wide-ranging. Because the different theories tend to speak to different empirical issues, the above review of theories was intended to serve as a background for situating some of the research questions we subsequently address, rather than to set the stage for a systematic evaluation of each viewpoint against the others. Nonetheless, our survey of findings on age differences in memory should reveal that each of the theories under consideration has some major strengths, particularly in its areas of primary application, but also some limitations.

IMMEDIATE MEMORY AND GENERAL CAPACITY

The idea of span as a basic measure of mental capacity, and particularly of immediate-memory capacity, has been central to the individual differences tradition in psychology since its earliest days. The idea of a limited span of primary or short-term memory became important to the field of memory in the late 1950s (e.g., Miller, 1956) and was included in multistore memory models, such as Atkinson and Shiffrin's (1968). In earlier studies, most span data were collected using "simple" span measures (see below) that ostensibly emphasized passive storage of verbal information. Since the 1980 publication of Daneman and Carpenter's landmark paper, a large body of evidence has also accumulated using more complex "working memory" measures (see also below) that impose simultaneous processing and storage demands. The popularity of the latter type of measure reflects, in part, a shift in the conception of short-term memory. In particular, current views emphasize that immediate memory functions as a system in which processing and storage demands trade off for capacity (hence the currently more popular term, *working memory*).

In the general cognitive literature, the capacities measured by simple span and working memory span have been implicated in a broad range of cognitive activities, including encoding of new information into long-term memory, retrieval of information from long-term memory, syntactic processing and language comprehension, and reasoning (see, e.g., Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Engle, Cantor, & Carullo, 1992; Just & Carpenter, 1992; Salthouse, 1993). Given these findings, it is not surprising that evidence also suggests that age-related declines in span, and particularly in working memory span, play a role in age differences in episodic memory and fluid cognition (cf. Verhaeghen & Salthouse, 1997). Examples come from studies investigating language comprehension and production (e.g., J. T. Hartley, 1988; Kemtes & Kemper, 1997; Light, Capps, Singh, & Albertson-Owens, 1994; Stine & Wingfield, 1987), reasoning (e.g., Salthouse, 1993, 1994), and episodic memory tasks (e.g., Cherry & Park, 1993; Hultsch, Hertzog, & Dixon, 1990; Park et al., 1996; for a review, see Park et al., 1996; Verhaeghen & Salthouse, 1997; but see also J. T. Hartley, 1988, 1993; Hasher & Zacks, 1988). We begin our discussion of age patterns in immediate memory with the simple span.

Simple Memory Span Measures

The digit span is an example of a simple span measure. The forward span version of the test measures the longest series of digits that a person can recall immediately after presentation and in the order in which the items were presented. This test (whether digits, letters, or words were used as materials) was once taken as a pure measure of short-term memory capacity.

Although individual studies have frequently reported small and nonsignificant age differences on simple span measures (e.g., see Craik, 1977), a recent meta-analysis (Verhaeghen, Marcoen, & Goosens, 1993) suggested that older adults are reliably poorer on simple span tasks than are younger adults. For example, the 13 young–old comparisons of forward digit span included in the meta-analysis showed an average effect size for age of −.53 compared with an effect size of −.91 for age on paired-associate recall. Such span differences are unlikely to be due entirely to basic differences in short-term memory capacity, however, because it has long been known that there is a contribution of long-term memory to these measures (e.g., see Craik, 1977). If so, the age difference in span may in part be due to age-sensitive factors affecting long-term memory processes: One such possibility is less rehearsal of the items by older adults (Kausler, 1994); another is discussed in the section below on working memory.

Baddeley's (1986) working memory model suggests another type of account of age differences in simple span. According to this viewpoint, working memory is not a unitary entity but is composed of multiple components. These include two "buffer" stores, the phonological loop for holding phonologically based verbal representations and the visuospatial sketchpad for holding visual and spatial representations, and a central executive that has monitoring, coordinating, and controlling functions in the service of ongoing processing. In the context of this model, it can be argued that simple span performance may primarily rely on the phonological loop rather than on the entire working memory system (cf. Baddeley, 1986). If so, and given that the presumed capacity of the phonological loop roughly corresponds to the number of items that can be subvocally articulated in 2 s, it becomes important to consider age differences in articulation rate. There is some evidence that the slower articulation rate of older adults contributes to their reduced span measures (Multhaup, Balota, & Cowan, 1996).

Working Memory Span Measures

The working memory span measure introduced by Daneman and Carpenter (1980) attempts to assess the individual's capacity to simultaneously store recently presented information (as simple span presumably does) while engaging in ongoing processing. Their basic task requires participants to read and comprehend a series of sentences while also remembering the final word of each. The test requires recall of the final words immediately following the last sentence of each set. Series lengths typically range from two to seven sentences, and starting with the shortest length, participants are given three to five sets of sentences before continuing on to the next set length. Working memory capacity (here specifically "reading span") is defined as the largest set for which the individual is able to both accurately comprehend the sentences and recall their final words. Daneman and Carpenter's initial measure has spawned many variations, including ones that use listening comprehension tasks instead of reading ("listening span") and ones that use arithmetic tasks along with recall of numbers from the arithmetic problems or randomly paired words ("computation" or "operation span"; see, e.g., Daneman & Merikle, 1996; Engle et al., 1992; Salthouse & Babcock, 1991).

As is the case for simple span measures, the research on complex measures is not entirely straightforward; most studies show age differences, some do not (see Light, 1991). The Verhaeghen et al. (1993) meta-analysis does, however, show a clear age effect of –.81. Note that part of the inconsistency in age differences across individual studies may stem from the contribution of vocabulary (and its correlates) to working memory span measures. In view of the fact that age differences in vocabulary, if present, generally favor older adults and that there is a positive correlation between vocabulary and span (Daneman & Carpenter, 1980), age differences in working memory span may be underestimated.

Interpretations

Older adults appear to have smaller span measures whether measured by simple or complex measures, and individual differences in span are important predictors of performance on other tasks, including language comprehension and reasoning tasks (e.g., Just & Carpenter, 1992). As we indicate in the following several paragraphs, a variety of theoretical viewpoints can potentially provide insight regarding the mechanisms underlying these important findings.

Baddeley's Working Memory Model

Although the Baddeley (1986) working memory model has stimulated considerable research on span and its determinants, including age differences, there is no easy meshing of these findings with the specifics of Baddeley's model. The strongest connection is the one that has already been mentioned, between the simple span data and the phonological loop, and even that connection is somewhat indirect. The working memory span measures that have gained so much attention in recent years do not precisely match any of the specific components of Baddeley's model, although the closest connection is the central executive: In requiring coordination between simultaneous processing and storage demands, the Daneman–Carpenter (1980) procedure seems to capture at least one essential feature of Baddeley's (1986) central executive, its role in coordinating among different processes (in the working memory span measures, between processing of new information and rehearsing a subset of previous information). To the degree that this proposed connection has validity,[3] it is of interest to consider a theoretical viewpoint that Baddeley (1986, 1996) has pointed to as having a strong influence on his concept of the central executive, namely, the viewpoint of D. A. Norman and Shallice (1986) regarding the "supervisory attentional system." This limited-capacity mechanism, which is presumed to be localized in the frontal lobes, is involved in strategic control of processing (i.e., planning, decision making, and coordination of resources) during the performance of nonroutine tasks.

Hasher and Zacks' Inhibition-Deficit View

Hasher and colleagues (Hasher & Zacks, 1988; Hasher et al., 1999; Zacks & Hasher, 1994) have also built on the work of D. A. Norman and Shallice (1986) and, more generally, on the work of attention theorists who have

[3]One factor that makes this connection tentative is that the conceptualization of the central executive is still under development, as Baddeley (1986, 1996) has readily acknowledged.

a selection-for-action focus (e.g., Navon, 1989a, 1989b; Tipper, 1992) in their analysis of working memory. One of their three inhibitory processes is critical to thinking about age differences in span measures: the deletion process. This is a mechanism responsible for clearing from working memory information that is no longer relevant to a current task. Because of the efficient operation of this mechanism, younger adults can readily suppress no-longer-relevant information, sometimes to below its preexperimental baseline level of availability. By contrast, because of less efficient operation of this mechanism, older adults have difficulty suppressing no-longer-relevant information (see also the section on circadian rhythms). What impact might this have on span tasks? As May, Hasher, and Kane (in press) pointed out, span tasks are actually a series of recall tests on lists that increase in length from the shortest to the longest. On each test trial, only the most recently presented string of items (digits, letters, words, or sentences) is relevant to the recall task. To accomplish focusing on only the current list, suppression of previous input (study lists) and outputs (retrievals) is required. If older adults are less able to do this than younger adults (see Hasher et al., 1999; Zacks & Hasher, 1994), items from previous lists will be more accessible in memory than they should be, creating larger sets of items to be searched through to produce the correct items from the current test list. In other words, the functional list length for those with poor inhibitory control will be longer than the functional length for those with efficient suppression. A large literature in memory confirms that list length[4] is a major determinant of the proportion recalled; and the typical explanation of this finding is based in interference theory: With longer lists, there is greater competition at retrieval among potential candidates for response (e.g., Watkins & Watkins, 1975). We note that larger search sets are known to have two effects on retrieval, one on amount recalled (reducing it) and one on speed of recall (slowing it). Hence, older adults may show smaller spans because of deficient inhibitory control over deleting no-longer-relevant information from working memory.

The evidence in support of this line of reasoning is not extensive, but it is encouraging. In a recent study, reading span materials from Daneman and Carpenter's (1980) study were presented in their standard, ascending list length order (as described above) or in a nonstandard, descending list length order (i.e., starting with the largest set size and going backward

[4]We use the term *list-length difficulty effect* to refer to a group of phenomena that go by various names, including the *fan effect* and the *cue overload effect*. In our view, these are all examples of the competition at retrieval induced by larger search sets, that is, by increases in the number of potential targets that are activated by a retrieval cue. It should also be noted that competition at retrieval is the major mechanism that classic interference theory used to explain proactive interference (cf. Baddeley, 1990).

through the series; May, Hasher, & Kane, in press). This manipulation was intended to reduce carryover (or proactive interference) effects from short lists to long lists, and it was indeed successful: Working memory span estimates were as large for older adults as for younger adults when span was measured in a descending manner. When measured in an ascending manner (with proactive interference effects increasing as list length increases), younger adults had their usual advantage in span.

Salthouse's Slowing View

A final viewpoint on the mechanisms underlying the aging and span findings is the speed of processing hypothesis (e.g., Salthouse, 1994, 1996; Salthouse & Meinz, 1995). According to the speed hypothesis, the age-related decline in span is mediated by slowing of processing, which somehow limits the amount of information that can be held or processed in immediate memory. Support for this account comes from the following pattern of findings (see recent reviews by Park et al., 1996; Salthouse, 1996; and Verhaeghen & Salthouse, 1997): First, there is the basic finding that measures of speed of processing show pervasive slowing with increasing age. Second, age-related declines in speed of processing share considerable variance with age-related differences in measures of short-term memory and working memory capacity. Third, age-related declines in speed of processing also share considerable variance with age differences in episodic memory and fluid-intelligence measures. Finally, structural equation modeling and other statistical and quantitative modeling procedures frequently show that speed is a stronger mediator of age-related variance on memory, reasoning, and language tasks than is working memory capacity. This pattern has been taken to suggest that slowing of processing is a "fundamental" underlying mediator of age deficits in a broad range of cognitive tasks and that it is relatively more fundamental than changes in working memory capacity (e.g., see Park et al., 1996, p. 634).

However, there are complications to this picture. Most important, factors beyond speed frequently emerge as significant mediators of age-related deficits in episodic memory and fluid-intelligence tasks. Of these additional factors, short-term memory, or working memory, is the most common (cf. Park et al., 1996; Salthouse, 1993, 1994; Verhaeghen & Salthouse, 1997). As Verhaeghen and Salthouse noted in discussing the mediational model generated from their meta-analysis of a large number of adult developmental studies, "age-related declines in speed *and* working memory capacity, efficiency, or both appear to be involved in the age-related decline in more complex aspects of cognition" (p. 246, italics added). Another issue is the limitations of the available data: The evidence supporting the speed hypothesis primarily comes from individual difference or statistical control methods and only some potential mediators of age deficits in complex cognition have been systematically studied (cf. Verhaeghen & Salthouse, 1997). For example, according to the inhibitory view, slowing could be due to increased mental clutter engendered by inefficient suppression processes. Finally, it can be noted that the mechanisms by which slowing might negatively impact on performance remain to be clearly specified and tested for many cognitive tasks (cf. Craik & Anderson, 1999).

This lack of theoretical resolution should not detract from the fact that the study of age differences in simple and complex span measures has presented us with some compelling findings, both about age differences and about how those differences might relate to performance on more complex cognitive tasks.

LONG-TERM MEMORY

Long-term memory includes vastly different sorts of memories, from remembering where one put one's key a few minutes ago and what one ate for breakfast a few hours ago to remembering how to shift gears, even though one has driven only automatic transmission cars for many years. In response to this diversity, Tulving (1972) proposed that long-term memory is not a unitary entity but is composed of distinct systems (originally, episodic and semantic memory) that have different functional properties and that are served by different brain structures. Almost 30 years later, memory researchers still debate whether it is best to consider long-term memory a unitary system or not, and if nonunitary, what the important subdivisions are (e.g., Schacter & Tulving, 1994; see chap. 2, this volume). Even though the theoretical issues are not settled, much of current research on long-term memory focuses on the properties of different types of long-term memory rather than on questions common to all of long-term memory. Nowhere is this trend more salient than in research on implicit memory.

Implicit Memory

By contrast with *explicit memory*, which is measured by tests including deliberate reference to a previous event, the term *implicit memory* refers to memory for a prior experience that is revealed by performance effects in the absence of deliberate recollection. Thus, implicit or indirect memory tests (Johnson & Hasher, 1987) measure the residue of previous stimulus exposure through changes in response accuracy, reaction time, or response bias (transfer effects or "priming"). Many of the most commonly used implicit memory tests involve measures of *repetition priming*. In repetition priming procedures, individuals first participate in a study phase in which they are exposed to a set of stimuli under the guise of some orienting task. This is followed by a test phase in which processing of the studied or related stimuli is compared with processing of unstudied, baseline stimuli. For example, in the test phase of a *fragment completion test*, participants are asked to complete word fragments (e.g., _ol___r) with the first word that comes to mind. Repetition priming is indicated by the increased likelihood of completing the fragments with words that had been studied (e.g., *soldier*) relative to a baseline unstudied condition. Other examples of repetition priming measures include stem completion (in which the test items are the first two or three letters of the target words), latency of word and picture naming, and lexical decision speed, among others.

Similar to research comparing amnesic patients to age-matched normal controls (e.g., Graf, Squire, & Mandler, 1984), research comparing healthy older adults with younger adults frequently shows a striking dissociation between explicit and implicit memory tests. For example, in an early study modeled after the one performed by Graf et al., Light and Singh (1987, Experiment 2) found a significant age deficit on word-stem cued recall but only a small and nonsignificant age difference on word-stem completion. Adding to the salience of these results is the fact that the only difference between the word-stem completion and the explicit cued-recall tests was the instructions: For the explicit test, participants were told to use the cues (three-letter stems) to help them retrieve words from the study list; for the implicit test, they were told to complete the stems with the first word that came to mind. It appears from these findings, and many others, that implicit memory tests provide an exception to the general finding of an age-related deficit in long-term memory for new information. This exciting possibility has generated a considerable body of research on adult age differences in implicit memory, which has been the subject of several recent reviews (Fleischman & Gabrieli, 1998; La Voie & Light, 1994; Light & La Voie, 1993; Rybash, 1996).

These reviews reach similar empirical conclusions about age effects on implicit memory tasks. The most general conclusions are that older adults show robust repetition priming effects across a wide variety of implicit memory tasks and that age effects on implicit memory tests are either nonsignificant in individual experiments or notably smaller than age effects on explicit memory tests (Fleischman & Gabrieli, 1998; La Voie & Light, 1994; Light & La Voie, 1993; see also Graf, 1990; D. V. Howard, 1988; Light, 1991; Rybash, 1996). However, the occasional significant age difference almost always favors the young group, as do the majority of nonsignificant trends (Fleischman & Gabrieli, 1998); and La Voie and

Light's (1994) meta-analysis indicates a reliable age decrement in implicit memory, although the age effect size (.30) is smaller than for explicit memory tests (.97 and .50 for recall and recognition, respectively).

Other important but slightly more tentative findings relate to different kinds of repetition priming. One question that has received some study is whether aging patterns are similar for *perceptual* and *conceptual* priming tasks (see Roediger & McDermott, 1993). The perceptual priming category includes tasks (e.g., perceptual identification and picture naming) that are presumed to rely heavily on analysis of the perceptual features of inputs, whereas the conceptual priming category includes tasks (e.g., answering general information questions and retrieval of category instances) that appear to be sensitive to analysis of conceptual or meaning features of inputs. Comparisons of age effects on these two types of priming tasks have produced some divergent findings: For example, Small, Hultsch, and Masson (1995) found no age deficit on a conceptual priming task and a significant age deficit on a perceptual priming task, whereas Jelicic, Craik, and Moscovitch (1996) found the reverse pattern of age effects. In addition, other data (Multhaup, Hasher, & Zacks, 1998) suggest that there are circumstances in which older adults show reliable conceptual priming, whereas younger adults do not. However, despite these divergent findings in individual studies, the literature as a whole suggests equal age effects in the two types of priming paradigms (Fleischman & Gabrieli, 1998; La Voie & Light, 1994).

At this time at least, it appears that a similar conclusion applies to comparisons between *item* and *associative* priming, the former referring to facilitation from the repetition of familiar individual stimuli and the latter to facilitation from the repetition of novel connections between stimuli. Also included in the category of associative priming tasks by Light and colleagues (La Voie & Light, 1994; Light, Kennison, Prull, La Voie, & Zuellig, 1996; Light, La Voie, & Kennison, 1995) are tests of repetition priming using novel stimuli, such as nonwords (*kensess, obnel*) constructed by swapping syllables from words (*kennel, obsess*) or novel compound words (*fishdust, waygirl*). La Voie and Light's meta-analysis indicates that the age effects are roughly equivalent on associative and item priming measures (see also Fleischman & Gabrieli, 1998).

Given that older adults show clear deficits in learning new associations when such learning is measured on explicit retrieval tasks (see Kausler, 1994, for a comprehensive review), it is surprising that indirect tests measuring priming for new associations should show as modest an age deficit as item priming tests. This outcome suggests that clear age deficits in memory for new associations seen on explicit tests are due to retrieval rather than encoding or binding problems (cf. La Voie & Light, 1994). However, such conclusions should be treated with caution until there are more aging studies of associative priming, particularly ones using tasks tapping the formation of novel associations between distinct stimuli as contrasted with the more ambiguous cases of novel nonwords or compound words. It would also be useful to have more experiments that involve dependent measures other than reading speed because this measure may be sensitive to associations formed at a presemantic level, namely, to connections between elements of an output or motor program (i.e., motor fluency effects) rather than to the kinds of associative, semantic level connections that are the primary basis of performance on most deliberate memory tests (Spieler & Balota, 1996; see also Monti et al., 1997; Poldrack & Cohen, 1997). Further discussion of the theoretical interpretation of implicit memory findings follows a brief summary of research on a closely related phenomenon, implicit learning.

Implicit Learning

Seger (1994) defined *implicit learning* as the "learning [of] complex information without complete verbalizable knowledge of what is learned" (p. 163). Although there are clear similarities between implicit learning and implicit memory (diminished involvement of conscious mechanisms of memory retrieval and relative lack of impairment in individuals with amnesia; Nissen, Willingham, & Hartman, 1989), the two phenomena are demonstrated under quite different learning conditions (Seger, 1994). In particular, whereas most repetition priming tests measure memory for single stimuli or novel associations after a single study trial, implicit learning procedures generally measure learning of novel patterns or rules involving complex stimulus arrays over many trials. Almost all the studies comparing implicit learning in younger and older adults have used variants of the *serial reaction time (SRT) task* (Nissen & Bullemer, 1987). In this task, participants respond (e.g., by pressing a corresponding button) to each stimulus (e.g., onset of one of several lights) in a long series. Learning is shown by faster responding in a condition in which the stimuli appear in a repeating sequence (typically 8 to 12 elements long) versus a condition in which the stimuli appear in a random order. The random versus repeating sequence conditions are sometimes compared between subjects. More often, the comparison is within subjects through the use of random sequence blocks intermixed with repeating sequence blocks. The learning effect reflected in reaction time facilitation is not dependent on explicit awareness of the repeating sequence: Individuals with amnesia (e.g., Nissen et al., 1989), older adults (e.g., D. V. Howard & Howard, 1989), and a subgroup of young adults who demonstrate little or no explicit knowledge of the sequence can show as much reaction time speedup as individuals who become aware of the repeating sequence and can report what it is.

With few exceptions, the literature on aging and implicit learning has found robust learning of novel patterns in older adults when that learning is measured indirectly through improvements in performance of the required responses. For example, in the D. V. Howard and Howard (1989, 1992) studies, both younger and older participants showed more rapid responding for the repeating sequence than in the random condition of a SRT task and more rapid responding for both 10- and 16-element sequences. Furthermore, initial indications of learning emerged after a comparable number of repetitions (<20) of the sequence for the two age groups.

Although older adults generally show reliable implicit learning, there are sometimes age differences in the amount of learning seen in indirect as well as direct measures. In particular, whereas D. V. Howard and Howard (1989, 1992) reported no age differences on the reaction time measures of implicit learning, other investigators have reported age deficits under certain training conditions (i.e., dual-task demands; Frensch & Miner, 1994), for certain types of sequences (i.e., sequences of greater "complexity"; Curran, 1997; Harrington & Haaland, 1992), and for specific subgroups of older adults (i.e., lower ability older adults; Cherry & Stadler, 1995). It also appears that younger and older adults can show differences in what is learned, with older adults showing less implicit knowledge of higher order statistical dependencies in the repeating sequence (J. H. Howard & Howard, 1997). On the other hand, explicit knowledge of the sequence (as assessed by posttraining ability to recall, recognize, or consciously generate the sequence) has been found to show clear age deficits (e.g., D. V. Howard & Howard, 1989, 1992).

Theoretical Interpretations

The similarity between implicit memory and implicit learning does not end with the basic results; they also share a number of issues that complicate theoretical analysis of the findings. One of these issues is the interpretation of the frequent null age effects, particularly in cases involving reaction time measures of priming (e.g., picture or word naming) or implicit learning (SRT task): Specifically, given age-related general slowing, similar absolute reaction time benefits for younger and older adults have been interpreted by some investigators as indicating less priming or less implicit learning for the slower older group (cf. Fleischman & Gabrieli, 1998; Rybash, 1996). In line with this possibility, some investigators (e.g., Cherry & Stadler, 1995) have used proportional priming or learning scores (amount of speedup relative to a baseline reaction time) to adjust for general slowing. Others disagree with this procedure, citing questions about assumptions underlying the proportional slowing correction and other statistical issues (Curran, 1997; D. V. Howard & Howard, 1992; J. H. Howard & Howard, 1997).

Another complication is the possibility that *explicit contamination,* the use of explicit retrieval strategies to bolster performance on ostensibly implicit tests, could account for the intermittent findings of significant age decrements on implicit memory (e.g., Habib, Jelicic, & Craik, 1996) or implicit learning tasks (J. H. Howard & Howard, 1997): Younger adults' better explicit memory of the studied materials means that this group has a greater potential for conscious recollection to benefit their performance on implicit tasks. Alternatively, or additionally, young adults may be more likely than older individuals to use self-initiated conscious retrieval strategies (cf. Craik, 1986) when performing the implicit task.[5] In the case of implicit memory, a number of different approaches have been used to measure or eliminate explicit contamination: interviewing participants on strategies used on the implicit test, demonstrating that variables (e.g., level of processing) known to affect explicit memory do not affect implicit memory, and using individuals with amnesia as a comparison group lacking explicit memory (e.g., Fleischman & Gabrieli, 1998; Habib et al., 1996; La Voie & Light, 1994; Light & La Voie, 1993). Although each of these approaches is acknowledged to have limitations,[6] the results of their application generally support the conclusion that the small but persistent age differences in implicit memory are real and not merely an artifact of explicit contamination.[7]

So where does this leave us theoretically? Given the similarity between the aging and amnesia data in the early research on implicit memory and on implicit learning, a multiple brain systems approach seemed to be gaining ascendancy. In general, this approach claims that there is differential age-related deterioration in the brain structures underlying explicit memory versus those underlying implicit memory and learning (e.g., Squire, 1987; Tulving & Schacter, 1990). Chapter 2 describes this approach

[5]Explicit contamination has also been suggested as an explanation for the indications that, despite being superficially similar, implicit stem completion and fragment completion tasks show different age patterns, namely, frequent reports of age differences on stem completion but not on fragment completion (e. g., Winocur, Moscovitch, & Stuss, 1996). However, some findings support an alternative explanation in terms of the differential involvement of strategic processing dependent on the frontal lobes (Winocur et al., 1996) for stem completion but not for fragment completion.

[6]For example, the use of null effects of variables known to affect explicit memory helps rule out explicit contamination only for perceptual priming tasks (Fleischman & Gabrieli, 1998). For conceptual implicit tests, level of processing and similar variables are expected to have effects that parallel those seen on explicit tests.

[7]Issues relating to the experimental tasks are also of concern. The almost exclusive use of the SRT task to study implicit learning in older adults is problematic. Although the aging and implicit memory literature includes a much broader range of tasks, how to categorize some of them has turned out to be controversial. For example, usually stem completion is considered a perceptual task, but on occasion (e. g., Rybash, 1996), it has been categorized as a conceptual priming task.

in much greater detail, including an assessment of its current status among cognitive neuroscience researchers. For more behaviorally oriented investigators, it is our impression that the increasingly complex patterns of findings in the area seem to be leading to more of a reserve-judgment stance. As La Voie and Light (1994) have pointed out, the pattern that emerged from their meta-analysis (smaller age-related decrements on implicit memory tasks than on explicit memory tasks) is an example of what Shimamura (1993) called a "partial dissociation," a pattern that has ambiguous theoretical implications. It could be consistent with views assuming that there are qualitative differences between implicit and explicit memory, either in the processes or in the brain systems involved, and that there is age sparing in the process (system) that serves implicit memory but not in the one that serves explicit memory. Or it could be consistent with alternative interpretations, including ones that suggest only quantitative differences between younger and older adults coupled with tasks differing in difficulty (see La Voie & Light, 1994, pp. 547–551). Or, as we suggest in the final segment of this chapter, there may be a number of moderating variables whose roles on implicit memory tasks remain to be explained before final conclusions can be drawn. It is our judgment that further investigation of age differences in associative priming using tasks where priming effects are not tied to facilitation of motor-output mechanisms will be essential to the resolution of theoretical questions about implicit memory and implicit learning. We also note that two recent studies suggest that, at least with respect to stimuli that were designated as distractors at encoding, older adults' implicit retrieval of such information can leave them at an advantage relative to young adults (May, 1999; Multhaup et al., 1998).

Deliberate Remembering: Encoding and Retrieval Processes

The findings from tasks in which participants are asked to deliberately remember specific information contrast sharply with those from implicit memory and implicit learning tasks on which age-related differences are small and sometimes nonexistent. Older adults typically perform more poorly than younger adults on direct or explicit tests of memory. In recall, older adults omit more of the originally occurring information than do younger adults, include more never-presented items (intrusions), and repeat more previously recalled items. On recognition tests, older adults are more likely than younger adults to accept as old never-presented items (called *foils* or *lures*), especially if those lures share a conceptual, schematic, or perceptual resemblance to the presented items. There are exceptions to these general findings (see the later discussion on narrative recall; see also, e.g., Craik, Byrd, & Swanson, 1987; Rahhal & Hasher, 1998), and these exceptions suggest the presence of moderating variables that might prove to be deeply important, both practically and theoretically (as is outlined in the final major section of this chapter).

Despite the exceptions, reduced recollection, coupled with heightened errors, is at the focus of much work in aging and memory. Of particular interest is the pattern of high levels of omission for presented items coupled with intrusions bearing a systematic relation to presented information. Note that this is precisely the pattern that stimulated work on schema or constructivist theories of memory in the 1970s and 1980s; in many ways, the return of interest in such errors in the explicit memory tradition heralds the renaissance of a constructivist view of memory (see Johnson & Raye, in press ; Schacter et al., 1998).[8] Before considering errors in detail, we begin with general attempts to explain the most striking findings in aging and deliberate memory, the poorer overall retrieval of older adults as compared with younger adults.

Some earlier attempts to account for the poorer deliberate memory of older adults have emphasized processes occurring either at encoding or at retrieval. Such views have generally met with mixed success (e.g., Light, 1991). One example is the hypothesis that older adults engage in shallower, less elaborate processing at encoding than do younger adults (Craik & Byrd, 1982; Rabinowitz, Craik, & Ackerman, 1982). Tests of this hypothesis have involved procedures (instructions and orienting tasks) that control how participants process inputs at encoding, with the idea that age differences will be eliminated, or at least reduced, if younger and older adults encode in the same way. Studies using such procedures have produced a conflicting and confusing array of findings (Craik & Jennings, 1992; A. D. Smith, 1996), even among studies carried out by the same group of investigators. For example, Park and colleagues have used encoding conditions that promote increased elaboration of memory targets in a number of experiments and have found that such conditions produce (a) greater benefits for older adults (Park, Smith, Morrell, Puglisi, & Dudley, 1990), (b) equal benefits for older and younger adults (Park, Puglisi, & Smith, 1986), and (c) smaller benefits for older adults (Puglisi & Park, 1987).

It is likely that some of the divergence in findings is due to differences in the retrieval tests that were used, among other factors. If so, one has to consider that differences in encoding can typically be observed only on a retrieval test of some sort and that encoding differences are known to interact with differences in the retrieval demands of different types of

[8]See Alba and Hasher (1983) for a review of the earlier work on schema theory and for a criticism of the overextension of conclusions from that work—a criticism with relevance to some of the current work as well. By contrast, see Brewer and Nakamura (1984).

memory tests (Baddeley, 1990; Craik, 1977). These considerations suggest that it can be difficult to draw sharp distinctions between encoding and retrieval factors as sources of age-related deficits in deliberate remembering. Indeed, in contrast to the past, there has recently been relatively less work with older adults on traditional encoding and retrieval variables (e.g., acoustic vs. semantic encoding tasks and recall vs. recognition tests). In addition, more recent theoretical viewpoints, including those described earlier, tend to attribute age deficits in deliberate remembering to factors that are presumed to operate at both encoding and retrieval. For example, in the absence of explicit guidance from the environment or strong support from the learning materials, the reduced-resources/reduced self-initiated processing view (Craik, 1986; Craik et al., 1995) predicts that older adults are less likely to engage in effective strategic processing, both at encoding and at retrieval. Likewise, the inhibitory-deficit view (Hasher & Zacks, 1988; Hasher et al., 1999) argues that inefficient suppression mechanisms not only impede effective encoding (e.g., more extraneous associations are formed) but also impede retrieval through (a) the reactivation of enriched memory bundles that include extraneous associations and (b) the slowed suppression of any nontarget associations that are activated.

Given this situation, we make no attempt to maintain a strong separation between encoding and retrieval processes in the following discussion. Furthermore, in order not to repeat the thorough and excellent reviews of explicit memory work in previous reviews of the aging and memory literature (e.g., Craik et al., 1995; Craik & Jennings, 1992; Light, 1991; A. D. Smith, 1996), we deal with a limited set of topics of current interest. We begin with a task variable, divided attention, that is known to have a major impact at encoding but has also been investigated for its effects at retrieval.

Divided Attention

Possibly because of the widespread belief that older people are especially impaired when doing two things at once, the study of age-related differences in divided-attention costs on cognitive performance has been an active research domain. Studies investigating divided-attention costs on episodic memory commonly use procedures in which a "secondary" reaction time or short-term memory task is paired with the encoding or retrieval phase of a "primary" episodic memory task (e.g., see Craik, Govoni, Naveh-Benjamin, & Anderson, 1996). For example, in a recent study by Anderson, Craik, and Naveh-Benjamin (1998) involving groups of younger and older adults, a continuous reaction time task was combined with either encoding or retrieval for a free-recall or cued-recall test. In such experiments, divided-attention costs are revealed by poorer performance (lower accuracy on the memory test, slower responding on the reaction time task) in either or both the primary and secondary tasks when they are performed together versus separately.

Reduced-resources approaches to cognitive aging predict that divided-attention costs will be larger in older adults than in younger adults, except perhaps when the tasks being combined are both distinctive and relatively automatic tasks. Experimental situations involving online performance measures (e.g., reaction times) generally provide support for this prediction (e.g., A. A. Hartley, 1992), although there are exceptions (e.g., Somberg & Salthouse, 1982; Tun & Wingfield, 1994). In addition, questions have been raised about how to best account for age differences in baseline or single-task control conditions in measuring divided-attention costs (Naveh-Benjamin & Craik, 1998; Salthouse, 1991; Salthouse, Fristoe, Lineweaver, & Coon, 1995).

With respect to the specific question of whether older adults show larger divided-attention costs on explicit memory tasks than do younger adults, there are different findings depending on whether one looks at costs on the primary or the secondary task. To be specific, as predicted by reduced-resource views, the secondary task measures typically indicate greater costs for older adults at both encoding and retrieval (especially the latter) and particularly when the memory task is one that is presumed to involve greater self-initiated processing (free recall vs. cued recall or recognition; Anderson et al., 1998; Craik & McDowd, 1987; Whiting & Smith, 1997; but see Park, Smith, Dudley, & Lafronza, 1989). By contrast, the most common finding on the primary episodic memory task is that younger and older adults show equivalent divided-attention costs that are substantially greater when a secondary task is performed during encoding rather than at retrieval (Anderson et al., 1998; Nyberg, Nilsson, Olofsson, & Bäckman, 1997; Park, Puglisi, Smith, & Dudley, 1987; Whiting & Smith, 1997; but see Park et al., 1989). The pattern of greater divided-attention costs for older adults on the secondary task along with equivalent disruption of primary task performance provides mixed support for a reduced-resources view. However, it might be possible to fully reconcile these data to a reduced-resources view if it could be shown through instructional manipulation that the pattern of results reflects participants' strategic inclinations to protect performance on the primary memory task at the expense of the secondary task. (See also the later discussion on automatic retrieval.)

Effects of Structure and Prior Knowledge on Deliberate Remembering

Memory for structured materials that relate to prior knowledge is generally better than memory for materials that either are unstructured or make little contact with what the individual already knows. But how do these types of effects come about, and, especially important in the current context, are there age-related differences in the effects of structure and prior knowledge on memory? (Because of the close relationship between structure and prior knowledge—i.e., prior knowledge frequently determines whether inputs are seen as structured or not—we treat them together in the following discussion.)

Much of the early research in this domain used lists of words or pictures containing groups of related items, for example, several instances from each of several different taxonomic categories. In general, such lists produce better memory performance than lists of unrelated items, but the size of the benefit is known to be influenced by other variables, including the typicality of the category instances, the list presentation format (random order or blocked by category), and the type of memory test (free recall, cued recall, or recognition). At a global level at least, all these variables have similar effects for younger and older adults (cf. Kausler, 1994). That is, for both age groups, memory is enhanced by the presence of a categorical structure in the list; and for categorized lists, memory is better when the list is presented in a blocked-by-category fashion rather than a random fashion and when recall is cued by the category labels rather than when no cues are provided. Also, when a free-recall memory test is used, both younger and older adults show grouping or clustering of items from the same category in their recall orders. Like young adults, older adults' recall is also affected by other types of list structure, including the presence of sets of rhyming words (Mueller, Rankin, & Carlomusto, 1979) or the inclusion of groups of items relating to different scripted activities (Hess, Flanagan, & Tate, 1993).

Our emphasis on the global similarity of structural effects for younger and older adults should not be taken to mean that there are no age differences. Kausler's (1994) summary of the relevant literature documents the frequent findings of quantitative differences between younger and older adults (e.g., lower clustering scores or smaller cuing effects in older adults). But these differences do not detract from the fact that older adults show robust effects of the structure that may be present in a memory list, indicating that they reliably encode the structure and use it in retrieving list items. The same basic sensitivity to structure in the input and prior knowledge is seen in findings on older adults' memory for sentences and prose passages (cf. Light, 1992).

Effects of Different Levels of Linguistic Structure

Sentences and longer segments of prose contain structure at several hierarchical levels, some relating to individual sentences (phrase, clause, or proposition) and others relating to the connections among propositions and sentences. In theories of text processing (e.g., Kintsch, 1988; Kintsch & van Dijk, 1978), the structural components of larger text units include the *microstructure* of a discourse (the structure relating individual propositions to each other) and its *macrostructure* (the structure of the major themes of a discourse). On top of these more or less text-based levels of structure, Kintsch and others (e.g., Zwaan & Radvansky, 1998) have argued that deep comprehension of a prose passage involves the construction of a *situation model*, a high-level representation that captures the gist of the situation described by the text. Recent work has produced interesting findings regarding effects of these different levels of structure on older adults' comprehension of and memory for prose. (For more details on this literature, see chap. 6, this volume.)

Text-Based Levels. As an example of research investigating lower structural levels, we consider findings from a paradigm that has been used in several studies by Wingfield and colleagues. This paradigm involves the use of prerecorded speech passages that are presented in segments of either the participant's or the experimenter's choosing, with each segment being followed by immediate recall of the preceding unit of speech. When participants are allowed to select their own segments by stopping the tape recorder as often as they would like, younger and older adults show similar segmentation and recall patterns. Both age groups tend to interrupt the tape at syntactic (i.e., phrase, clause, or sentence) boundaries, and both age groups show excellent recall of the selected segments (Wingfield & Butterworth, 1984; Wingfield, Lahar, & Stine, 1989). This pattern holds even for relatively unpredictable text (Wingfield & Lindfield, 1995) and for relatively fast speech rates (Wingfield & Stine, 1986). On the other hand, when the speech segments are predetermined by the experimenter, age differences are affected by the location of the interruptions. When the speech is segmented at syntactic boundaries, the age deficit is smaller than when it is segmented at random intervals (Wingfield, Tun, & Rosen, 1995). Furthermore, in contrast to what is true for syntactic segments and self-selected segments, fast presentation rates result in greatly impaired recall by older adults in the random segment condition. This pattern of results is interpreted as indicating that older adults are efficient online processors of the syntactic and prosodic structure of speech and that they can use these levels of structure to parse the speech into coherent units and to guide their recall. Wingfield and colleagues (e.g., Wingfield et al., 1995) also suggested that because of the availability of different types of structure (i.e., syntactic or prosodic) in speech, at least the early stages of speech processing appear to be relatively free of short-term memory capacity constraints.

Research on the *levels effect*, the finding that the central propositions of a text are more likely to be recalled than less important propositions, likewise shows that younger and older adults are, with some qualifications, similar in their processing of text-based levels of linguistic structure (J. T. Hartley, 1993). This conclusion also applies to higher level structures to which we now turn.

Situation Models. As has already been indicated, a situation (or mental) model of a prose passage is a high-level representation of the state of affairs described by the text (rather than a representation of the text itself; cf. Zwaan & Radvansky, 1998). The creation of situation models involves the conjoining of information retrieved from general knowledge to text-based information. The result is a representation that incorporates inferences about such features as characters' predispositions, their emotional states, and their goals, as well as about the spatial relationships among the people, objects, and events that are described (Morrow, Stine-Morrow, Leirer, Andrassy, & Kahn, 1997; Zwaan & Radvansky, 1998). Consequently, the construction of a situation model and the updating of that model as new information is encountered result in a richer understanding of a text than would be possible from text-based representations alone.

In an early demonstration of the importance of situation models, Garnham (1981) showed that if distractor and originally processed sentences describe the same situation, young adults have difficulty discriminating between them on a recognition test. For example, the original sentence "The hostess bought the mink coat from the furrier" is likely to be confused with a distractor sentence consistent with the same situation, namely, "The hostess bought the mink coat at the furrier's." The suggestion is that a situation model had encoded the description, and because both sentences satisfy the model, each is acceptable. By contrast, fewer confusions occur for another pair of sentences that, at text-based levels, are as similar to each other as the first pair but that are unlikely to refer to the same situation model (e.g., "The hostess received a telegram from the furrier" vs. "The hostess received a telegram at the furrier's"). Using lists of sentences structurally similar to the examples, Radvansky, Gerard, Zacks, and Hasher (1990) found that although older adults made more errors overall than younger adults, the pattern of those errors was very similar: Both groups made many more false alarms to same-situation distractors as compared with different-situation distractors, suggesting similar use of mental models across age groups.

Other studies have investigated not only older adults' ability to construct a situation model of a text but also their ability to update the model. For example, in two studies by Morrow and colleagues (Morrow, Leirer, Altieri, & Fitzsimmons, 1994a; Morrow et al., 1997), participants first memorized a map of a building (e.g., a research center) in which there were several rooms, each of which contained several objects. They then read narratives that included statements about the protagonist moving from one room to another. Such circumstances are thought to elicit the construction of a spatially organized situation model centered on the protagonist and her or his current location. Movement of the protagonist to a new location elicits updating of the situation model to maintain the centered position of the protagonist (Morrow et al., 1997).

In the study by Morrow et al. (1994a), reading of the narratives was interrupted at various points with probe questions about objects that were near or far from the protagonist's current location. For both younger and older adults, answers to probes were more accurate and faster the closer the probed object was to the protagonist. Morrow et al.'s (1997) study produced similar findings with a more direct measure, reading time. This was assessed for target sentences that referred to objects that were in the room the protagonist had just entered or to objects that were in other rooms at various distances from the current location of the protagonist. Like younger adults, older participants took longer to read target sentences that mentioned more distant objects. Both age groups also showed a benefit when the target sentence explicitly mentioned the room location of the critical object. These results suggest that the two age groups are similar in their use of the memorized map and other background information to create a situation model of the narrative that centers on the protagonist and his or her current location and that is updated as the protagonist moves through space. The data could also be taken to suggest that implicit use of spatial context is spared with aging.

Note that both of the Morrow et al. studies found that older adults took longer than younger adults to memorize the maps. In addition, older adults were not only slower overall on the critical dependent measures (probe answering time in the Morrow et al., 1994a, study; target sentence reading time in the Morrow et al., 1997, study), but they also showed a larger distance effect than did younger adults. Morrow et al. (1997) interpreted their findings as indicating that "older and younger adults used qualitatively similar strategies to update situation models from narratives" (p. P78) but that the updating process was more effortful, or at least took longer, for older adults.

An additional set of findings confirming age invariant use of spatial situation models comes from the fan effect literature. Although it is generally the case that fact retrieval is slower and more error prone as the number of responses associated with a particular cue gets larger and that these effects are larger for older adults than for younger adults (Cohen, 1990; Gerard et al., 1991; see also previous discussion), there are situations in which fan effects can be eliminated. One such situation occurs when a spatial mental model is provided to organize information. For example, the facts "The potted palm is in the hotel lobby" and "The pay phone is in the hotel lobby" can be readily integrated into a single situation model of the "hotel lobby." For sets of facts that permit integration through such a mental model, the fan effect is largely and equally eliminated for both younger and older adults (Radvansky, Zacks, & Hasher, 1996). Again, spatial models prove useful for older adults. In addition, Radvansksy and Curiel (1998) recently showed that the representation of protagonists' goals is another aspect of situation model processing that differs little between younger and older adults.

Thus, across several paradigms, younger and older adults are similar with respect to the construction, updating, and use of situation models (at least ones organized around space and goals) in representing text. To be sure, there are subtle age differences suggesting that use of such models may be more demanding for older adults (Morrow et al., 1994a, 1997), but this finding is not uniform (cf. Radvansky & Curiel, 1998; Radvansky et al., 1996). In general, it seems clear that the findings on situation models are consistent with the data from studies of other encoding processes (organization and schema use) that suggest similarity in encoding between younger and older adults, coupled with some quantitative differences. There are even instances (e.g., Adams, Smith, Nyquist, & Perlmutter, 1997; see the section on social contexts) in which older adults appear to encode more of the deep and symbolic meaning of a text than do younger adults.

Expertise. Before leaving the topic of memory for structured materials, we briefly consider whether there are age differences in memory performance for domain-specific knowledge such as is possessed by experts in an area but not by nonexperts. It has been known for some time (e.g., Chase & Simon, 1973) that because of their superior domain knowledge, experts more quickly and more effectively encode the underlying structure of new inputs in their area of expertise than do novices, and consequently, they remember these inputs better on both immediate- and delayed-retention tests. Not much research has specifically addressed the impact of expertise on the memory ability of older adults, but the studies that have been done show memory benefits of expertise in older as well as younger adults. For example, Morrow, Leirer, and Altieri (1992) compared young and older pilots with young and older novices on their memory for narrative passages concerning aviation or nonaviation themes. For both ages, expertise was associated with increased memory for the aviation-related narrative, but the pilots and nonpilots showed similar age deficits in performance whether they were recalling the aviation or the nonaviation passage. In a more recent study, Morrow, Leirer, Altieri, and Fitzsimmons (1994b) compared younger and older pilots and nonpilots on short-term recall of heading, altitude, speed, and frequency commands in a simulated air-traffic control communication situation. Short-term memory tasks were also used by Halpern, Bartlett, and Dowling (1995) in their investigation of effects of musical experience on auditory recognition of transposed melodies and by Meinz and Salthouse (1998) in their study of recall of visually presented musical melodies. With minor exceptions (recall of heading commands in the Morrow et al., 1994b, study and one of four experiments in the Halpern et al., 1995, study), the pattern of findings in these other studies is similar to the pattern demonstrated in the narrative recall results of the Morrow et al. (1992) study. Specifically, all ages showed a benefit of expertise on memory for domain-relevant information, but expertise was not associated with reliable attenuation of age differences in performance. Morrow et al. (1994b) claimed that their exception to this trend, the finding that old pilots recalled heading commands as well as young pilots, is meaningful. They suggested that of all the types of information they tested, recalling the heading commands may be most relevant to pilots' expertise, thus allowing expertise to compensate for age-related cognitive deficits. Aside from this suggestive finding, the literature on expertise effects on memory in older adults joins the other findings described in this section of the chapter in showing that structure and prior knowledge in various forms have similar effects on younger and older adults' memory performance; however, these effects do not reliably attenuate the age difference in deliberate memory.

Retrieval Phenomena

We now shift to topics that focus more heavily on retrieval than encoding processes. The first topic in this category deals with an aspect of retrieval for which there is intriguing evidence of relative insensitivity to age effects.

Automatic Retrieval

The notion that at least one aspect of retrieval is obligatory or automatic comes from several recent lines of work. Consider first an aspect of the work we previously mentioned by Craik and colleagues (Anderson et al., 1998; Craik et al., 1996; see also Jennings & Jacoby, 1993; Moscovitch, 1994; Nyberg et al., 1997) on the memory effects of divided attention manipulations. That work shows that divided-attention costs at retrieval primarily impact on the secondary task (and more so for older adults), with little impact on the memory task itself. An implication of this pattern of findings is that retrieval processes are effortful but obligatory. Work of this sort is exciting because it dovetails nicely with two other lines of research, one behavioral and the other more neuropsychological.

One of the lines of work supporting the ideas that aspects of retrieval can be automatic and equivalent for older and younger adults is that of Jacoby and colleagues (Jacoby, 1991; Jacoby, Yonelinas, & Jennings, 1997). On the basis of the claim that all memory tasks involve a combination of automatic and deliberate processes (none are "process pure"), Jacoby developed a research strategy, the "process–dissociation paradigm," in which conscious recollection and automatic retrieval are pitted against each other.

One example of the implementation of this strategy is in a series of experiments on the "false-fame effect" (e.g., Dywan & Jacoby, 1990; Jennings & Jacoby, 1993). For example, in the Dywan and Jacoby study, participants first read a list of nonfamous names. Then they were given a new list consisting of three types of names: those from the first list, additional nonfamous names, and moderately famous names. Their task was to indicate which of the names were famous. Participants were informed that the names on the original study list were nonfamous, and so any names that were recognized from that list could be excluded from consideration. The rationale behind this design is as follows: Studying a nonfamous name increases its familiarity (and familiarity mediates automatic retrieval), and unless this enhanced familiarity response is counteracted by the conscious recollection that the name had appeared on the original study list, the individual is likely to misinterpret familiarity as fame (the false-fame effect). Dywan and Jacoby found a larger false-fame effect for older adults as compared with younger adults.

A later experiment (Jennings & Jacoby, 1993) compared the condition just described with one in which participants were told that the names that they had read previously were actually obscure famous names; in this case, it was appropriate to label a familiar name as famous whether or not the individual had a specific recollection of having studied it previously. The condition included in the Dywan and Jacoby (1990) study is termed an *exclusion condition* (exclude any names recollected from the initial list). The condition added in the Jennings and Jacoby study is termed an *inclusion condition* (include any names whether recollected or only familiar). The data from experiments that include both of these conditions can be analyzed to provide quantitative estimates of conscious recollection and automatic retrieval (e.g., Jacoby, 1991). In the Jennings and Jacoby study, the estimates of conscious recollection were lower for older adults than for younger adults, but the estimates for the automatic retrieval component did not differ across age groups. This suggests that being old impairs conscious recollection while leaving automatic retrieval (familiarity) unchanged.

The age findings in the false-fame studies have been confirmed in studies using other implementations of the process–dissociation procedure. For example, Jennings and Jacoby (1997b) used a procedure in which participants first learned a list of words and then were given a recognition test in which the distractor words were repeated at varying lags. In the exclusion condition, participants were instructed to respond "no" to repeated distractors (which presumably should be somewhat familiar because of their prior occurrence). In the inclusion condition, they were told to respond "no" only to entirely new distractors; any familiar item could legitimately receive a "yes" response. Once again, the estimates from the process–dissociation analysis showed lower recollection for older adults, along with no age difference in automatic retrieval (see also Jennings & Jacoby, 1997a; Salthouse, Toth, Hancock, & Woodward, 1997; Titov & Knight, 1997). Thus, the pattern of age-related decline in conscious recollection and age constancy in automatic retrieval appears to be robust. However, it should be noted that the process–dissociation paradigm is not without its critics (Curran & Hintzman, 1995; Dodson & Johnson, 1996; Graf & Komatsu, 1994). Of particular concern for aging studies is the possibility that older adults may have greater difficulty than younger adults switching retrieval strategies in response to the instructions for the inclusion versus the exclusion condition. Final interpretation of the aging data derived from the Jacoby paradigm will have to await resolution of these criticisms.

In addition, the work of Moscovitch and colleagues suggests (along with Schacter et al., 1998) that some aspects of retrieval are obligatory responses to cues, whereas others require more (frontally mediated) control. Older adults may be particularly impaired at the latter processes, which Moscovitch and Winocur (1992) termed "working with memory." Work of this sort dovetails nicely with work in the process–dissociation tradition.

Errors in Memory

We return now to an observation made at the beginning of our discussion of deliberate remembering—that there is currently a heightened interest in errors. This can probably be traced to three lines of work: (a) research investigating the highly predictable errors produced in recall and recognition in the Deese–Roediger–McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), (b) research in the memory for source tradition (Johnson et al., 1993; Schacter et al., 1998), and (c) research on the misinformation effect (e.g., Loftus, 1992). We primarily focus on the first two because of their substantial link to the current aging and memory literature.

Misrecall and Misrecognition of Related Items

Consider Reder, Wible, and Martin's (1986) landmark investigation of the patterns of errors made by older and younger adults. In Experiment 1, participants read a series of stories and subsequently were asked to identify which sentences had or had not been presented. The critical foil sentences were either highly or moderately plausible inferences from the text. Older adults were far more likely than younger adults to falsely recognize sentences that were related to the original story. This general finding has since been replicated several times (e.g., May, Hasher, & Stoltzfus, 1993; Yoon, 1997). Reder et al. focused on retrieval strategies to explain their findings. In particular, they suggested that relative to younger adults, older adults were more likely to use a plausibility criterion ("If it is consistent with the story, call it old") rather than a direct retrieval strategy when they judged items as old. Other data support the idea that older adults are more likely than younger adults to rely on plausibility or heuristic decision rules (as compared with analytic rules) at retrieval rather than on direct retrieval (Stine & Wingfield, 1987; Tun, 1989; Wingfield et al., 1995). As Reder et al. pointed out, if relatedness helps performance, older and younger adults will do equally well; if it does not, differences will arise (see their Experiment 2).

The general finding that predictable errors in recall and recognition are more common for older adults than for younger adults has been repeatedly demonstrated in a task specifically implemented to show high rates of such errors, the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995). In this task, participants typically hear a series of lists (or sublists, if one long series is used) of words (e.g., *thread, pin, eye, sew*), each of which is composed of the associates of a particular, never-presented lure (e.g., *needle*). When tested at the end of the presentation series, lures are highly likely to be produced in recall or accepted as old in recognition (Roediger & McDermott, 1995; see review by Schacter, Koutstaal, & Norman, 1997).[9] Recent studies have found that acceptance of lures, even weakly associated ones, as old is more common for older adults than for younger adults. Acceptance of lures as old is also more common for older adults even when their recognition of old items does not differ from that of younger adults (e.g., K. A. Norman & Schacter, 1997; Tun, Wingfield, Rosen, & Blanchard, 1998). Tun et al. also found that lures are actually termed "old" *more quickly* by older adults than by

[9]In the current literature, these errors are referred to as "false memories" rather than as false alarms or more generally as errors. We use the more neutral terms because of the politically charged debate over false and recovered memories and because of the tenuous relationship we see between most laboratory studies and critical real-life issues (but see Christianson, 1992).

younger adults, which is consistent with the suggestion from Reder et al. (1986) that different decision criteria are used by the two age groups, with older adults relying more frequently than younger adults on plausibility or similarity.

In the general memory literature, and particularly in the DRM paradigm, another explanation for errors is tied to the elaborative or associative encoding people are thought to engage in as each item is presented (see Underwood's, 1965, notion of implicit associative responses). If a self-generated item then occurs at test, people may call it old because it occurred in the context of the experiment (see the next section on source errors). However, if older adults are somewhat less likely than younger adults to use elaborative encoding (or self-initiated processing) in the first place (Craik, 1986; A. D. Smith, Park, Earles, Shaw, & Whiting, 1998), they should be less likely to generate at encoding the lures that subsequently occur at test. This would then result in reduced rates of errors for older adults rather than in the actually observed heightened rates. As a direct test of the lure-generation hypothesis, Koutstaal and Schacter (1997) presented photographs of category instances (e.g., shoes) selected in such a way as to preclude the possibility that participants would generate during encoding the exact instance that then served as a lure during testing. Even with such materials, older adults still showed higher rates of false alarms than did younger adults. A plausibility or gistlike retrieval criterion, and age differences in reliance on this criterion, seems strongly implicated in these error patterns.

Other evidence suggests that testing circumstances can substantially alter the degree to which schematic retrieval plans or heuristic decision rules, on the one hand, versus direct retrieval plans or analytic decision rules, on the other, are used at test by both younger and older adults (Dodson & Johnson, 1993; Multhaup, 1995; Multhaup, De Leonardis, & Johnson, 1999). These studies are discussed below. We note here, however, that a key finding in the schema theory literature in the 1970s is that the pattern of retrieval will vary as a function of the instructions given at test, with some instructions encouraging gist- or schema-level recall and others encouraging more reproductive strategies (see Alba & Hasher, 1983; Brainerd & Reyna, 1990). Thus, even though much current work suggests that older adults are more likely than younger adults to use low-demand retrieval strategies (e.g., gist- or schema-based ones), and low-demand decision rules (heuristic ones such as plausibility), their use is not inevitable, even by older adults.

One additional encoding process might play a role in producing errors in the DRM paradigm. Note that even for younger adults, the greatest numbers of errors occur when sets of related items are grouped in a series rather than distributed throughout the presentation list (McDermott, 1996).

A blocked series of related items is thought to encourage *relational* encoding rather than *item-specific* or distinctive encoding (Hunt & McDaniel, 1993). Recent work suggests that encouraging young adults (R. E. Smith & Hunt, 1998) and both younger and older adults (Weichmann & Hasher, 1998) to engage in item-specific encoding radically reduces the overall rate of intrusions of lures at recall (see also Israel & Schacter, 1997). Thus, it is possible that older adults are more likely than younger adults to engage in relational encoding processes unless the encoding circumstances dictate otherwise. Without item-specific information available, and with little press for analytic decisions at test, many related items will be judged old. If so, these findings suggest that although relational or gist coding can be and often is used by participants in DRM paradigm tasks, it is not inevitably used. As is also suggested above, although heuristic decision rules can be, and often are, used in DRM paradigm and other tasks, these too are not inevitable—for either younger or older adults.

Source Errors

As was indicated earlier, the theoretical frameworks of Johnson et al. (1993; Johnson & Raye, 1981) and of Schacter et al. (1998) argue that events are encoded as bundles of conceptual and perceptual features and that the properties of these bundles of features (how strongly different features are encoded, how well the features are bound together), along with processes occurring at retrieval, determine the ability to judge the source of a memory (among other important uses of memory). This approach has stimulated a number of lines of research, including work on age differences in source memory; and that work has joined with an existing line of work on age differences in context versus content memory. For present purposes, these two topics are intermixed.

Findings on Age Differences in Memory for Source. Research on memory for contextual features and source typically uses deliberate memory tasks and, with a few notable exceptions (see below), shows that older adults are less accurate at recalling and recognizing contextual features of events than are younger adults (see Spencer & Raz, 1995, for a meta-analysis). For example, older adults are at a disadvantage relative to younger adults in remembering various perceptual details, such as the color, case, or font, in which target items occurred (e.g., Kausler & Puckett, 1981; Naveh-Benjamin & Craik, 1995; Park & Puglisi, 1985); their locations (e.g., Chalfonte & Johnson, 1996; Cherry & Park, 1993; Light & Zelinski, 1983; Park, Puglisi, & Lutz, 1982; Uttl & Graf, 1993); their temporal sequence (Kausler, Salthouse, & Saults, 1988); and even seemingly potentially more salient characteristics, such as whether the speaker was male or female (Bayen & Murnane, 1996; Kausler & Puckett, 1981), whether the items were presented in a video or photo format (Schacter, Koutstaal, Johnson, Gross, & Angell, 1997), and whether items were presented auditorially or visually (Light, La Voie, Valencia-Laver, Albertson-Owens, & Mead, 1992).

Older adults are also at a disadvantage in remembering attributes that code for differences in enactment, such as actually saying or doing something versus merely imagining doing so (Cohen & Faulkner, 1989; Guttentag & Hunt, 1988; Hashtroudi et al., 1989, 1994; Hashtroudi, Johnson, & Chrosniak, 1990) and actually reading or hearing something versus generating it on the basis of cues (Brown, Jones, & Davis, 1995; K. A. Norman & Schacter, 1997). Indeed, some have suggested that heightened false memories in the DRM paradigm itself can be taken as evidence of confusion between seen (old items) and imagined events (lures). Several investigators have noted that even when event memory is equivalent between younger and older adults, the latter can be at a disadvantage in remembering source (Chalfonte & Johnson, 1996; Henkel et al., 1998; Johnson, De Leonardis, Hashtroudi, & Ferguson, 1995; Schacter et al., 1997; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991). These findings are taken to suggest that either the encoding of attributes or their binding together with items is generally poorer for older adults than for younger adults (e.g., Chalfonte & Johnson, 1996; Johnson, 1997). It is also taken as evidence that older adults have even greater memory problems with context information than they do with content.

One novel way of studying recollection of the features of items is to use a task developed by Johnson and colleagues (e.g., Johnson, Foley, Suengas, & Raye, 1988), the Memory Characteristics Questionnaire. Versions of this task require participants to indicate the characteristics they recollect for each item or event judged as old (e.g., spatial arrangement of objects and associated feelings). Variants of the questionnaire have been used with younger and older adults in both source-monitoring and DRM paradigm tasks, with the findings generally showing age differences in the characteristics that are remembered. For both younger and older adults, items that were presented and are recognized have more sensory (e.g., color) and contextual (e.g., list position) information than do nonpresented lures that are misrecognized as old. Of special note, however, is the finding that for items judged as old, the differences in reported features between actual old items and lures are smaller for older adults than for younger adults (Hashtroudi et al., 1990; K. A. Norman & Schacter, 1997). Presumably, then, older adults have less detailed information in memory to distinguish between types of events than do younger adults. It is no surprise, then, that older adults have more difficulty distinguishing between sources originating in the same general domain (e.g., two voices in the perceptual world or a thought and an image in the conceptual world) than in distinguishing between sources that cross these domains (a speaker and a thought; Johnson et al., 1993).

The evidence we have reviewed so far suggests that one "source" of the age-related increase in source errors is the reduced discriminability of old items and lures. It remains to be learned what the cause is of the reduced discriminability. Because different features take different amounts of time to recover once retrieval is initiated (see Johnson et al., 1993) and because older adults say "yes" faster to lures than do younger adults (Tun et al., 1998), it is possible that older adults respond with less information than younger adults and so answer questions differently. It is also possible that older adults have slowed or reduced access to features in experiments because the features of different items in a list may be quite similar and because the retrieval costs of similarity are greater for older adults (e.g., because they have created functionally larger search sets for themselves and so greater competition at retrieval). Relevant here are findings indicating that similarity between and among features is a critical variable in determining source-monitoring difficulties (Johnson et al., 1993). One recent experiment in the source memory tradition asked younger and older adults to look at versus imagine a series of pictures (Henkel et al., 1998). Among the imagined items were some that were perceptually similar to seen objects (e.g., a lollipop and a magnifying glass) and others that were conceptually similar to seen objects (e.g., a banana and an apple). In addition to the expected finding that older adults were less able to discriminate between seen and imagined objects than were younger adults, the findings also showed that both perceptual and conceptual featural similarity between imagined and seen objects were differentially disruptive to older adults (see Bayen & Murnane, 1996; Bayen, Murnane, & Erdfelder, 1996). Given the well-established role of similarity in causing retrieval difficulties (i.e., interference in memory), this finding could also be taken to point toward retrieval problems. If so, the finding is consistent with the view that older adults are more vulnerable to sources of interference than are younger adults (see Kane & Hasher, 1995).

This differential vulnerability to interference among similarly featured events could also play a role in the "reminiscence bump," the elevated levels of recall shown by older adults for memories from their 10th to their 30th years relative to other time periods. Rubin, Rahhal, and Poon (1998) reviewed research showing that this bump is present for personal or autobiographical memories and for memories judged as most important or most vivid. Similar bumps (albeit with different overall life-span curves as well as slightly different age ranges for the bump) are also seen for questionnaire research using historical events and people as targets (e.g., Botwinick & Storandt, 1980; Rubin et al., 1998). Thus, more of the events that older adults recollect come from a time in their lives (late adolescence and early adulthood) that probably offered more unique events than any other time period.[10] This argument claims that distinctiveness insulates memories from interfering with each other, thereby potentially helping to preserve these early memories. Of course, multiple interpretations have been offered for these patterns of recollection (see Burke & MacKay, 1997; Rubin et al., 1998).

"Remember–Know" Paradigm. To return to the issue of memory for source, we turn to findings from the "remember–know" paradigm (Gardiner & Java, 1993; Tulving, 1985) findings, which are also suggestive of reduced availability of contextual features for older adults. The remember–know paradigm explores the difference between episodic recognition judgments that are accompanied by recollection of contextual details present at the time of encoding and ones that are empty of such details, with recognition being based on decontextualized familiarity of the target. The procedures involve variants of standard recognition memory tests in which participants decide, for each item recognized as old, whether they consciously recollect having previously studied that item (remember judgment) or merely find the item familiar (know judgment). In general, remember–know studies comparing younger and older adults have found a lower proportion of remember responses for the older group but equal or greater know responses for older adults than for younger adults (e.g., Java, 1996; Mäntylä, 1993; Parkin & Walter, 1992; Perfect & Dasgupta, 1997). In other words, even for items that are recognized as coming from the study list, older adults are less likely to have clear source information than are younger adults.

Incidental Tests of Memory for Source. So far, we have considered deliberate tests of source memory. Memory for source can also be tested incidentally—that is, the ostensible task relies on the use of some information whose importance is not deliberately noted at encoding, at retrieval, or both. Consider the "misinformation" paradigm (e.g., Loftus, 1992) by which two successive, related events occur with the second event providing (or not providing in the control condition) a critical fact or observation that contradicts information in the first event. At test, participants are asked to choose between items they saw in Phase 1 and new items. Included in this list is a lure containing the Phase 2 error. Partici-

[10]A typical procedure in the autobiographical memory tradition is to provide participants with a long series of cue words used to retrieve personal memories. The memories are then self-dated. The bumps are found within the 50% of memories that do not come from the most recent year (see Rubin et al., 1998).

pants can potentially discriminate between the two sets on the basis of temporal information (which came first), modality information (if, for example, the first were presented as a film and the second as a written description of the film's incident), or any other contextual cues that distinguish the two sources. If contextual features are less accessible to older adults than to younger adults, they might be expected to make more such errors than younger adults, and they do (Cohen & Faulkner, 1989). Among related findings, we include the false-fame findings mentioned earlier (e.g., Dywan & Jacoby, 1990; see also Bartlett, Strater, & Fulton, 1991). Lack of access to temporal attributes may also lie behind other patterns of errors shown by older adults (e.g., Jennings & Jacoby, 1997b).

By contrast, however, it is also worth noting that the provision of contextual cues that might otherwise be difficult to retrieve (e.g., location) appears to help older adults at least as much as younger adults (e.g., Cherry & Park, 1993; Cherry, Park, & Donaldson, 1993; Earles, Smith, & Park, 1994; Naveh-Benjamin & Craik, 1995). There are also reports that context actually helps older adults more than younger adults (e.g., Park et al., 1990). This suggests that features may be coded but difficult to retrieve. Other evidence further suggests that age differences in context memory are substantially reduced when testing is implicit rather than explicit (Light et al., 1992; Vakil, Melamed, & Even, 1996; see also the section on situation models). Together, such evidence seems to point toward deliberate retrieval problems rather than encoding problems.

Moderating Factors. Are older adults inevitably worse on source memory tasks than younger adults? There is, in fact, some suggestive work that might be taken as evidence for boundary effects for source deficiencies. For one thing, the nature of the stimulus materials may well influence the degree to which older adults show source deficits. Several studies suggest smaller age deficits (or even nonexistent ones) when the materials are engaging and well-known to the older adults (Brown et al. 1995; McIntyre & Friesen, 1998). Roles in social contexts may also influence the size of source errors shown by older adults (Brown et al., 1995), with better memory when older adults are active participants rather than (as is the case in most studies) passive observers. Instructions to older adults to focus on facts rather than on affect while listening to a play being read will also reduce source differences (Hashtroudi et al., 1994).

Coupling interesting materials (facts) with the use of instructions that emphasize the acquisition and use of *knowledge* rather than *memory* for that information also appears to eliminate age differences in memory for source (Rahhal & Hasher, 1998). Changing decision criteria from loose (or gistlike ones) to tight, reasoned ones will also influence source-based errors and can even eliminate age differences (Multhaup, 1995; Multhaup et al., 1999).

Encoding Factors and Age Differences in Source Memory. As we have seen, the findings on age differences in memory for contextual features and source are complex. There generally is an age deficit, but the size of the deficit and the overall performance of younger and older adults are a function of numerous factors. That both ages are more accurate under some instructions than others, with some materials than others, and that age differences can even be eliminated (even if rarely) seems particularly important both to our understanding of source memory and to our understanding of memory more generally. Here, we try to draw out the theoretical implications of the variability of source memory and age differences therein for viewpoints on age differences in source errors that emphasize encoding factors. Such viewpoints might claim that fewer features were encoded in the first place or that those features that were encoded were insufficiently "bound" or associated, so that the retrieval of one or more features does not succeed in retrieving others. Both of these types of explanations are called into question by the powerful effects of retrieval conditions (e.g., instructions) and materials. If a particular feature were not encoded, no retrieval manipulations could induce its recollection or its use. Likewise, effects of retrieval manipulations also challenge at least the strong form of the view that age deficits are the result of weaker binding or integrating of features by older adults. In terms of broad implications, we note that very different views of retrieval accuracy will be the result of assumptions that suggest encoding processes that leave inaccurate traces or incomplete features in memory once the episode is encoded versus processes that leave traces that may or may not be retrieved in detail. Herein lies the contrast between constructivist views (with inevitable errors; e.g., Brewer & Nakamura, 1984; Schacter et al., 1998) and flexible views of memory, views that suggest that a number of variables can influence performance, with retrieval looking more or less detailed, depending on circumstances (e.g., Alba & Hasher, 1983; Johnson & Raye, in press).

This is not to say that encoding processes play no role in the ultimate success of retrieval. One view (Hasher et al., 1999; Zacks & Hasher, 1994) proposes that the speed and accuracy of retrieval will be partly determined by encoding processes that influence the size of the "fan" stemming from a cue. If the fan includes relevant information only, retrieval will be faster and more accurate than if the fan includes relevant and irrelevant information. Thus, control over access of relevant and irrelevant information to working memory at encoding is part of what determines retrieval (Hasher et al., 1999; Zacks & Hasher, 1994). Older adults may have less control over working memory and so have far less ability to ignore distraction in the environment (see, e.g., May, 1999; Multhaup et al., 1998), in thought (see below), or from the recent past (May et al., in press).

Furthermore, from the perspective of a young or middle-aged experimenter, older adults may have goals that are different from those set by the instructions and so have a greater tendency than younger adults to pay attention to the emotional and interpretive qualities of input along with or rather than the factual qualities (e.g., Adams et al., 1997; Hashtroudi et al., 1994). Or they may attend more to their own emotional responses to a situation and less to the events in the environment than do younger adults (Hasher & Zacks, 1988; Johnson et al., 1996; see also chap. 11, this volume; Johnson & Raye, in press). Thus, age differences in goals and in control over working memory can influence retrieval efficiency (see Burke & MacKay, 1997, for a different view).

Prospective Memory

Regardless of the participant population involved, most research on deliberate memory has been concerned with *retrospective remembering*, recall or recognition of experiences that occurred in the past. We end our discussion of explicit memory with another category of deliberate memory functions—*prospective remembering*, or remembering to perform a planned action sometime in the future. Prospective memory is critical to the accomplishment of everyday social and personal goals. A person who chronically forgets dates with family and friends, who misses appointments with health professionals, and who forgets to carry out intended household chores is likely to both suffer from and cause numerous problems in everyday life.

Despite its obvious importance, memory researchers have only recently engaged in a concerted effort to study prospective memory. One factor contributing to this situation is the difficulty of defining the unique characteristics and essential components of prospective memory so that appropriate experimental tasks can be designed. A number of authors have commented that prospective memory situations are multidimensional and involve several qualitatively different components, including retrospective memory elements (e.g., remembering what the required action is) and elements such as compliance and motivation that are rarely considered in research on retrospective memory (Dobbs & Reeves, 1996; Maylor, 1996). Given this situation, it is not surprising that there is some divergence among authors as to what are the critical components of prospective memory tasks. For example, Maylor focused on remembering an intention to carry out a specified action in the absence of external prompting. Although Craik and Kerr (1996) agreed that prospective memory involves the retrieval of intentions, they also focused on the planning and monitoring components of prospective memory tasks (cf. Dobbs & Reeves, 1996). Another characteristic that is frequently mentioned in relation to prospective memory is the use of dual-task situations in which the participant is required to interrupt an ongoing or primary task to carry out the prospective action, as often occurs outside of the lab (e.g., Einstein, Smith, McDaniel, & Shaw, 1997; Maylor, 1996; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997).

Much of the theorizing in prospective memory has been grounded in Craik's (1986) views, which argue that the magnitude of age deficits will be a joint function of the reduced processing resources of older adults, environmental support for effective encoding and retrieval strategies, and task demands. In this view, a critical factor is the amount of self-initiated processing the memory task requires. On the basis that retrieval in a prospective memory task occurs on the individual's own initiative rather than being initiated by the experimenter, Craik had predicted large age deficits in prospective memory, even relative to other deliberate memory tasks, such as cued recall. Reviews of aging and prospective memory research (e.g., Dobbs & Reeves, 1996; Einstein & McDaniel, 1996; Maylor, 1996) indicate only partial support for this prediction. In fact, there is considerable variation across studies in the magnitude and even in the occurrence of age deficits in prospective memory. To a degree at least, these variations may be generally consistent with Craik's viewpoint.

Consider, for example, the difference between two nominally distinct types of prospective memory tasks, those in which the prospective action is to be performed at a *particular time* (time-based tasks) versus those in which the prospective action is to be performed in conjunction *with a particular external event* (event-based tasks). The importance of this distinction was signaled by the unexpectedly good prospective memory performance of older adults in a series of studies conducted by Einstein, McDaniel, and colleagues (Einstein, Holland, McDaniel, & Guynn, 1992; Einstein & McDaniel, 1990). Einstein and McDaniel hypothesized that the absence of a prospective memory age deficit in their experiments was due to the use of an event-based prospective memory task requiring relatively little self-initiated processing (a keypress was required on the presentation of a particular target word). They also predicted, and later found (e.g., Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995), significant age deficits on a time-based prospective memory task for which there was not a specific external trigger to cue the required action (a keypress was required every 5 or 10 min). The latter study also found that older adults engaged in less monitoring behavior (checking the clock) than younger adults when performing a time-based prospective memory task (see also Park et al., 1997).

The difference between time-based and event-based prospective memory situations is not the only factor determining the size of age differences in this type of memory. One important factor relating to the dual-task nature of most prospective memory situations is the processing load of the nonprospective or primary task. Einstein et al. (1997) recently reported findings indicating that more demanding primary tasks are associated with larger age deficits in prospective memory. Another aspect of the dual-task context of prospective memory tasks is the degree to which the prospective memory and primary tasks are related or unrelated in terms of cognitive process and/or relevant stimuli (Maylor, 1996). For example, in the Einstein and McDaniel (1990) procedure, the prospective cues were words that were presented as part of the ongoing short-term memory task. By contrast, the event-based cues in the Park et al. (1997) study were irrelevant background patterns on the video monitor. Although both experiments involved event-based tasks, the prospective cues were much more embedded in the primary task in the Einstein and McDaniel study than in the Park et al. procedure. This fact may in part account for the contrasting results of the two studies: no age differences in the former versus a significant age deficit in the latter. Other properties of the cues used in event-based tasks have been investigated as well: Age differences are more likely when multiple rather than single prospective cues are designated (Einstein et al., 1992; Kidder, Park, Hertzog, & Morrell, 1997) and when less typical instances of category-defined cues are used (e.g., *milk* vs. *ink* given as cues when participants are told to respond to instances of the category liquid; Mäntylä, 1994).

Another point is that although the distinction between event-based and time-based prospective memory tasks may appear to be fairly clear-cut, this is only true in tightly controlled circumstances. In less controlled circumstances, indications are that at least some individuals turn time-based tasks into event-based tasks. For example, a number of "naturalistic" studies have used nominally time-based tasks in which participants are asked to mail postcards and/or make phone calls to the experimenter at specified future times. These studies have generally not imposed any restrictions on the way participants go about remembering how to carry out the prospective tasks. For the most part, age differences are minimal in these studies. For example, in Maylor's (1990) study, 222 women between the ages of 52 and 95 years were asked to call the experimenter once a day from Monday to Friday, either between two times or at an exact time. They were also asked to complete a questionnaire at the end of the week and to mail it in as soon as possible. Overall, there was a weak trend toward the older participants performing better on the prospective memory tasks than the younger adults, but this trend was limited to individuals using self-initiated strategies in which the prospective action was linked to some external trigger (e.g., performing it in conjunction with a routine daily activity, such as morning coffee, or using a calendar notation). In effect, these strategies turned a nominally time-based task into an event-based task. Among individuals who tried to rely only on internal time cues, poorer performance was associated with greater age.

As this summary of age differences in prospective memory suggests, prospective memory is similar to other forms of deliberate remembering, both in the fact that age deficits are frequently obtained and in the fact that the magnitude of age differences is variable. As a first approximation at least, the pattern of findings is generally consistent with Craik's (1986) hypotheses regarding reduced self-initiated processing in older adults. There are some recent arguments, however, that Craik's viewpoint may provide an incomplete account of prospective memory findings. For example, on the basis of participant reports that the prospective action seems to "pop into mind," Einstein et al. (1997) have recently suggested that retrieval of a prospective action seems to be relatively spontaneous and to not rely heavily on self-initiated processes. Note that age differences in prospective memory would be tied to differences in the ability to maintain activation of the intended action in working memory. Such ideas are consistent with earlier discussed automatic retrieval mechanisms being spared with age.

MEMORY AND ITS MODERATORS

To a large degree, the study of both basic memory processes and age differences in those basic processes takes the approach that these phenomena can be studied in isolation from other aspects of cognitive, social, and biological functioning. This "isolationist" approach to the study of memory and its aging seems to be changing, in part because of large-scale cross-disciplinary longitudinal studies of aging (e.g., Lindenberger & Baltes, 1997; McDonald-Miszczak, Hertzog, & Hultsch, 1995; Nilsson et al., 1997) and also because of developments in cognitive neuropsychology, including a productive line of work connecting age differences in memory to changes in brain function (see chap. 1 and 2, this volume; see also Johnson & Raye, in press; Moscovitch & Winocur, 1992; Perfect, 1997; Schacter et al., 1998; Stuss, Craik, Sayer, Franchi, & Alexander, 1996). However, other developments are also contributing to the breaking down of this isolationist approach. Here, we consider several that have special relevance to aging and memory. In general, the work suggests that the study of basic memory processes might benefit greatly from situating them into their social as well as their biological contexts (see also chap. 11, this volume). We begin with some biological issues.

Biological Contexts

Here, we consider several issues, including general and circadian arousal and health changes associated with aging and their impact on age differences in memory.

General and Circadian Arousal

Although the relationship between general arousal and memory performance is extremely complex (e.g., Christianson, 1992), there is reason to consider the role that this variable (and others, such as self-efficacy and stereotype vulnerability, which may themselves operate through heightened arousal) might play in influencing age differences in memory. Consider the study of competitive-level miniature golfers (Bäckman & Molander, 1986a, 1986b) in which age was associated with different patterns of arousal and these differences were especially notable on measures taken on practice versus competition days. For young adults, measures did not change much across the two types of days. For older adults, performance declined from practice to test days, suggesting that arousal differences can impact negatively on well-learned motor skills and on the thoughts needed to maintain those skills (see also Boutcher & Stocker, 1996).

Suppose arousal level for older adults in experimental situations is elevated more so than for younger adults (Fisk & Warr, 1996; McDowd & Birren, 1990; but see Levenson, Carstensen, & Gottman, 1994). Or suppose that arousal is better controlled by most younger adults than by most older adults (e.g., in novel situations it returns to baseline more quickly). What might one expect to see in memory performance? Age differences in performance should be reduced when arousal is statistically controlled, and some evidence suggests it is, at least for a computer-based associative learning task (Fisk & Warr, 1996). Age differences also should be reduced when instructions are used that de-emphasize more threatening aspects of a task, and this expectation is also confirmed (Rahhal & Hasher, 1998).

It is possible, as Christianson (1992) has argued is true for people in highly arousing situations, that content (or central) information will be encoded at the expense of context (or peripheral) information. Insofar as the source memory literature suggests age differences in context information as compared with content information (or the differential binding of those attributes), is it possible that age differences in arousal are moderating variables (see, e.g., Johnson et al., 1996)?

Eysenck and Calvo's (1996) processing efficiency theory suggests that increased anxiety will enable task-irrelevant, worrisome thoughts to enter working memory, thereby reducing its capacity for task-relevant information processing. This view overlaps with the notions of Hasher and Zacks (1988; Hasher et al., 1999) regarding inhibitory control over working memory. It is conceivable, then, that the impact of arousal on memory, including on memory-based language comprehension tasks, will be very similar to those suggested by the inhibitory framework, a topic we consider next.

Casual observation and interaction with younger and older research participants (i.e., college students and community-dwelling older adults) suggest that these two groups of people are on different circadian schedules. Of particular importance here is the suggestion in recent work that these differences in temporal schedules are real; impact on aspects of cognition including both explicit and implicit memory tasks; and can, depending on when testing occurs, influence conclusions arrived at regarding the magnitude of age differences in memory performance.

Work on circadian arousal patterns is not, of course, new to some areas of psychology (e.g., human performance), although it is relatively new to work in mainstream cognition. A substantial literature suggests that circadian patterns can be measured in a number of ways, but perhaps most easily with a valid and reliable paper-and-pencil inventory introduced by Horne and Östberg (1976, 1977; see Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1998; May et al., 1993). A series of normative studies using this inventory shows that peak times of functioning for young adults tend toward midday and later, whereas peak times for older adults center on early to midmorning (see, e.g., Hoch et al., 1992; Intons-Peterson et al., 1998; May et al., 1993; Yoon, 1997). According to U.S. norms (May & Hasher, 1998), only a small proportion of older adults (<3%) are evening-type people, with 75% or so falling into the morning-type category. By contrast, only around 5% to 6% of young-adult college students are morning types, with approximately 35% being evening-type people. Depending, of course, on the degree to which a cognitive process is influenced by circadian arousal, as well as on when in the day testing actually occurs, different conclusions may be reached if these general age trends are ignored. Is this a worrisome matter for the memory literature and for conclusions about age differences in memory? A tentative answer is yes.

It was known in 1990 (Bodenhausen, 1990) that young adults are more likely to rely on schematic or heuristic judgment principles at their nonoptimal times of day than at their optimal times, when they are more likely to rely on individual evidence or analytic decision rules. As we saw earlier (in the section on memory errors), older adults rely more heavily on schematic or heuristic retrieval principles than younger adults (Reder et al., 1986). In an initial study, May et al. (1993) considered whether reliance on schematic memories (acceptance of foil sentences that are meaningfully related to those in the story but that were never actually presented; see Reder et al., 1986) would vary across the day. In that study, as in several others in this tradition (but see Intons-Peterson et al., 1998), morning-type older adults and evening-type younger adults were tested early in the morning or late in the afternoon. In addition to confirming the Bodenhausen finding that reliance on schematic information increased at nonoptimal times of day, the pattern of performance on a recognition task varied across the day for both older and younger adults but did so differently for the two age groups (May et al., 1993). Young adults' recognition performance increased from morning to afternoon, whereas older adults' performance declined across the same time frame. Thus, recognition (a task with substantial contextual support; see Craik, 1986) can be impacted by time of testing, and the patterns of performance from morning to afternoon are different for older and younger adults.

Other evidence suggests that even implicit memory performance can vary across the day in patterns that are different for older and younger adults. In particular, May and Hasher (1998) showed that there were implicit memory differences following an encoding task that required suppression of highly probable but no-longer-relevant information along with the acquisition of new, relevant information. Participants' ability to suppress the no-longer-relevant information was measured by their tendency to later use that information in generating completions for incomplete sentence frames. Consistent with earlier findings (Hartman & Hasher, 1991; Hasher, Quig, & May, 1997), the data indicate that older adults were generally less able to suppress no-longer-relevant information than were younger adults. Both age groups, however, showed strong synchrony effects, with suppression greater at optimal than at nonoptimal times. Of special note was the startlingly poorer performance of older adults tested late in the afternoon, performance that left them showing no implicit access to newly acquired information. These data suggest the possibility that the acquisition of new information is impaired for older adults when a new response needs to be learned in the presence of a well-established response, particularly when the learning occurs at nonoptimal times. The data also suggest that both the suppression of irrelevant information and the "binding" of new information are processes influenced by circadian arousal levels.

There is some suggestion that prospective memory may also show a circadian pattern for groups of older adults such that compliance with a drug-taking regimen and with appointment keeping is greater in the morning than at other times of day (Leirer, Tanke, & Morrow, 1994). Additionally, there is the suggestion that some classic neuropsychological tests (Stroop and Trail Making) may also show circadian patterns, particularly for older adults who show larger Stroop and Trail Making effects in the afternoon than in the morning (May & Hasher, 1998; but see Davidson & Zacks, 1998).

To our knowledge, there is little evidence on any number of other tasks and processes that are relevant to memory researchers. However, work with younger adults does suggest that circadian patterns can influence their recall of newly learned information (Petros, Beckwith, & Anderson, 1990), and there seems to be every reason to suggest that similar effects would be seen with older adults. Still other work shows circadian effects on some attentional cognitive-control tasks (Intons-Peterson et al., 1998; May, 1999).

Not all tasks show circadian patterns, for either younger or older adults for that matter. On the basis of current evidence, very well-learned skills and tasks tapping semantic memory appear to show equivalent performance across the day (see, e.g., Hasher et al., 1999; Li, Hasher, Jonas, Rahhal, & May, 1998; Yoon, May, & Hasher, 1999).

To date, evidence suggests circadian synchrony effects in the acquisition of new information, in the implicit and explicit use of that information, and in those tasks requiring inhibitory control over physically present distraction (May, 1999) and possibly over strongly activated responses (e.g., Intons-Peterson et al., 1998). On the basis of current findings, including the fact that approximately 75% of older adults are morning-type people, it no longer seems appropriate to treat time of testing as a noise factor in studies of aging and memory. Failures to take this into account can increase (or decrease) estimates of age differences, depending on the task or processes studied and on the testing times used for younger and older participants.

General Health

Aging is associated with increasing health problems, and these in turn are associated with higher use of medications. It is possible that some portion of the age differences seen on a variety of memory and cognitive tasks is associated with health factors. Research on these factors presents a mixed picture, but one we believe bears watching. (For a discussion of the related topic of associations between age-related changes in perceptual and intellectual functioning, see chap. 3, this volume.)

Work on health factors has been done using both subjective measures (self-ratings of health status) and more objective indicators, including physiological data, number of hospitalizations, and number of chronic illnesses. Although the two types of indicators show significant correlations, there are reasons to be cautious about data involving subjective ratings (see Salthouse, 1991). For one thing, subjective ratings of health tend to be more optimistic than objective measures. Additionally, there are potential age differences in how subjective instruments are interpreted (e.g., whether the reference group used in making subjective ratings consists of age peers or, in the case of older adults, consists of younger adults). In any event, subjective indicators do not strongly support the idea that health predicts performance. For example, in two studies conducted by Salthouse and colleagues (Salthouse, Kausler, & Saults, 1988; Salthouse & Mitchell, 1990), those individuals who rated their health status as "excellent" were compared with the entire sample. Health status did not predict cognitive performance in either study, either as a main effect or in interaction with age (see also Earles & Salthouse, 1995;

Salthouse & Babcock, 1991). There are some indications, however, that health ratings may show a stronger relationship to more basic cognitive tasks (Hultsch, Hammer, & Small, 1993).

The literature using more objective measures is also mixed in terms of what health status does predict. For example, work on physical fitness suggests that long-term fitness programs may improve certain aspects of attention and memory performance (e.g., Kramer et al., 1998), but this is not always found to be the case (Blumenthal et al., 1991; Hill, Storandt, & Malley, 1993). Similarly, work on current fitness levels also shows a mixed pattern of findings (Bunce, Barrowclough, & Morris, 1996). Work on "biological life events" (which include exposure to organic solvents, anesthesia, mild head injuries, and the presence vs. absence of birth complications) does suggest some impact on measures of choice reaction time, movement speed, and Stroop color naming (Houx & Jolles, 1993; Houx, Jolles, & Vreeling, 1993). In addition, chronic smokers have been found to show lower scores than nonsmokers on tests of fluid intelligence (Hill, Nilsson, & Nyberg, 1998). By contrast, several studies have also suggested that the contribution of health factors to cognitive functioning is not large (e.g., Lindenberger & Baltes, 1997; Luszcz, Bryan, & Kent, 1997; Nilsson et al., 1997). We note that recent work from a longitudinal study (Small, Viitanen, & Bäckman, 1997) suggests that older adults whose performance on memory tasks is particularly poor at one time (and who are symptom free by standard measures of AD) are far more likely to show AD symptoms at a subsequent testing than are other older adults (see also Sliwinski, Lipton, Buschke, & Stewart, 1996). In this way, health, or at least undetected AD, may well contribute to the widely reported increases in variability of performance associated with aging and may also lead to overestimates of age differences, ones that may be greater the older the sample of older adults (Sliwinski et al., 1996).

Social Contexts

The concept of self-efficacy refers to beliefs about one's abilities to exercise control over cognitive and motivational resources so as to be responsive to both local and more global task demands (Bandura, 1986, 1997; Cavanaugh, 1996; see also chap. 7, this volume). This concept has played an influential role in the literature on social development, where it has been shown to be a powerful variable determining a broad range of behaviors from classroom learning to condom use (e.g., Bandura, 1997). In general, people with higher levels of self-efficacy show greater effort across a broad range of tasks than do people with lower levels of self-efficacy. However, self-efficacy beliefs can be manipulated in the context of an experimental setting, even in groups that begin a task at equal levels of performance. As an example, consider a study in which Stanford University MBA students played a managerial simulation game under high versus low self-efficacy instructions (Wood & Bandura, 1989). The two groups showed equivalent performance initially but rapidly diverged, with those under high self-efficacy instructions improving their performance and those under low self-efficacy instructions showing a considerable decline.

With respect to aging and self-efficacy, or lack thereof, there is a substantial literature showing that across all adult ages, North Americans hold negative stereotypes about cognition and aging in general and about memory and aging in particular (e.g., Bieman-Copland & Ryan, 1998; Erber, 1989; Heckhausen, Dixon, & Baltes, 1989; Ryan, 1992). If older adults are more likely to hold such views about themselves than are younger adults (see, e.g., Cavanaugh & Green, 1990; Hertzog, Dixon, & Hultsch, 1990; West & Berry, 1994), it would be no surprise that relative to younger adults, older adults might be less motivated to perform well in memory tasks, to consider strategies appropriate for the tasks, and to use any feedback that is provided to modify their behavior so as to improve performance. In other words, it would be no surprise if older adults behaved as if they had lower self-efficacy than younger adults.

However, the literature on self-efficacy and memory does not strongly support the conclusion that this variable is correlated with memory performance or that changes in individuals' self-efficacy will result in associated changes in memory performance (see, e.g., Cavanaugh, 1996; Cavanaugh, Feldman, & Hertzog, 1998; Hultsch, Hertzog, Dixon, & Davidson, 1988; Lachman, Weaver, Bandura, Elliott, & Lewkowicz, 1992; Ryan, 1992; Welch & West, 1995).

A related literature considers the memory performance of groups of younger and older adults who differ in their stereotypes about aging. Levy (1996) demonstrated that implicit activation (through "subliminal" presentation of words, such as *senile* and *wisdom*) decreased the subsequent memory performance of older adults and increased the subsequent memory performance of younger adults. An earlier study (Levy & Langer, 1994) compared younger and older adults sampled from mainland Chinese residents, members of the American Sign Language (ASL) community, and U.S. residents. Stereotypes regarding aging and cognition are more positive among the first two groups than among the last group; and consistent with the view that stereotypes (and attendant self-efficacy) mediate performance, no age differences on memory and other cognitive tasks were found for Chinese participants, small age differences were found for ASL participants, and larger age differences were found for Americans. Dramatic as these findings are, they were limited to a small number of participants in each group (*n*s = 10). In a replication comparing younger and older recent Hong Kong Chinese immigrants to Toronto with younger and older nonimmigrants (*n*s = 24–28 per group), the usual age differences were found (Yoon, Hasher, Rahhal, & Winocur, 1998), with little suggestion that negative stereotypes (which did differ between the two cultural groups) mediated performance.

A final study in this series is particularly interesting with respect to stereotypes, self-efficacy beliefs, and their possible impact on source memory tasks (Rahhal & Hasher, 1998). In this instance, trivia statements, selected so as to not be in the knowledge base of either younger or older adults, were presented with immediate feedback as to their truth or falseness. Afterward, the original trivia statements were presented amidst a series of new ones and participants were asked to indicate the status of items: Were they old or new, and if old, were they true or false? Half the participants in each age group were given instructions that emphasized the memory nature of the task, whereas the other half were given instructions that emphasized the knowledge acquisition aspect of the task. Although both instructional groups were told about an upcoming test, performance patterns varied with instructions. With memory instructions, the usual age differences were present; with knowledge instructions, they were not (see also McIntyre & Friesen, 1998). A related set of findings has been reported by Earles and Kersten (1998), who showed that after performing a series of tasks (five each from the categories of memory, speed, knowledge, and problem-solving tasks), younger adults were more likely to remember the ones they rated as difficult, whereas older adults were more likely to remember the ones they rated as relatively easy. Taken together, these findings suggest that task perception can be quite different for younger and older adults and that performance differences may sometimes be tied to beliefs and concerns about skill levels.

We note that the Rahhal and Hasher (1998) findings are generally consistent with the notion of "stereotype vulnerability" (e.g., Steele, 1997), such that performance on the very same task will vary as a function of whether it is framed (or spoken about) in such a way as to evoke a negative stereotype (which may reduce self-efficacy or heighten arousal) or not. Note in particular that all implicit or indirect memory tasks avoid reference to a memory task. As we indicated previously, older adults frequently show as much priming on implicit tasks, and occasionally even more (Multhaup et al., 1998), than do younger adults. Of course, the pattern of findings on explicit tasks is quite different, an outcome which might partly be due to the tendency for deliberate memory instructions to activate negative stereotypes in older adults.

More generally, however, these findings raise questions about the social situational variables that differentially alter performance of older adults relative to younger adults (see, e.g., Hess & Pullen, 1996). Such issues take on special importance in light of recent findings in the storytelling literature in which older adults' production and reproduction of stories are judged as being better than those produced by younger adults (e.g., Pratt & Robins, 1991). The goal of older adults is to tell interesting stories, and there is the possibility that in story recall tasks, there is a greater match between the objectives of the experimenter and those of the older participants than may be the case in other areas of the experimental study of memory (see, e.g., Dixon & Gould, 1996). Other considerations also suggest that goals may have a general role in determining memory performance (see, e.g., Blanchard-Fields & Abeles, 1996).

An interesting alternative interpretation of these findings fits nicely, however, with the age invariance seen in the situation model findings reviewed earlier. If we assume (see Adams et al., 1997) that in comprehending a text, individuals may construct a high level of representation that codes its symbolic or interpretive meaning, then on this dimension there may be an advantage in recall for older adults as compared with younger adults. Except for the situation model research, there has not been much emphasis in the literature on such levels of text representation, but it may be that older adults prefer encoding at deep, interpretive levels (see, e.g., Carstensen & Turk-Charles, 1994; Labouvie-Vief, 1990) and so they pay less attention to those levels closer to the more factual, propositional levels that permit the detailed recall most often assessed in experiments (Hashtroudi et al., 1994). As previously mentioned, in many situations (including in experiments), older adults may pay relatively more attention to their own and others' emotional responses than to events in the environment (see chap. 11, this volume; Johnson et al., 1996). All attentional control theories have as a basic assumption that goals control allocation of attention (e.g., Duncan, Emslie, Williams, Johnson, & Freer, 1996; Hasher & Zacks, 1988; D. A. Norman & Shallice, 1986). If young adults are more likely to share the goals of the experimenters than are older adults, instructions may constrain the processing of the younger participants more than they constrain the processing of the older participants. In any event, research on the interrelated sets of variables of arousal, self-efficacy, stereotypes, and goals would be most valuable; our understanding of age patterns in memory abilities would likely be enriched.

CONCLUSIONS

The study of the aging of human memory continues to be a vital domain of investigation, with recent work reinforcing, adding to, and modifying our understanding. It is clear that there are no simple rules that allow us to predict when age differences in memory will and will not occur, and if they do occur, whether the differences will be small, modest, or large.

The work reviewed here joins other reviews to suggest that a number of factors are involved in this determination. As a field, we have known about some of these factors for a while (e.g., the importance of environmental support for task performance, the difference between indirect and direct memory tasks), with more recent work confirming their importance. We have been reminded of the impact of other factors (e.g., the amount of interference present in the materials and tasks, the goals of individuals involved, and constructive processes in recall), with recent work suggesting some of the sources of age differences. We are learning more about still other factors (e.g., the impact of higher order structure inherent in to-be-remembered materials), with the exciting suggestion that older and younger adults may be able to use and update such structures equally well. Other factors appear to be relatively new (e.g., the importance of decision strategies induced or adopted at retrieval, the framing of the task itself, the minimal age differences found under more automatically driven retrieval circumstances, and substantial age differences in source memory). These lines of work will enrich the picture of age differences and similarities in memory. Additionally, there are new trends in the literature that are directed toward integrating memory in its larger cognitive, biological, and social contexts, trends that seem likely to improve our understanding of basic memory phenomena.

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