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CHAPTER 25

Memory in Elderly People

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THEORETICAL BACKGROUND

Memory difficulty is one of the most common complaints of older adults (e.g. Hertzog & Dixon, 1994), so the study of age-related changes in memory function is motivated by practical as well as theoretical considerations. This chapter reviews the major empirical findings in memory and aging research, with particular emphasis on recent work. In order to provide a contemporary context for understanding and evaluating the many results, we first summarize four major theoretical approaches to understanding memory and aging. At the end of the paper we will spell out the theories more fully, and discuss the extent to which each theory is able to accommodate current findings.

The four theoretical approaches are a decline in processing speed, reduced processing resources, age-related inhibitory deficits, and decreased cognitive control. The slowing of behavior in old age is widely accepted and well documented (Birren, 1965; Salthouse, 1991, 1996). The basic notion is that decreased speed of mental processing underlies many if not all age-related cognitive deficits, either directly (i.e. behavior is slow and inefficient) or indirectly by disrupting the timing of a complex sequence of mental operations. Within this framework, then, age-related decrements in memory performance are not attributed to impaired memory processes per se, but to a generalized age difference in speed of processing.

A somewhat different viewpoint from the speed of processing framework suggests that aging is accompanied by a depletion of attentional resources available for cognitive processing (Craik & Byrd, 1982). An underlying assumption of the reduced resources perspective is that attention is required to carry out cognitive tasks, and difficult tasks require more attentional capacity than simpler tasks. Thus, age-related reductions in attentional resources will impair older adults' ability to carry out cognitively demanding processes, such as the deep, elaborative encoding operations known to facilitate learning, or strategic search at retrieval.

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Hasher & Zacks (1988) introduced a third important framework for memory and aging research with their proposal that older adults are less efficient at inhibiting partially activated representations. Inhibitory function is putatively important for at least three processes relevant to memory. First, it provides control over access to working memory, thus restricting access to task-relevant information. Second, it supports the deletion of no-longer relevant information from working memory. Third, it provides for the restraint of strong but situationally inappropriate responses (Hasher et al., 1999; Zacks et al., 2000).

The fourth framework encompasses notions from both the reduced resources and the inhibitory deficit perspective in the idea that older adults suffer from an impairment in executive control of cognitive processing. This notion relies heavily on the distinction between automatic processing, which requires little attentional capacity and occurs without intent, and controlled processing, which is effortful, consciously controlled, and requires intent (Hasher & Zacks, 1979; see also Hay & Jacoby, 1999). Automatic processing is assumed to be immune to the effects of aging, while controlled processing declines with age. An age-related deficit in controlled processing affects both the initiation of cognitively effortful processing such as that required by deep, elaborative encoding and strategic search at retrieval, and the inhibition of irrelevant information or processes. It is possible of course that aspects of all four of these approaches may play some part in age-related memory decline.

EMPIRICAL FINDINGS

A distinction can be drawn between direct memory tests that require subjects to verbally report information from memory, and indirect memory tests in which memory is inferred from changes in behavior as a result of previous experiences. In a typical test of indirect memory subjects are unaware that their memory is being tested. The dichotomy between direct and indirect memory tests is closely related to theoretical distinctions that have been drawn between memory systems (declarative vs. nondeclarative; implicit vs. explicit) and memory processes (conscious vs. nonconscious; controlled vs. automatic). A discussion of the merits of these various taxonomies of memory is beyond the scope of this chapter; we have thus attempted to organize the empirical data according to the nature of the task used to assess memory, without appealing to any one theory of systems or processes. Indirect tests of memory reviewed here include motor learning, visuospatial memory and priming. In the second section, we review direct tests of memory, including semantic, episodic, working, prospective and source memory tasks as well as false memory and metamemory.

Indirect Memory Tests

Motor Learning

Older adults are clearly impaired on most features of motor performance, including speed of movement, perceptual functioning, target tracking, use of spatially incompatible stimulus-response mapping, and so forth (Welford, 1985). What is less clear, however, is the effect of old age on the ability to learn and retain new motor skills. The performance of older subjects appears to improve at approximately the same rate as younger adults on some tasks, while lagging behind on other tasks (see Willingham, 1998, for a more comprehensive review of the data and various theoretical accounts).

One common task used to study motor learning involves a pursuit rotor, or a computerized analogue thereof. In that task, the subject is instructed to keep the tip of a hand-held stylus in continuous contact with a moving target. Motor skill is measured by the proportion of time that the subject can in fact keep the stylus in contact with the target during a time-limited trial; motor learning is evidenced by increased time-on-target across repeated trials. Older adults demonstrate learning at a slower rate than younger adults (Ruch, 1934; Wright & Payne, 1985). Similar tasks, where subjects are only able to view their hand and the tracking target in a mirror (Ruch, 1934; Wright & Payne, 1985) also show age-related impairments in learning.

A potential confound plaguing these studies concerns the fact that the experimenter controls the pace in each of the tasks. Given that older adults tend to be slower at performing motor tasks, experimenter paced tasks may put older adults at a disadvantage relative to younger adults, thereby making it difficult to determine whether age-related impairments in learning are due to memory difficulties or more peripheral motor difficulties.

In contrast, age differences have not been found on tasks where the task is subject paced, and requires learning of a sequence of motor movements or a new stimulus-response mapping, e.g. Wishart & Lee (1997) required subjects to produce a continuous movement comprising three distinct spatial segments, each with specific timing requirements. Learning was assessed by rate of initial acquisition and subsequent reacquisition, as well as transfer to a similar task. Although older adults performed less accurately and consistently on the task, there were no age-related differences on any of the three measures of learning.

Similar results have been found with the serial four-choice response time task in which the stimuli appear in a repeating sequence. Subjects pace the task themselves: the next stimulus in the sequence is not presented until the subject responds. Even though subjects are often unaware of the repeating sequence, learning is evidenced by decreased reaction times after several repetitions. Older adults show normal learning in this task (Howard & Howard, 1989), even when the stimulus and response are spatially incompatible, thus requiring new stimulus-response mapping (Willingham & Winter, 1995). Stimulus–response mapping must also be learned in tasks where subjects are required to navigate a maze presented on a computer screen, utilizing either a computer keyboard or mouse. Again, no age-related differences in learning have been found, even when the older adults had never used a computer mouse before (Willingham & Winter, 1995).

Thus it seems that although older adults are not as adept as younger adults at performing motor tasks, they are equally skilled in learning, retaining, and transferring motor skills–if they are allowed to pace themselves during learning. A possible exception to this conclusion is a finding by Harrington & Haaland (1992). The researchers used a serial response time task, but instead of pressing a key, subjects had to respond to each stimulus with a different hand posture. Unlike younger adults, older adults failed to show learning. Willingham (1998) argued that age differences on this task could be explained in terms of speed of processing limitations. Even though the task is subject paced, subjects are required to maintain multiple cognitive processes simultaneously in order to both learn the repeating sequence and map the stimuli onto the appropriate hand posture. According to the "simultaneity mechanism" (Salthouse, 1996), products of an early mental operation that are needed for a later operation may be lost due to slowness in executing the later operation. Through this mechanism limitations on processing speed may hamper the ability to coordinate multiple streams of processing.

Visuospatial Memory

Closely related to motor learning is memory for visuospatial information. Age-related decline in memory for spatial location has been widely reported in the literature (e.g. Naveh-Benjamin, 1987; Zelinski & Light, 1988; Uttl & Graf, 1993; Foisy, 1994). Experiments have looked at memory for the spatial location of objects (e.g. Rutledge et al., 1997; Desrocher & Smith, 1998) as well as route learning (e.g. Wilkniss et al., 1997; Newman & Kaszniak, 2000). Several recent studies have incorporated ecologically valid procedures that require subjects to move about during encoding, allowing the integration of sensorimotor information. Rutledge et al. (1997) conducted a study in which participants viewed 20 common objects in one of four rooms, and were later asked to place the object in the room and location in which they had previously seen it after a retention interval of 3, 15 or 30 min. Older adults demonstrated significantly less accurate spatial memory than younger subjects following a 30 min retention interval, whereas the age-difference was non-significant (although of a small to moderate effect size) at the two shorter retention intervals.

Wilkniss et al. (1997) had subjects follow an experimenter along a novel route in order to examine age-related differences in memory for spatial information. Older adults were impaired at retracing the route and ordering landmarks, but unimpaired at recognizing landmarks. In a second task, subjects were allowed to study a two-dimensional map of a route, and then navigate the route from memory. Older adults had more difficulty than young adults in memorizing and navigating the route. Janowsky et al. (1996) examined whether age-associated memory impairments were comparable in the verbal and non-verbal domains by asking participants to learn the identity and location of objects. Later, participants were asked to verbally recall the objects as well as their spatial location. The researchers found that verbal memory was disproportionately impaired relative to spatial memory.

Several studies have demonstrated that age-related differences in visuo-spatial memory can be greatly reduced (Cherry & Park, 1993; Park et al., 1990) or even eliminated (Sharps, 1991) by a visually distinctive context. This is consistent with Craik's (1986) environmental support theory, which proposes that age-related memory impairments can be ameliorated by supportive contexts that reduce the need for self-initiated processing. On the other hand, Arbuckle et al. (1994) presented evidence that spatial layouts inconsistent with well-established schemas are in fact more difficult for older adults to learn and remember, perhaps because of a decreased ability to inhibit prepotent information. These seemingly inconsistent conclusions could potentially be reconciled by appealing to the process of forming internal spatial representations. Sharps (1998) has suggested that age-related impairments in visuospatial memory are underscored by a diminished ability to represent and process visual images. Spatial layouts unsupported by well-learned schemas would be particularly difficult to form internal representations of; however, distinctive visual features may be able to support memory performance in the absence of a well-integrated representation of the space. This analysis suggests that when age deficits are observed in visuospatial memory, they may be attributable to impaired encoding due to difficulties in perceptual processing.

Priming

Priming is observed when the processing of a stimulus is influenced by past experience with that stimulus or related stimuli, and is often measured as a change in response accuracy, reaction time, or response bias. Performance on priming tasks has often been equated with implicit memory, but explicit processes can also influence performance on priming tasks. This indirect measure of memory has received considerably more attention from aging researchers than motor memory or visuospatial memory. The general finding is that older adults show strong priming effects, and age differences are notably smaller than on comparable direct tests of memory, often failing to reach statistical significance (for more comprehensive reviews, see Light & La Voie, 1993; La Voie & Light, 1994; and Fleischman & Gabrieli, 1998).

Light & Singh (1987) illustrated this pattern using the word stem completion task. Both younger and older adults showed priming effects when they were given the first few letters of a word and asked to complete the stem with the first word that came to mind; all subjects were more likely to complete the stems of previously studied words than unstudied words, and the slight age difference was not significant. However, when subjects were asked to use the stems consciously and deliberately to retrieve studied words (cued recall—a direct test of memory), young subjects were now significantly superior. Interestingly, these results parallel those found when comparing amnesic patients to normal controls (e.g. Graf et al., 1984). A second example is provided by a study of skill learning reported by Hashtroudi et al. (1991). Participants were presented with a series of inverted words (each for 450 ms) and asked to identify the words by saying them aloud. On some trials, words were repeated, allowing for an examination of priming effects for the two age groups. The results revealed that older adults showed less improvement in the skill of reading inverted words relative to the younger adults, but the priming effect did not differ between the two age groups. However, when older adults were presented with the word stimuli for 900 ms, the age-deficit in skill learning was eliminated. Thus, similar to motor skill learning, age-related impairments in learning a cognitive skill such as inverted reading may be more attributable to limitations on speed of processing or perceptual difficulties, rather than to memory problems *per se*.

Researchers have made the distinction between various types of priming, including perceptual and conceptual priming (Roediger & McDermott, 1993) and item and associative priming. Perceptual priming tasks, such as picture naming and perceptual identification, are presumed to rely heavily on processing of perceptual features, whereas conceptual priming tasks, such as general knowledge questions and generation of category exemplars, rely more on processing of stimulus meaning. Item priming refers to facilitation in the processing of individual stimuli, as is seen in word stem completion tasks, while associative priming involves learning of novel associations between stimuli, such as word pairs, nonwords constructed from word parts, and novel compound words. Although the results of experiments comparing these different types of priming have been somewhat inconsistent (Jelicic et al., 1996; Cherry & St. Pierre, 1998), in general it appears that age effects are similar for perceptual and conceptual priming (La Voie & Light, 1994; Jelicic, 1995; Fleischman & Gabrieli, 1998), as well as for item and associative priming (La Voie & Light, 1994; Light et al., 1995, 1996).

The failure to find a disproportionate age deficit in associative priming is in marked contrast to the clear age deficit in associative learning found using direct memory measures (Kausler, 1994; Naveh-Benjamin, 2000). In a similar vein, Vakil et al. (1996) reported age differences in memory for context when measured directly, but no differences when measured indirectly. Subjects were presented with pictures of one common object on top of another common object (e.g. a book on a chair), and instructed to remember the top object (e.g. the book). Later, recognition memory was tested with the target object (book) in the same context (chair), a neutral context (white background), or new context (different background object). Recognition of the context objects (e.g. chair) was also tested. While older adults showed impaired recognition of the context objects, both older and younger adults showed the same benefit of context reinstatement when recognizing the target objects. This contrast between direct and indirect memory measures has been taken as evidence that age-impairments in learning of new associations seen on direct tests reflect deficits at retrieval, rather than at encoding.

Direct Memory Tests

Semantic Memory

Semantic memory tasks probe subjects' knowledge of the world, including facts, concepts, propositions, and the meaning of words. Intact conceptual priming in older adults (see previous section) has been taken as evidence for the preservation of conceptual knowledge into old age (Laver & Burke, 1993). Direct tests of semantic memory seem to paint a similar picture. Older adults show minimal declines in vocabulary (Giambra et al., 1995), knowledge of historical facts (Perlmutter et al., 1980), knowledge of concepts (Eustache et al., 1998), and production of category exemplars (Mayr & Kliegl, 2000). One difficulty in measuring long-term memory for facts is the influence of cohort effects: the seemingly poor performance of young adults might be a function of the fact that they have not been exposed to or learned the information. However, age differences remain minimal even when efforts are made to correct for cohort differences in the knowledge base (Lachman & Lachman, 1980).

Charness (2000) proposed that a preserved knowledge base might compensate for age-related declines in other areas of memory and cognitive functioning. Evidence suggests that prior knowledge can in fact compensate for declines in episodic memory (Gillund & Perlmutter, 1993), memory for scene information (Hess & Slaughter, 1990), face recognition (Bäckman & Herlitz, 1990) and comprehension and memory for textual information (Radvansky, 1999) and spoken language (Wingfield, 2000). On the other hand, domain specific expertise (e.g. knowing how to play a musical instrument or fly planes) benefits memory for domain-relevant information in both younger and older adults, but has not been found to reliably attenuate age differences (Morrow et al., 1994; Meinz & Salthouse, 1998). Similarly, studies comparing university professors to blue collar workers (e.g. Christensen et al., 1997) have found that the high academic ability is not associated with slower rates of decline in memory performance.

All of the studies referenced so far examined older adults' ability to retrieve already learned information from semantic memory. Age effects on new learning of semantic information have received considerably less attention. Work by Hasher and colleagues suggests that new learning of semantic information may also remain relatively intact in old age. In one study (Rahhal et al., 2002), subjects listened to multiple spoken statements that were identified as either true or false. Older adults were impaired at later recalling which speaker stated each item, but did not differ from younger adults in labeling statements as true or false. More research is needed directly addressing age effects on acquisition of new semantic information.

An important exception to the general finding of preserved semantic memory in old age is an age-related deficit in the retrieval of familiar words. Older adults are less accurate than younger adults on picture naming tasks (Bowles et al., 1989) and in producing words in response to definitions (Bowles & Poon, 1985). When recalling a sequence of videotaped events (Heller et al., 1992) or a memorable personal experience (Ulatowska et al., 1986), older adults produce more pronouns and other ambiguous references. Measures involving speed of retrieval or speed of decision are particularly vulnerable; e.g. Madden & Greene (1987) showed that lexical decision times increased with age, and Madden (1985) found that synonym decisions were slower in older than in younger adults. However, later work by Mayr & Kliegl (2000) suggests that the age-related difficulty is in the nonsemantic components rather than in the semantic components of retrieval.

The most dramatic example of older adults' word-finding difficulties is their increased susceptibility to tip-of-the-tongue (TOT) states. A TOT state involves the inability to recall a sought-after word, combined with a strong feeling that the word is in fact known. Older adults generally experience more TOTs (both naturally occurring and laboratory induced), report less partial information about the target word (such as number of syllables, stress pattern, initial sound), and take longer to resolve TOT states, relative to younger adults (Burke et al., 1991). Proper names are the most common category of words for which TOTs occur, for both younger and older adults, and the relative proportion of proper name TOTs appears to be greater for older adults (although see Maylor, 1997). The available evidence suggests that TOT states reflect a selective failure in accessing phonological information, and that providing phonological cues is equally beneficial to both older and younger adults in preventing and resolving TOT states (James & Burke, 2000).

Episodic Memory

Episodic memory refers to the ability to recall specific events and is typically measured by either recognition or recall of materials presented in the laboratory. Age effects on memory for autobiographical events occurring outside the laboratory have received less attention, and involve less controlled techniques, such as asking subjects to generate memories in response to cue words, and examining the distribution of memories across the lifespan. In a series of studies, Rubin and colleagues (Rubin & Schulkind, 1997a, 1997b; Rubin et al., 1986) utilized this technique with various age groups. The distribution of memories from the most recent 10–20 years of life did not differ across age groups: recent memories were the most available, and retention decreased monotonically with increasing time since the event occurred. It has also been found that memories from early childhood are distributed similarly across age groups (Waldfogel, 1948; Crovitz & Harvey, 1979; Crovitz et al., 1980), with very few memories from before the age of four or five. This pattern of results is consistent with the notion that once level of learning is equated, age-related differences in retention are negligible. Older adults' distribution of memories differs from young and middle aged adults in the existence of a so-called reminiscence bump—a disproportionate number of memories from early adulthood (Rubin et al., 1986). Several explanations have been proposed for the existence of the bump, including peak cognitive performance during early adulthood and a greater number of significant life events occurring at that time. It is likely that this bump is overshadowed in middle-aged adults by memories for recent events.

In contrast to memory for well learned life events, episodic memory tasks that measure memory for events occurring in the past few minutes, hours, or days, show more marked age deficits, e.g. Zelinski & Burnight (1997) reported the results of a 16 year longitudinal study that incorporated measures of recall and recognition. They found that participants who were aged 55 years and older at the beginning of the study showed reliable 16-year declines in both text recall and word list recall, but not in recognition memory. Participants who were aged 30–36 years at the start showed a decline in text recall only, so this measure appears to be the most sensitive to the effects of aging.

It has been known for some time that age-related declines in recognition memory are less severe than the comparable declines in recall. The effect was first documented by Schonfield & Robertson (1966) and has been noted by various other researchers since then (for review, see Craik & Jennings, 1992). Reduced processing resources (Craik & Byrd, 1982) have been proposed as a theoretical framework for interpreting the differential effects of aging on recall and recognition. The notion is that recall demands more attentional resources than does recognition, creating difficulty for resource-depleted older adults. Recognition tasks, where the same item is presented at study and test, provide high levels of environmental support (Craik, 1986), thereby minimizing age related decrements in performance. Support for this account is provided by the results of a study by Craik & McDowd (1987) in which subjects performed a secondary reaction-time (RT) task concurrently with recall or recognition. Recall was associated with greater RT costs (i.e. greater slowing of the RT task) than was recognition, and these costs were particularly high in older adults. Anderson and her colleagues (Anderson, 1999; Anderson et al., 1998; see also Whiting & Smith, 1997) reported similar results using a choice RT task as the concurrent secondary task at both encoding and retrieval. RT costs were greater at retrieval than at encoding, and were again greatest for older adults during the retrieval phase of a free recall task. Secondary task costs declined from free recall to cued recall to recognition, in line with the notion that the greater provision of environmental support at retrieval reduces the need to expend processing resources, and that this benefit is especially useful to older adults.

Bäckman & Small (1998) extended this line of thinking to include patients with Alzheimer's Disease (AD). They tested a large sample of residents from a section of Stockholm on two occasions, 3 years apart. The memory task was free recall of a word list, and the potential supports to performance included: (a) more time to encode the words; (b) the provision of words that could be organized by category; and (c) the provision of cues at retrieval. Normal older people were able to improve their performance using all three types of support; AD patients benefited only from cues at retrieval, and participants who were free of dementia on the first test but diagnosed with AD on the second test responded to all three types of support on the first test, but only to retrieval cues on the second test. It thus seems that the gradual loss of ability to utilize some types of cognitive support is a hallmark of AD.

It should be emphasized that although most studies have reported greater age-related losses in recall than in recognition, this result is not always found (Salthouse, 1991), e.g. Baddeley (1996) reported a study in which the difficulty of recall and recognition test was equated, and found equivalent age-related losses in the two types of test. Clearly, task difficulty is a factor that should be taken into account before reaching a firm theoretical conclusion. It is also the case that small age-related decrements in recognition memory are typically reported (e.g. Verhaeghen, 1999). Such decrements are often most apparent as age-related increases in the liability to make false-positive errors (Schacter et al., 1997a), although it is also possible to reduce this liability by inducing richer encoding of perceptual features at encoding and more careful scrutiny of each item at retrieval (Koutstaal et al., 1999).

Finally, Baddeley's (2000) recent proposal of an "episodic buffer" component in his model of memory suggests some interesting lines of research in the present context. If episodic memory for recent material is more vulnerable to loss in the elderly, e.g. it would be expected that delayed recall would show greater age-related losses than immediate recall.

Working Memory and Executive Processes

In the original model of working memory proposed by Baddeley & Hitch (1974) the central executive system was supported by relatively automatic modality-specific "slave systems", such as the articulatory loop and the visuo-spatial sketchpad. Adult age differences in these slave systems are slight, so tasks that require only brief holding and verbatim repetition of a string of words, letters or digits show comparatively small age-related decrements (for review, see Craik & Jennings, 1992). Floden et al. (2000) illustrated this result using the Brown–Peterson paradigm in which sets of three consonants are presented and then recalled after intervals of 0–60s. Floden and her colleagues adjusted the difficulty of the distractor task, used to prevent rehearsal during the retention interval, until it was equivalent for all participants. Using this technique, unadjusted scores showed a faster rate of forgetting for older than for younger participants, but decomposition of the total score into primary memory and secondary memory components showed that this effect was due entirely to a lower probability of recall from long-term or secondary memory; the forgetting rate from primary memory was identical for younger and older participants.

Two recent studies have provided further useful information about age-related differences in short-term or working memory. The first involved a modified version of the reading span paradigm, in which participants read a list of two, three or four sentences and then attempt to recall the last words from each sentence (Daneman & Carpenter, 1980). Typically, list lengths are tested in ascending order; thus a good deal of proactive inhibition may accumulate by the time longer lists are tested. May et al. (1999) showed that age-related decrements in reading span were greatly reduced (although not entirely eliminated) first by providing breaks between trials, and second by presenting the sequences in descending order of list length (i.e. testing the longest list first). The result of their study strongly suggests that proactive inhibition is a factor in reading span performance, and that older participants are more vulnerable to such inhibitory effects. The second study, by Murphy et al. (2000) showed that the impaired performance of older participants on a short-term recall task involving five word pairs can be mimicked in younger adults by presenting the pairs to be remembered auditorily and in a noisy background. The researchers concluded that the results demonstrated either that the sensory input to older participants was weak and "noisy", or that both normal aging and the addition of noise in younger participants reduced the effectiveness of encoding processes and thus reduced later retrieval performance.

These results notwithstanding, many researchers have shown that performance on working memory tasks, requiring online manipulation as well as passive storage, declines across the adult lifespan (Bäckman et al., 2000; Verhaeghen et al., 1993; Zacks et al., 2000). The factors responsible for this decline are still under active debate. One such factor is likely to be the greater vulnerability of older adults to interference from irrelevant or distracting information (e.g. May et al., 1999). It is unlikely that an age-related decline in inhibitory processes is the whole story, however; older adults also show difficulties in the self-initiation of novel patterns of thought and action, and in boosting task-appropriate responses as well as inhibiting task-inappropriate responses (Craik, 1986; Hay & Jacoby, 1999). Such findings suggest strongly that the central executive component of working memory declines in efficiency with increasing age, and this decline in turn likely reflects the reduced efficiency of frontal lobe processes in older adults (Glisky et al., 1995). In line with the notion that normal aging is associated with reduced frontal lobe functioning, one study found that the performance of older adults on a word list learning task resembled the pattern shown by young adults with lesions in the right dorsolateral prefrontal cortex (Stuss et al., 1996).

A further area of general agreement is that normal aging is accompanied by a reduction in the efficiency with which the various aspects of an encoded event are bound together to form an integrated, coherent episode. One account of this age-related failure attributes it to the declining efficiency of consciously experienced reflective processes in working memory (Mitchell et al., 2000). Other theorists have described the problem as a difficulty in the integration of focal items with their context (Smith et al., 1998), as a deficit in ensemble processing (Bayen et al., 2000) or, most generally, as an age-related deficit in associative processing (Naveh-Benjamin, 2000).

One final set of results in this area concerns the difficulties experienced by older adults in dealing with divided attention or dual-task situations. Such difficulties are also reflective of the declining efficiency of executive processes. Studies by Nyberg et al. (1997) and by Anderson et al. (1998) found that when a memory task is carried out simultaneously with a secondary task, memory performance declined by a similar absolute amount in younger and older adults relative to the memory task performed on its own, but that secondary task performance declined much more in the older group. This pattern was especially pronounced during the retrieval phase of the memory task. In an interesting variant of this procedure, Lindenberger et al. (2000) measured walking accuracy and speed in younger and older adults while they attempted to memorize a list of words. The researchers found greater dual-task costs in the older group, and attributed this result to the greater need for executive processes in older adults, partly to carry out the appropriate memory encoding processes, but also because the sensorimotor processes governing walking require greater degrees of cognitive control and supervision in the elderly. Interestingly, this current suggestion is very much in line with proposals put forward some years ago by Welford in his classic monograph, Ageing and Human Skill (1958).

Prospective Memory

"Prospective memory" (PM) refers to situations in which a person forms the intention to carry out an action at some future time, and then either remembers or forgets to carry out that action. The topic has received a lot of attention recently (e.g. Brandimonte et al., 1996), especially in the context of studies of aging. Some initial reports using laboratory-based techniques suggested that age differences were minimal in PM (Einstein & McDaniel, 1990), but further studies have shown, on the contrary, that age-related impairments in PM can be substantial (Cockburn & Smith, 1991). Such failures have important real-life consequences—forgetting to take medications, for example, or to lock doors or to turn off the stove. One large-scale study that demonstrated a clear age-related decline in such abilities was reported by Mäntylä & Nilsson (1997). Their study involved 100 subjects in each of 10 age cohorts ranging from 35–80 years, and the task was to remind the experimenter at the end of a testing session that the subjects should sign a form. Performance on this simple task dropped from 61% of subjects aged 35–45 remembering successfully, to 25% of subjects aged 70–80. This age-related decline is greater in people of lower ability (Cherry & Le Compte, 1999).

PM tasks may be classified as either time-based (e.g. remembering to make a phone call at 2.30 p.m.) or event-based (e.g. remembering to ask John a question when you next meet him). Einstein et al. (1995) found age-related decrements in time-based but not event-based tasks, and suggested that this pattern may be attributable to the greater demands for self-initiated processing on time-based tasks, which lack any external reminders. This suggestion is in line with Craik's (1986) proposal that self-initiated processing declines with age as a consequence of a decline in attentional resources, or possibly reflects an age-related decline in frontally-mediated cognitive control (West, 1996). Other studies have shown age-related declines in both event-based tasks as well as in time-based tasks (e.g. Maylor, 1996) although the decline may be greater in the latter (Park et al., 1997). At least one study has shown the opposite result (d'Ydewalle et al., 1999), so it may well be the case that the pattern of results is less dependent on the category of task (e.g. time-based or event-based) than on such aspects as the salience of event-based cues, the difficulty of the ongoing background activity and the number of PM intentions to be borne in mind.

Some evidence on these modulating variables comes from recent studies. Both Kidder et al. (1997) and Einstein et al. (1997) demonstrated that age-related decrements in a PM task were greater when the background task (the ongoing activity) was more demanding. The study of Einstein et al. (1997) also found that increasing background task demands at encoding decreased performance equally for younger and older adults, but that increasing demands at retrieval penalized older participants in particular. In general, it makes sense that PM failures are likely to be greater when the ongoing background activity is interesting and absorbing. It also seems possible that older adults (like patients with frontal dysfunction) have greater difficulty in switching their attention from the background task to the PM task. Some portion of age-related PM failures may reflect a failure to remember the action to be performed, but such impairments of retrospective memory cannot account for all cases (Park et al., 1997).

Maylor (1996) found that participants of all ages show fluctuations in their ability to remember a series of PM activities; that is, success on one trial may be followed by failure on a subsequent trial (forgetting), or failure may be followed by success (recovery). Maylor found that such fluctuations were more common in older people, who thus show a greater tendency to experience "momentary lapses of intention" (Craik & Kerr, 1996). West & Craik (1999) explored this phenomenon further and concluded that older adults retain their sensitivity to PM cues, but show a decline in accessibility of the appropriate cue-action pairing. In general, PM situations are often those in which habitual behavior on the background task dominates thought and action, especially for older people. In this sense an age-related reduction in self-initiated processing (Craik, 1986) will contribute to the failure to break such automatic modes of behaviour, although Zacks et al. (2000) make the useful point that some instances of PM success appear to involve little deliberate attentional processing; rather, the intention simply seems to "pop to mind".

Finally, there is an interesting discrepancy between laboratory-based and real-life PM tasks, in that large age-related decrements are typically found in the former but not in the latter. In a particularly convincing study, Rendell & Thomson (1999) found that adults in their 60s and 80s performed better than a group in their 20s on PM tasks taking place in the course of daily living, although the same groups of older adults performed less well than the younger group on laboratory-based PM tasks. Rendell & Craik (2000) hypothesized that the superiority of older adults on real-life tasks might reflect their more structured daily lives, and attempted to tap this greater structure in a laboratory board game called "Virtual Week". However, the results showed that older adults performed less well than their younger counterparts on the board game although they again outperformed the young group in real life. It is unlikely that this latter superiority is due simply to older adults relying more on external aids, since all participants in both of Rendell's studies were instructed not to use aids, and later reported compliance with this instruction. The superiority of older adults on real-life PM tasks may thus be attributable to such factors as greater motivation, more adequate learning, or greater compliance on the part of older adults. In any event, it is encouraging to find at least one class of memory task in which older adults consistently do better than their younger counterparts.

Source Memory

The capacity to accurately remember the origin of our knowledge allows us to evaluate the relevance of that knowledge for a given task or situation. In this section, we review multiple sources of evidence that the elderly suffer disproportionately from an inability to remember the context of material that they have learned.

The prototypical task used in source memory experiments involves external source monitoring (Johnson et al., 1993); in which the subject must select a correct contextual detail about the prior physical presentation of a stimulus. Often this task is combined with an item memory task, in which the subject is simply asked to recall or recognize studied stimuli prior to the source memory decision (see previous section on episodic memory). A wide variety of studies have demonstrated greater impairment of source than item memory in the elderly, with physical contextual characteristics including the color of words and pictures (Park & Puglisi, 1985), typeface (Kausler & Puckett, 1980; Naveh-Benjamin & Craik, 1995), and presentation modality (Light et al., 1992; McIntyre & Craik, 1987). The deficit in source memory even arises under conditions in which item memory is equated (Ferguson et al., 1992; Schacter et al., 1991) or the relationship between item memory and age is partialled out statistically (Erngrund et al., 1996).

Some authors have suggested that this deficit simply reflects group perceptual differences, whereby the elderly are less able to distinguish between multiple perceptually similar sources than are the young. Consistent with this view, Ferguson et al. (1992; see also Schacter et al., 1991) found that making the sources more distinctive—such as using one male and one female voice, as opposed to two female voices—eliminated age differences in source memory. This view is also consistent with the arguments sometimes forwarded by those who study cognition from an individual differences perspective and call attention to the large proportion of age-related variance in memory performance that covaries with perceptual acuity (Baltes & Lindenberger, 1997; Frieske & Park, 1999).

However, other results are inconsistent with a purely perceptual explanation, e.g. source memory deficits can be shown when the sources are not primarily perceptual in origin. Tasks that involve internal source monitoring (Johnson et al., 1993) require the subject to distinguish between sources that are not physical, such as doing versus imagining (Cohen & Faulkner, 1989), and the results suggest that the age-related effects on such tasks are no different than on tasks involving external sources (Brown 1995). Some authors have even shown age-related deficits in internal, but not external, source monitoring (Degl'Innocenti & Bäckman, 1996).

There is also evidence from the "false-fame" task (e.g. Jacoby et al., 1989) that is inconsistent with a perceptual explanation of source memory deficits. In that task, subjects are asked to evaluate the fame of names, some of which had been previously viewed. The typical finding is that variables that decrease the probability of remembering the earlier presentation of the name increase the likelihood of attributing fame to a previously seen nonfamous name. One such variable is age: The elderly show much larger false-fame effects than do the young (Bartlett et al., 1991; Dywan & Jacoby, 1990). Such results indicate that older subjects perceive the studied materials adequately, otherwise the names would not be sufficiently familiar to evoke mistaken feelings of fame! Yet those same subjects were unable to accurately attribute the basis for those feelings of familiarity to the prior exposure, indicating a deficit specific to source monitoring.

Similar evidence is provided by older adults' performance on exclusion tasks, in which subjects are required to endorse only one subset of the previously studied items. Manipulations that enhance memory for the eventually to-be-rejected items, such as repetition (Jacoby, 1999) or spacing (Benjamin & Craik, 2001), increase the probability of correct rejection in the young but increase the probability of incorrect endorsement (i.e. false alarms) in the elderly. This pattern of errors could arise only if the elderly perceive the stimuli well enough to encourage their (correct) belief that they were studied, but fail to remember the correct source.

It is worth noting that, although the aforementioned results are largely inconsistent with the hypothesis that a failure to adequately perceive and encode contextual dimensions underlies source memory deficits in the elderly, they are not inconsistent with other perceptually-based hypotheses. It may be the case, for example, that older adults do indeed perceive the contextual elements perfectly well, but that the greater effort it takes to do so (because of declining perceptual faculties) draws resources away from the mnemonic processes that would help them recover the source later.

Several authors have attempted to link source memory deficits in the elderly to frontal dysfunction. Frontal patients show many of the same characteristic deficits as the elderly (e.g. Janowsky 1989), and several authors have found correlations between frontal function and source memory performance (Craik et al., 1990; Glisky et al., 2001; Parkin & Walter, 1992). However, others have failed to find any such relation (Degl'Innocenti & Bäckman, 1996; Dywan et al., 1994; Spencer & Raz, 1994).

Schacter et al. (1994) proposed that the apparent source memory deficit with aging reflects the fact that most source memory experiments used many-to-one fact-to-source mapping. They suggested that older people might simply be more prone to the effects of cue overload, and ran an experiment in which each item was accompanied by a combination of cues yielding a unique presentation context. Disproportionate impairment of source memory was still evident, suggesting that the particular mapping between items and sources was not central to the source memory deficit (see also Glisky, 2001).

Although these results suggest that the source memory impairment in the elderly is indeed a memory deficit—and not a perceptual or attentional capacity deficit—there are variables that reduce or even eradicate the difference between old and young. As mentioned earlier, making the sources highly perceptually distinct benefits the elderly (Ferguson et al., 1992), as does encouraging subjects to consider the factual and not the emotional aspects of previously uttered statements (Hashtroudi et al., 1994), using statements that have personal rather than general relevance (Brown et al., 1995), using source dimensions that are associated with truth value or personality characteristics (Rahhal et al., 2002), and utilizing contextual dimensions that are less peripheral to the task (Spencer & Raz, 1995). Consistent with the idea that older subjects employ different bases for evaluating fame, Multhaup (1995) showed that encouraging them to adopt stringent criteria reduced false-fame effects.

In sum, these results seem to indicate that source memory deficits in the elderly are reliable and at least in part mnemonic in origin. However, the numerous manipulations that attenuate or even eliminate the effects suggest that such deficits do not necessarily implicate a separate and impaired source memory system, but rather reflect the different ways in which the elderly strategically deploy their more limited mnemonic skills.

False Memory

The previous section on source memory delineated ways in which older subjects have particular difficulty with remembering the context in which information was learned, and some examples of false memory are a natural consequence of this inability, e.g. older subjects are more susceptible to misleading postevent suggestion (Cohen & Faulkner, 1989; Schacter et al., 1997b). A natural interpretation of such results is that the elderly fail to remember whether their memory for the suggested information came from the postevent period or from the event itself. Similarly, the enhanced false-fame effects in the elderly described earlier can be explained by the inability to localize the source of a name's familiarity to the study episode, rather than the popular media.

Other findings are somewhat more complex. Older adults are more likely to falsely recall and recognize stimuli that are highly related to previously studied materials, regardless of whether that relationship is semantic (Norman & Schacter, 1998; Rankin & Kausler, 1979; Smith, 1975; Tun et al., 1998) or phonological (Watson et al., 2001) and even when the stimuli are pictures (Koutstaal & Schacter, 1997; for review, see Schacter et al., 1997a). One interpretation of these effects is consistent with the source memory deficit discussed above; namely, that subjects covertly "generate" plausible foils when studying highly related stimuli, and that their later memory for them is an example of a reality monitoring deficit: they fail to attribute their memory for the item to their imagination, rather than to a physical presentation. This hypothesis is inconsistent with several results, however.

The encoding-based explanation of false-memory effects predicts that manipulations that enhance learning of the study materials should also increase false-memory effects. On the contrary, a persistent finding in the literature is that, in general, increased learning increases true but decreases false recognition (Benjamin, 2001; McDermott, 1996; Schacter et al., 1998), and that groups (such as the elderly) that show poorer veridical memory also show greater false memory (e.g. Watson et al., 2001). These findings are most interpretable in the context of a regularity in recognition memory known as the mirror effect. This effect refers to the general tendency of increases in veridical memory performance (i.e. hit rate) to be accompanied by decreases in false memory (i.e. false-alarm rate). Numerous theories have been advanced to account for these findings (e.g. Benjamin et al., 1998; Glanzer et al., 1993) but a review of such theories is outside the scope of this review.

What is of present interest, however, is the failure to find a mirror effect for the elderly (Benjamin, 2001). In that experiment, subjects studied lists of words either once or thrice, and both veridical and false memory for the lists was assessed. For the young subjects, multiple study-list exposures increased true memory and decreased false memory. For the old subjects, multiple exposures increased both true and false memory, suggesting that, although semantic priming and activation is intact in the elderly (e.g. Balota & Duchek, 1991; Duchek & Balota, 1993), the inability to attribute that activation to likely sources and thereby set appropriate decision criteria leads them to be more prone to false memory.

Metamemory

There are several partially overlapping literatures that address metacognition, or knowledge about memory. These topics can be roughly categorized as follows:

- General beliefs about the structure and function of memory.
- Assessment of memory self-efficacy.
- Monitoring of memory performance.
- Strategic use of memory.

In this section, we briefly review key findings from these domains. Understanding metacognition in the elderly is particularly important because of its link with memory training and rehabilitation, in which strategies that circumvent or obviate memory deficits are taught.

Older people consistently complain that their ability to learn and remember information has declined (e.g. Hertzog & Dixon, 1994). In longitudinal studies subjects report deteriorating faculties regardless of whether they show an increase in self-reported forgetting over that time frame (Zelinski et al., 1993) or not (Taylor et al., 1992). This result suggests that memory complaints are based at least in part on an implicit theory that is held about the nature of memory decline, rather than strictly on an evaluation of their own memory performance (McDonald-Miszczak et al., 1995).

If older adults maintain a bleaker view of their own memory ability than do the young, and indeed even more so than is warranted by their performance, then they may set their goal levels unnecessarily low and thus engage in suboptimal strategy use (see e.g. Berry & West, 1993). Several sets of findings bear this hypothesis out. First, programs aimed at increasing memory self-efficacy improve memory performance (e.g. Lachman et al., 1992), as does simply providing older adults experience with the use of effective strategies on a memory task (Welch & West, 1995), although it should be noted that such strategies improve the performance of young adults too—sometimes even more than the performance of older adults (Kliegl et al., 1989). Such training appears to have long-lived consequences, up to 3 years or greater (Neely & Bäckman, 1993). Second, de-emphasizing the "memory" component and emphasizing the "knowledge" component of memory tasks reduces or even eliminates age differences on tasks such as remembering the truth value of a fictitious trivia statement (Rahhal et al., 2001). Such findings illustrate that stereotypes about memory in the elderly may play a limiting role in older adults' performance. For more comprehensive reviews on metacognition and aging, the reader is directed to Cavanaugh (1996), Dunlosky & Hertzog (1998), Hertzog & Dixon (1994), and Verhaeghen et al. (1992).

SUMMARY AND CONCLUSIONS

As is clearly demonstrated by the preceding review, age-related effects on memory performance are not uniform across tasks. Aspects of memory performance that appear to hold up well to the aging process include the following: motor learning, priming, semantic memory (with the exception of word-finding difficulties), episodic memory for well-learned life-events, passive short-term storage of information (primary memory), recognition memory, and prospective memory in everyday life.

More substantial age-related decrements are seen in three main areas of memory processing. First, older adults seem particularly impaired at tasks that require online processing to be carried out while simultaneously holding information in mind, as evidenced by their poor performance on working memory tasks (Zacks et al., 2000). Secondly, older adults appear to have difficulties with encoding of new information in a deep and elaborative manner, most likely due to inefficiencies in processing related to lack of cognitive control and suboptimal strategy selection. Finally, the elderly experience trouble retrieving information from memory, particularly when retrieval requires effortful processing, as in uncued recall, prospective memory tasks, or recovery of specific details, as in source memory tasks.

The challenge presented to a scholar of memory and aging is thus the development of a theoretical framework that can parsimoniously explain why age related deficits are quite significant on some tasks, and minimal or even non-existent on others. How well do each of the theoretical frameworks outlined at the beginning of the chapter accommodate the pattern of findings described here?

Speed of Processing

Explanations based on speed of processing limitations work best for memory tasks in which speed clearly plays a role, such as experimenter-paced motor learning tasks (e.g. Wright & Payne, 1985), or tasks that require timely coordination of multiple processes (Harrington & Haaland, 1992). Salthouse (1996) suggests that age-related impairments on tasks that do not have an obvious speed component, such as free recall tasks, can be explained via the simultaneity mechanism: the products of earlier processes are lost before later processes are carried out. While it is compelling to note that much of the age related variance on free recall tasks can be explained by decreased speed of processing, it is not clear either what exactly the "earlier" and "later" processes involved in free recall are, or what the optimal timing for these processes should be. Moreover, correlations between measured speed and memory performance do not necessarily imply that speed logically precedes memory ability; it is quite possible that both effects derive from some other source, such as widespread neurological changes associated with aging. Additionally, Rabbitt (1993) has presented evidence to show that aging is related strongly to memory performance independently of changes in speed of information processing. Until the subprocesses involved in tasks such as free recall are specified to a greater degree and related more directly to speed of processing, the usefulness of generalized slowing as an explanatory concept in memory and aging research remains in question.

Reduced Processing Resources

The finding that older adults have particular difficulties on tasks that demand a great deal of cognitive effort, such as free recall (e.g. Zelinski & Burnight, 1997), prospective memory (e.g. Mäntylä & Nilsson, 1997) and source memory (e.g. Naveh-Benjamin & Craik, 1995), fits nicely with the notion that aging is accompanied by a depletion of attentional resources. Also consistent with this framework is the finding that environmental supports such as re-presentation of studied items (as in recognition tasks: Craik & Jennings, 1992), distinctive perceptual cues (e.g. Ferguson et al., 1992), and supportive contexts (e.g. Rendell & Thomson, 1999) can greatly reduce age-related differences in performance. Finally, preservation into old age of some memory processes that are presumed to be automatic and therefore require few attentional resources, such as priming (Fleischman & Gabrieli, 1997) provide further support for the reduced resources hypothesis. However, other memory processes, such as spatial learning, are also presumed to be automatic in nature, and yet show substantial age-related decrements (e.g. Wilkniss et al., 1997). Perhaps the most potent criticism of the reduced resources framework is the nebulous nature of its core construct: attentional resources. Working memory tasks have been proposed as a potential measure of attentional capacity (Park, 2000); however the central executive component of working memory has likewise been criticized for its vague formulation.

Inhibitory Deficit

Many of the findings regarding age-differences in working memory functioning can be easily explained within the framework of age-related inhibitory deficits. For example, when age differences are found on span tasks, they may be attributable, at least in part, to interference from items activated on successive trials, but not subsequently deleted from working memory by the elderly (May et al., 1999). The inhibitory deficit hypothesis deserves further credit for sparking interest in how the contents of working memory, as well as the capacity, may differ between old and young. However, it is less clear how inhibitory deficits can explain age-related differences in tasks such as free recall, where there appears to be a failure of activation rather than inhibition. Nor does it explain deficits in source memory—if older adults are less able to inhibit irrelevant information, one would expect that they would encode more peripheral details of the context than younger adults. It seems sensible to postulate that efficient information processing requires control over both the activation and suppression of information, and that aging is accompanied by a reduction in both kinds of control.

Control

The theoretical proposal of an age-related decrement in executive control over cognitive processes combines the explanatory power of the reduced resources and inhibitory deficit frameworks by postulating that older adults have difficulty both with the initiation of effortful processing, such as required by deep and elaborative encoding and strategic retrieval searches, and with the active suppression of task irrelevant information. It is thereby able to accommodate much of the data pointing to age differences in working memory, episodic memory, source memory, prospective memory, and false memory. However, the concept of an executive dysfunction suffers from the same criticism as reduced resources: What exactly is meant by the terms "executive functioning" or "controlled processing?" The finding that tasks proposed to be heavily reliant on executive functioning are especially sensitive to frontal lobe functioning (e.g. Stuss et al., 1996) provides some support for the view that executive functions are a discrete subset of cognitive processing, subserved by a particular region of the brain. The ability of the impaired executive control framework to account for a wide variety of findings in the field of aging and memory underscores the need for further research aimed at illuminating the nature or executive functioning, its relation to memory performance, and the aging process.

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