In J. E. Birren & K. W. Schaie (Eds.), Handbook of the Psychology of Aging (4th ed., pp. 251-265). San Diego: Academic Press.

Fourteen

Language, Memory, and Aging: Distributed Deficits and the Structure of New-versus-Old Connections

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This chapter reviews recent theory and data on language, memory, and aging while attempting to avoid overlap with other recent reviews (e.g., Kemper, 1992b; Light, 1992). Findings in four broad and seemingly disparate categories are reviewed: language production, direct versus indirect tests of memory, language comprehension, and encoding under time pressure. Across these four areas emerge three closely interrelated themes or hypotheses: the language-memory hypothesis, the new-versus-old connection hypothesis, and the distributed defect hypothesis. We first outline these hypotheses and then show how they stem from data in each of the four categories.

I. Language, Memory, and Aging: Three Hypotheses

Under the *language-memory* hypothesis, functionally identical mechanisms underlie the acquisition, comprehension, and production of words on the one hand, and the encoding, storage, and recall of words in studies of verbal memory, on the other. That is, processes for encoding and retrieving experimentally constructed verbal materials, and processes required for acquiring, comprehending, and producing written and spoken language, at any age, are not just dependent on or related to one another, but are identical and impossible to distinguish. Language abilities and memory abilities involving verbal materials are not separate, but unitary, even though different verbal memory tasks tap into these unitary language-memory abilities in different ways (see, e.g., MacKay & Burke, 1990).

This language-memory view of the relation between language and memory is genuinely new and contrasts sharply with traditional views of memory, where words are comprehended, stored, retrieved, and produced in four distinct, independent, and sequentially ordered stages. In this traditional view, the storage stage begins only after comprehension is complete, and the word production stage begins only after the word retrieval stage is complete (see, e.g., Gordon, 1989, pp. 196–216). The traditional view receives its first detailed critique in this review.

Our second hypothesis, concerning *new-versus-old connections*, originated in the observation that older adults exhibit differential decline in tasks that involve

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new versus old learning or fluid versus crystallized intelligence (e.g., Salthouse, 1988), and typically require more time than young adults to form the new connections for representing novel combinations of words (see, e.g., Burke & Harrold, 1988; also MacKay & Burke, 1990, for a review). What is new about the present treatment of this hypothesis is how it applies to recent studies of encoding under time pressure, to detailed aspects of language production, and to recent data from direct versus indirect tests of memory.

The third hypothesis, *distributed defects*, combines a new idea with an old one. The old idea is the connectionist point that cognition and memory reflect processes operating within a network of nodes linked to one another via connections of varying strengths (see, e.g., MacKay, 1987; Salthouse, 1985). The new idea is that aging causes nodes or the connections between them to become universally defective, resulting in processing deficits that are distributed throughout the information processing network rather than limited to a particular type of component or process within it (see, e.g., Salthouse, 1985). Examples are the general suggestions that cognitive aging resembles a home computer with a progressively increasing cycle time (Salthouse, 1985), or reflects "defects of some sort distributed throughout a neural network of some sort" (Cerella, 1990, p. 202). More detailed suggestions are that cognitive aging reflects declines in short-term memory (e.g., Stine, 1994) or in how much information can be processed, as in Cerella's complexity hypothesis, where age-linked deficits are "tied to the amount, not the type, of information processing" (1990, p. 201; also Myerson, Hale, Wagstaff, Poon, & Smith, 1990).

Although discovery of distributed defects constitutes a major goal of the field, not all recent theories assume a distributed defect. For example, the Inhibition Deficit hypothesis of Hasher and others (e.g., Hartman & Hasher, 1991; see McDowd, Oseas-Kreger, & Filion, 1994, for an excellent review) assumes that age-linked deficits are limited to a particular aspect of processing (inhibition) rather than being universal or distributed across all aspects.

II. Language Production, Memory, and Aging

Although it was once widely believed that verbal abilities are universally preserved in old age, recent data indicate that two fundamental aspects of language production exhibit age-related deficits: retrieval of particular words, and the process of planning what to say, and where, when, and how to say it. Both processes are relevant to the language-memory and new-versus-old connection hypotheses. For example, retrieving familiar words involves use of old connections (see Burke, MacKay, Worthley, & Wade, 1991), unlike planning what we want to say, and where, when, and how to say it, which invariably requires formation of new connections.

A. Word Retrieval Deficits

Older adults often report difficulties in retrieving familiar words (Burke et al., 1991; Cohen & Faulkner, 1984), and recent studies both document and expand on these reports. For example, picture naming exhibits age-related decrements in accuracy (e.g., Bowles, Obler, & Poon, 1989), and in naming time (e.g., Mitchell, 1989), and spontaneous speech exhibits similar age-linked word retrieval problems. For example, older adults produce more pronouns and other ambiguous references when describing a picture, when recalling a sequence of videotaped events (Heller, Dobbs, & Rule, 1992), and when recalling a memorable personal experience (Ulatowska, Hayashi, Cannito, & Flemming, 1986). When instructed to provide single-word names for pictures, older adults also

generate more circumlocutions and multiword responses than do young adults (e.g., Albert, Heller, & Milberg, 1988), and are slower and less accurate in producing words that start with a specified letter, or match an experimenter-provided definition (e.g., Bowles & Poon, 1985) or semantic category (e.g., McCrae, Arenberg, & Costa, 1987). Older adults even take longer than young adults to begin to read a visually presented word (e.g., Balota & Duchek, 1988), and spontaneously speak more slowly than young adults (e.g., Duchin & Mysak, 1987), due to longer and more frequent pausing as well as to word lengthening per se (e.g., Balota & Duchek, 1988). This age-linked slowing may reflect changes at the speech muscle level (Kahane, 1981), or at the phonological level (Burke et al., 1991), or both.

1. *Tip-of-the-Tongue Phenomenon*

The tip-of-the-tongue (TOT) phenomenon is an age-linked word-finding difficulty that is so dramatic, informative, and extensively studied as to require separate treatment. TOTs occur when speakers are temporarily unable to retrieve some or all phonological aspects of a word that they later rate as highly familiar. The most striking general finding is that laboratory-induced and naturally occurring TOTs exhibit remarkably similar characteristics. Diary procedures and retrospective questionnaires indicate that naturally occurring TOTs usually involve familiar words that are used relatively rarely, and have not been used recently, and experimental TOTs are easier to induce in response to definitions of words that are infrequent in the language (Burke et al., 1991). The aspects of words that speakers become aware of are also similar for naturally occurring and experimentally induced TOTs: Speakers can typically report the number of syllables, the stress pattern, and the initial sounds or letters of an otherwise irretrievable word during both naturally occurring and laboratory-induced TOTs (see, e.g., Burke et al., 1991).

Aging (beginning at about age 37) significantly increases the frequency of both naturally occurring and laboratory-induced TOTs (Burke et al., 1991). Once in the TOT state, older adults also report less partial information about the target (number of syllables, stress pattern, initial sounds or letters) than do young adults, and take more time to finally retrieve the target word, both in everyday life and in the laboratory (e.g., Burke et al., 1991). The largest category of naturally occurring TOTs for both young and older subjects is proper names (e.g., the family name of an acquaintance; Burke et al., 1991), and this effect interacts with age: Controlled for familiarity, relatively more of the naturally occurring TOTs of older than younger adults involve proper rather than common nouns, a finding that Burke at al. (1991) replicated in the laboratory.

These TOT findings support the language-memory hypothesis: Language production and retrieval from long-term memory are indistinguishable in the case of TOTs and are impossible to segregate into separate stages. The similarity of TOT data derived from retrospective questionnaires, everyday speech, and laboratory word retrieval tasks likewise suggests identical processing principles for language and memory. TOTs also indicate that even highly familiar information can become more difficult to retrieve with age, providing an important counterexample to the once popular view that only the ability to use or remember new information (fluid intelligence) exhibits age-related declines. TOTs also contradict Cerella's (1990) complexity hypothesis, that only the amount of information processed is relevant to aging: TOTs clearly indicate that the type of information processed (e.g., common versus proper nouns) determines whether age-linked deficits are small or large.

Effects of aging on TOTs also challenge

the popular hypothesis that inhibition causes TOTs (see, e.g., Jones, 1989). The focus of this inhibitory hypothesis is on persistent alternates (also known as *blockers* or *interlopers*; see Jones, 1989), that is, words that the speaker knows are inappropriate, but nevertheless come repeatedly and spontaneously to mind and often resemble the TOT word in sound, meaning, and syntax. An example from Burke et al. (1991) is *dacron*, a persistent alternate that the speaker rejected as inappropriate, but that came repeatedly and involuntarily to mind instead of the TOT target, *velcro*, a word similar in sound, meaning, and syntax (both are common nouns).

Occurrence of persistent alternates covaries with how long it takes to spontaneously resolve or come up with a TOT word (Burke et al., 1991), further suggesting that persistent alternates may inhibit or somehow block retrieval of TOT words. However, early evidence said to support this inhibitory account has encountered a string of empirical challenges and methodological criticisms (see, e.g., Burke et al., 1991). For example, older adults report fewer persistent alternates and less phonological information about the target (number of syllables, stress pattern, initial sounds, or letters), both in everyday life (e.g., Burke et al., 1991; Cohen & Faulkner, 1984) and in the laboratory (Burke et al., 1991). However, if inhibition from alternates causes TOTs, then one would expect more alternates for older adults, and fewer TOTs, because inhibitory processes tend to decline with age (see, e.g., McDowd et al., 1994). Inhibitory accounts also have difficulty explaining why persistent alternates accompany TOTs only *sometimes* (less than 50% of laboratory-induced TOTs have alternates) and why TOTs involve proper names more often than other word types, especially in the case of older adults.

However, all available TOT data fit the Transmission Deficit hypothesis, the distributed defect account of MacKay and Burke (1990). Under this account, the amount of priming transmitted across connections between all nodes in the network decreases with age, and TOTs originate when the lexical node for a target word becomes activated (providing access to its semantic information), but at least some of its connected phonological nodes remain unactivated because of the deficit in transmission of priming. Such transmission deficits are distributed throughout the interactive activation network, and increase in probability with aging and infrequent or nonrecent use of a connection; however, the *structure* of connections underlying, for example, proper versus common names, and phonological versus semantic nodes, modulate the degree to which transmission deficits become manifest in behavior (see Burke et al., 1991).

B. Language Planning Deficits

Major age-linked deficits have been repeatedly demonstrated in planning what one intends to say and how to say it during language production. The classic indicators of language planning problems are disfluencies (hesitations, false starts, and word repetitions), which consistently increase with age (e.g., Kemper, 1992a; Valencia-Laver, 1992). This link between age and disfluency carries practical significance because both young and elderly listeners use fluency as a cue to a speaker's competence (e.g., Kemper, 1992a).

Why do older adults speak less fluently? Further research into three interrelated issues is needed: Do age-linked fluency deficits differ in type and frequency for language versus other cognitive skills? Do age-linked fluency deficits reflect problems of older adults in remembering nonlinguistic information that they want to communicate? Do age-linked increases in disfluency reflect the usual decline in the ability of older adults to encode new information (see, e.g., Burke & Harrold, 1988)? Research on recall of stories from memory (e.g., Bayles, Tomoeda, & Boone, 1985)

clearly illustrates this last issue. Recalling story episodes involves retrieval of new information, that is, the new connection aspect of memory known to be problematic in older adults (see, e.g., MacKay & Burke, 1990). Consequently, age-linked disfluencies in story recall may reflect a general deficit in connection formation abilities rather than in a specific ability to communicate.

Free speech tasks (e.g., Glosser & Deser, 1992) avoid the problems of story recall, but introduce other methodological problems of their own. For example, accuracy in communicating one's intentions is typically unknown and uncontrolled in spontaneous speech, and may vary with age. Moreover, older subjects are free to compensate for retrieval deficits in spontaneous speech, or to voluntarily simplify one dimension (e.g., sentence syntax) while complicating another (e.g., narrative or plot structure; see Kemper, 1992a). As a result, reported age effects are often complex and difficult to interpret. For example, both false starts and filled pauses (*um* and *er*) interact with syntax (occurring more in embedded than in main clauses), which in turn interacts with age; that is, older subjects generate fewer embedded clauses than young subjects, a not uncommon baseline problem in free speech tasks (see Kemper, 1992b).

Lack of control in observations of spontaneous speech may also account for some conflicting reports in the literature. For example, differing effects of age on the disfluencies known as word repetitions have been reported. Valencia-Laver (1992) reported more word repetitions for older than young adults describing novel patterns of interconnected colored dots for a hypothetical listener to reconstruct, sight unseen. In contrast, Yairi and Clifton (1972) reported no more repetitions and *fewer* false starts and incomplete phrases for older than young adults creating stories appropriate for preschool children. The problem with this curious inverse deficit is that older subjects may have more extensive experience than young subjects in creating stories suitable for young children. To overcome such problems with story recall and free speech tasks, Heller et al. (1992) recommended use of on-line tasks, for example, having subjects describe filmed events as they unfold on a video monitor. However, such "modified free speech" tasks are also problematic. Video description may unfairly disadvantage older subjects by forcing them to describe unfolding events at an unnatural pace. In short, further research on fluency as a potential index of age-linked planning deficits is sorely needed.

III. Language Memory Tested via Direct versus Indirect Means

Indirect tests of memory involve either language production (e.g., word production time) or language perception (e.g., word recognition time) and show effects of prior presentation of a word (i.e., repetition priming) without seeming to require conscious recollection of the prior experience, whereas direct tests of memory (e.g., cued recall, recognition, and free recall) involve conscious recollection of the prior experience. Recent data from direct versus indirect tests support the language-memory hypothesis, and undermine the traditional basis for separating language from memory, namely the occurrence of language disorders without concomitant memory disorders and vice versa. For example, patients who show Wernicke comprehension deficits on direct tests show no deficits via tests that are on-line and indirect (Tyler, 1988), suggesting that a memory problem underlies this classic language comprehension deficit.

Recently demonstrated age differences for direct versus indirect tests further reinforce this general conclusion. Although older adults consistently perform more poorly than young adults on direct tests such as recognition and recall, they per-

form as well or nearly as well as young adults on many indirect tests (see, e.g., Howard, 1991, and Light & LaVoie, 1993, for extensive recent reviews). The practical significance of such age-linked dissociations in performance on direct-versus-indirect memory tasks has been widely recognized. As Howard and Wiggs (1993) pointed out, small or nonexistent age effects recommend indirect tests for facilitating morale in education programs designed for older adults. However, the theoretical import of these age effects remains controversial.

Some view the evidence as indicating the existence of explicit versus implicit memory systems that are separate and fundamentally different (e.g., Mitchell, 1989), whereas others argue that direct and indirect tasks tap into different aspects of a unitary language-memory system. For example, age differences between direct versus indirect tests may simply reiterate the old-versus-new connection theme (MacKay & Burke, 1990). Most direct measures test whether new connections have been formed at a relatively high level in the system, for example, between a stimulus word and its time, place, or context of use, a connection formation process that provides the basis for awareness and is especially subject to age-linked decline. However, most indirect measures test whether old connections have been activated and automatically strengthened, an unconscious process known as *engrainment learning* (MacKay, 1990) that is less subject to age-linked decline (see MacKay & Burke, 1990).

For example, when a subject hears a particular speaker repeat a familiar word in the repetition priming paradigm, no new connections are required to identify and say the word, but time to pronunciation is shortened because dozens of existing connections representing word phonology and acoustic characteristics of the voice have become automatically strengthened in both young and older adults. Repeated visual presentation of a word in the same familiar font likewise strengthens large numbers of existing connections at phonological and orthographic levels in both young and older subjects, a perceptual process that also requires no new connections. Age-linked dissociations between direct versus indirect tests may therefore reflect the greater age deficits for forming new connections than for using and strengthening old connections via engrainment learning.

Consistent with this hypothesis, a recent meta-analysis (Light & LaVoie, 1993) indicated that age differences for indirect tests were smaller than those for direct tests, but nevertheless did exist, with young adults showing larger repetition priming effects than older adults. However, Light and LaVoie urged caution in interpreting these results, especially for associative priming tasks, where a "temporally adjacent" stimulus (e.g., the first word in a familiar and recently presented phrase) facilitates recognition of the subsequent word. Indeed, many conflicting age effects have been reported for repetition priming tasks, and at least five different classes of explanation for these conflicting results have been suggested. One is that conscious or deliberate recollection processes may intrude and contaminate results for indirect tests, although two recent studies found that intrusion of conscious recall processes into an indirect test involving word completion was not responsible for age-related differences (Howard, Fry, & Brune, 1991) or lack of age-related differences (Park & Shaw, 1992).

A second explanation for age differences on indirect tasks invokes reduced elaborative encoding in older adults (Howard, 1991), but Moscovitch, Winocur, and McLachlan (1986) and Light and LaVoie (1993) found age effects using indirect tasks that require virtually no elaborative encoding.

A third suggested explanation is that older adults can form new connections assumed necessary for associative priming

effects, but simply require more time, that is, self-paced tasks (Howard et al., 1991). However, Moscovitch et al. (1986) found age differences even when older subjects received more processing time than young adults in an associative priming task. A fourth suggested explanation is that age effects are found when older adults must form an associative connection in only one trial, but not when they receive repeated trials (Howard, 1988b; Light & LaVoie, 1993). Again, however, exceptions exist (see, e.g., Davis et al., 1990). Moreover, repeated trials may enable use of conscious recall strategies, especially by young subjects, an age-linked contamination of indirect measures with an explicit or conscious process.

The fifth and most basic explanation of the conflicting results concerns power and sensitivity of the tests. Because studies to date have not adopted highly sensitive indirect measures (for example, reaction times), noneffects of age are difficult to interpret. More sensitive measures also seem essential in view of statistical power problems noted by Light and LaVoie (1993): Indirect tests seem to show age differences only for unusually large subject samples (e.g., Davis et al., 1990; Howard, 1991) or unusually powerful meta-analytic procedures (Light & LaVoie, 1993). Even this claim is controversial, however; Howard (1988b) found age differences with a relatively small sample, whereas Park and Shaw (1992) found no age differences with a relatively large sample.

The solution to these controversies may lie in developing a viable theory of how direct versus indirect measures tap into the information processing network. Future work in this area must become embedded within a detailed theory of language-memory that specifies how young and older subjects comprehend and produce words and connect words to one another and to aspects of the context. The recent study of Light, LaVoie, Valencia-Laver, Albertson-Owens, and Mead (1992) clearly illustrates this point. Light et al. presented words to subjects either visually or auditorily, and tested memory for the words or their modality of presentation either directly or indirectly. One direct test required yes–no recognition of the presented words versus foils, and a second direct test required recognition of what modality the words had been presented in. As is usual for such direct tests, recognition accuracy was much lower for older than young adults.

The indirect tests required subjects to identify words that had been presented either visually (with brief exposure) or auditorily (in noise), and subjects showed slightly greater repetition priming when test words appeared in the same modality as previously. These small effects were significant but equivalent in magnitude for young and older subjects, a surprising finding because Light and LaVoie (1993) labeled this an associative priming task of the sort that generally requires the age-sensitive process of forming new connections, here between the words and their cotemporal modality of presentation.

However, a strong case can be made that the assumption of Light et al. (1992) does not apply to this perception task because new connections play no role in identifying familiar words. When a word is presented, say, auditorily in a particular voice, preexisting connections between the many low-level nodes representing acoustic characteristics of the voice are automatically strengthened in both young and older adults. These strengthened acoustic-node connections will help both young and older subjects perceive this word when it is subsequently presented auditorily in noise, as Light et al. (1992) observed. They are inaccessible to awareness via direct tests of memory, however, and cannot facilitate perception when the word is presented visually, also as Light et al. observed. The situation is very different when subjects must directly recognize or recall the original modality of presenta-

sus everyday language production). Together with the fact that no theory of production has established a convincing dividing line between where memory retrieval ends and where word production begins, such close parallels suggest that language production mechanisms and word retrieval mechanisms are not just dependent on or related to one another, and therefore difficult to distinguish, but are identical and impossible to distinguish. This strong form of the language-memory hypothesis carries potential implications for the field at large. For example, if there are no articulatory loops or special memory buffers for verbal information that are separate from the mechanisms for acquiring, comprehending, and producing language per se, it makes no sense to ask whether working memory constraints are responsible for age differences in language perception or production. By the same token, asking whether processes for perceiving or producing language introduce constraints that are responsible for age differences in working memory likewise makes no sense. Instead, the language-memory hypothesis raises a whole new set of much more detailed questions, and as we have seen, recent data and theory (e.g., MacKay & Abrams, 1994) are already answering some of these questions for both new and old connections.

As to the distributed defect theme, data reviewed here on semantic priming in comprehension and on TOTs in production directly contradicted the complexity hypothesis, indicating that the type rather than just the amount of information being processed can determine whether one observes large age-linked deficits, small age-linked deficits, no age-linked deficits, or, indeed, age-linked facilitation. The diversity of these aging effects warns against distributed defect hypotheses that are overly simple. To be successful, distributed defect hypotheses must be embedded within a detailed theory of language-memory that specifies how words are processed and how concepts become connected to one another in the everyday use of language. The Transmission Deficit hypothesis exemplifies such an approach.

Under the Transmission Deficit hypothesis, general patterns of decline, for example, general slowing and problems in forming new connections (MacKay & Burke, 1990), reflect a truly distributed defect in transmission of excitatory and inhibitory priming across every connection between every node in the information processing network. However, the detailed nature of processes in the larger theory of language-memory within which the distributed defect known as transmission deficits is embedded plays a role in differential declines such as the age-linked differences between new-versus-old connections. Thus, the old connections for retrieving familiar but rare and not recently used words exhibit small but reliable age-linked declines because even highly practiced connections undergo deficits in priming transmission due to age and disuse. However, new connection formation exhibits much greater age-linked declines because the connection formation process is priming-intensive, and is therefore especially susceptible to transmission deficits (see MacKay & Burke, 1990).

The detailed structure of interconnections in a language-memory network containing transmission deficits also contributes to differential declines, such as the age-linked differences in learning and retrieving common versus proper nouns (see, e.g., Burke et al., 1991). Similarly, as we have seen, transmission deficits, together with age-linked differences in the number of connections that link semantically related words in memory, make sense of the fact that age-linked facilitation occurs under some conditions such as semantic priming tasks, but not others such as phonological retrieval tasks. Whether transmission deficits are the true underlying cause of such age-linked changes in behavior remains to be seen.

However, developing this or some other account that integrates the new-versus-old connection hypothesis, the language-memory hypothesis, and the distributed defect hypothesis into a single, unified theory seems likely to shape the course of research on language, memory, and aging into the next century.

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