Language, Aging, and Inhibitory Deficits: Evaluation of a Theory

Deborah M. Burke
Pomona College.

This article evaluates the success of Inhibitory Deficit theory in addressing two basic functions of a theory: explaining available results and predicting new findings. The review focuses on language comprehension and production, domains of cognition vulnerable to age-linked inhibitory deficits under the theory. Considerable research, however, reports remarkable age constancy in many aspects of language performance, contrary to the predictions of Inhibitory Deficit theory. For conditions that do produce age differences in language comprehension and production, evidence for inhibitory deficits is controversial at best. In predicting new findings, Inhibitory Deficit theory is constrained by lack of a well specified model, producing confusion between inhibition that occurs at a behavioral level versus a theoretical level. Modification of the theory is required to bring it in line with empirical findings on language and aging, and greater specification of underlying processes is required to reduce contradictions in predictions.

ALMOST 10 years ago, Salthouse (1988) lamented the slow development of theory in cognitive aging: “The field of cognitive aging is, currently, nearly devoid of explicit theories about the causes of age-related differences in cognitive functioning that are applicable to more than a few narrowly defined phenomena” (p. 3). The field of cognitive aging, like cognitive psychology in general, has been dominated until recently by an empirical epistemology in which gathering facts has overshadowed constructing theories: “Even the best psychologists sometimes seem to assume not just that experiments can proceed in the absence of theory but that potential experiments are finite in number and that our job as psychologists is to do them all” (MacKay, 1988, p. 562). A welcome exception is Hasher and Zacks’ recently proposed general theory of cognitive aging (e.g., Hasher & Zacks, 1988; Stoltzfus, Hasher, & Zacks, 1996; Zacks & Hasher, 1994). Their Inhibitory Deficit (ID) theory postulates age-linked deficits in inhibitory processes and has increased awareness of the possible importance of inhibitory processes in cognition and has catalyzed investigation of predicted age differences in inhibitory processes.

Two primary goals of a theory are to explain available findings and to predict new findings for future research. Evaluations of the success of ID theory in realizing these goals have been presented for research on selective attention and aging, and have refined the theory as applied to selective attention (e.g., Connelly & Hasher, 1993; Hartley, 1993; Kramer, Humphrey, Larish, Logan, & Strayer, 1994; McDowd, Oseas-Kreger, & Filion, 1995; Sullivan & Faust, 1993; see McDowd, 1997). Such evaluation of ID theory, however, is sparse for other areas of cognition (but see Light, 1991, 1994; McDowd et al., 1995). This omission must be redressed because the potential strength of ID theory lies in its generality in applying to “… a range of cognitive functions, including language comprehension, speech production, episodic memory. . . .” (Zacks & Hasher, 1994, p. 242). In this article we focus on two of these functions, namely, language comprehension and production, both prominent in studies garnered in support of ID theory. The goal is to evaluate the success of ID theory in predicting new findings and explaining well established empirical results for this domain of behavior. The outcome of this evaluation is relevant to the generality or distributed nature of an inhibitory deficit and, as we will see, to the success of ID theory in explaining other domains of behavior.

This article does not duplicate comprehensive reviews of research on language and aging already available (e.g., Kemper, 1992; Light, 1988; Tun & Wingfield, 1993). The review is motivated by the epistemological belief that the strongest support for a theory comes when it withstands vigorous attempts to falsify it, rather than attempts to find confirming results. Indeed, data that do not fit a theory are especially useful for its development (Churchland, 1986; MacKay, 1988). The goal is to increase our understanding of the adequacy of ID theory as applied to language data and, in the process, to identify components of the theory that may need development to account for language or cognitive functions more broadly.

Exposition of ID theory as applied to language has focused on interpretation of empirical findings (e.g., Zacks & Hasher, 1994), with well specified models of the inhibitory mechanisms conspicuously absent. As Houghton and Tipper (1994) pointed out, “Current proposals regarding the nature of the [inhibitory] mechanisms remain vague and intuitive” (p.65), which impedes effective explanations of data and detection of logical contradictions. Indeed, this vagueness has affected both theoretical goals reviewed in this article: It has resulted in contradictory predictions and has obscured facts about aging and language that are inconsistent with ID theory. Because the explicitness of a theory is related to its usefulness (Salthouse, 1988), the aim of this article is to stimulate greater specification of ID theory by identifying conditions under which these problems occur.
Inhibitory Deficit Theory

There is growing interest in the idea that cognitive processes include both excitatory and inhibitory components that together increase the sensitivity and speed of cognitive operations beyond that of a purely excitatory system (e.g., Houghton & Tipper, 1994; McClelland & Rumelhart, 1981). Under the Hasher and Zacks model, inhibition suppresses "...the activation of goal-irrelevant information so that such information is less likely to have access to working memory and so that irrelevant information that does enter working memory, as well as previously relevant information that is no longer useful, is quickly removed." (Radvansky, Zacks, & Hasher, 1996, p. 143; see also Hasher & Zacks, 1988). They postulate that inhibitory processes decline in old age so that older adults activate more irrelevant information which enters working memory, and are less efficient in suppressing irrelevant information once it enters working memory (e.g., Stoltzfus, Hasher, & Zacks, 1996; Zacks & Hasher, 1994). For example, when the visual quality of a text is disrupted by interspersing words in a different font throughout the text, reading is slowed and comprehension errors increase, with greater effects for older than younger adults, particularly when the interspersed material is related to the target text (Carlson, Hasher, Connelly, & Zacks, 1995; Connelly, Hasher, & Zacks, 1991). Within ID theory, older adults are more impaired because of their reduced ability to inhibit the irrelevant material. Moreover, related material has a greater effect for older than younger adults because of older adults' "...greater breadth of activation of ideas during reading... Younger adults who activate meaning more narrowly in a given context... have fewer accidental matches with the distracting material" (Carlson et al., 1995, p. 434).

Hasher and Zacks do not postulate localized inhibitory deficits that apply to some types or sources of information and not others. Rather, inhibition deficits are distributed across cognitive systems, affecting all levels of information that might enter conscious awareness within working memory. With respect to language functions, older adults are impaired relative to younger adults in comprehension by (a) retrieval from semantic memory of more contextually irrelevant word and sentence meanings, and by (b) inefficient inhibition of irrelevant meanings once activated. In language production, older adults would be impaired by (a) retrieval from semantic memory of more irrelevant phonemes and words and (b) inefficient inhibition of irrelevant sounds and words once activated. The retrieval predictions follow because "...inefficient inhibition will also prevent the dampening of activation along irrelevant retrieval pathways" (Hasher, Stoltzfus, Zacks, & Ryvma, 1991, p. 168) and "...the retrieval of well learned memories can, for older adults, be slowed by the enrichment of target information with irrelevant associations" (Zacks & Hasher, 1994, p. 259). The inefficient inhibition of retrieved information predictions follows because "Inhibition also functions to suppress (or remove from working memory) whatever irrelevant information happens to leak in as well as information that is no longer relevant because of a change in goals" (Zacks & Hasher, 1994, p. 242).

In studies of language comprehension, these predictions can be measured in online tasks, such as lexical decision, that measure activation of information during language processing. Under ID theory, older adults should show evidence of activation of irrelevant information in online tasks (see Stoltzfus et al., 1996). Thus, ID theory predicts that older adults process more irrelevant and more variable information in semantic memory tasks than younger adults, a prediction that conflicts with one of the most reliable patterns in cognitive aging, discussed next.

Language, Semantic Processing, and Aging

Single word processing. — Retrieval of semantic knowledge is remarkably stable in old age. Indeed, the "classic aging pattern" is that verbal IQ scores remain relatively constant in old age whereas performance IQ scores decline (Botwinick, 1984). More sophisticated experimental techniques for measuring mental operations in language processing also show remarkable age constancy. One of the most direct ways of determining whether older adults retrieve more irrelevant word meanings than do young adults is to compare word associations for the two age groups. Contrary to ID theory, young and older adults, with verbal ability or education controlled, do not differ in variability of responses (e.g., number of unique responses, overlap of responses), the relative frequencies of specific responses (Bowles, Williams, & Poon, 1983; Burke & Peters, 1986; Howard, 1979; Lovelace & Cooley, 1982; Scialfa & Margolis, 1986), or within subject variability (e.g., consistency of responses over time; Burke & Peters, 1986).

The semantic priming paradigm is probably the most popular technique for mapping semantic relatedness via the spread of activation within semantic memory. Latency to respond to a target word is faster when it follows a semantically related prime word, rather than an unrelated word, with the difference in latency constituting the semantic priming effect. If older adults' inhibitory deficits "...prevent the dampening of activation along irrelevant retrieval pathways," then we would expect them to show smaller semantic priming effects than young adults. That is, unrelated words would, on average, achieve higher levels of activation in older than young adults, because they would be less able to limit the spread of activation to related concepts. This would reduce the difference in activation levels between related and unrelated words, thereby reducing the semantic priming effect. This prediction, however, is the reverse of the larger priming effects found for older than young adults in meta-analyses of the many semantic priming studies (Laver & Burke, 1993; Myerson, Ferraro, Hale, & Lima, 1992). Note that semantic priming effects can be caused by either automatic spreading activation or controlled processes based on expectations for related words, and older adults' larger effects are found in both cases.

Parallel to the findings on generation of word associations, generation of scripts for familiar activities shows no age differences in typicality or variability of responses (Hess, 1985; Light & Anderson, 1983). For generation of instances in categories, there are also no age differences in variability of the instances generated (Howard, 1980). For
tasks requiring a decision about whether or not an instance belongs to a category, there are no age differences in effects of category dominance on the category-instance decisions (Mueller, Kausler, Faherty, & Olivieri, 1980; Nebes, Boller, & Holland, 1986; Petros, Zehr, & Chabot, 1983). Similarly, the effect of dominance of an attribute on noun-attribute decisions is age constant (Nebes & Brady, 1990).

Under ID theory, we would expect a reduced effect of dominance for older adults because inhibitory deficits would allow low probability, irrelevant instances, or attributes to achieve higher levels of activation for older than young adults, thereby reducing for older adults the difference in accessibility between high and low dominant instances/attributes. The basis for this prediction is the effect of inhibitory deficits on an automatic process: The automatic spread of activation along semantic pathways will involve more irrelevant pathways when inhibition is reduced. The opposite prediction, however, of larger dominance effects in old age may also be made under ID theory because of postulated changes in a controlled, attentional process: Older adults' "repeated encounters with retrieval failures lead to reduced attempts to retrieve and, thus, to compensatory changes in comprehension styles that rely heavily on . . . information that is easily accessed from memory." Such compensation for inhibitory deficits means older adults rely more on instances or attributes with "high levels of learning" (Hasher & Zacks, 1988, p. 217) and thus should show greater slowing than young adults for low dominance instances or attributes, increasing their dominance effect. Both predictions of ID theory are contrary to the observed findings. In sum, research on the breadth of associations to words and the variability in activating meaning of words provides no evidence for increased retrieval of irrelevant information in old age or greater reliance on high probability information.

Sentence processing. — Perhaps tasks involving semantic processing of single words are not vulnerable to age differences in inhibitory processes because they emerge only during the more cognitively taxing job of comprehending sentences. The finding that adults "... consider a broader range of candidates as completions for incomplete sentences than do younger individuals" (Stoltzfus, 1992, as reported by Zacks & Hasher 1994, p. 259) is consistent with the prediction that older adults access more irrelevant associations during sentence processing. Earlier research, however, reported no such age difference in the appropriateness or the variability of responses generated as completions for low and high constraint sentences (Cohen & Faulkner, 1983; Nebes et al., 1986; see also Light, Capps, Singh, & Owens, 1994). The effect of cloze value of sentences (i.e., probability of most frequent response) on latency to produce a completion was the same across age (Nebes et al., 1986).

An experimental paradigm designed to reveal the activation of relevant aspects of word meanings and the suppression of irrelevant word meanings during sentence processing (e.g., Tabossi & Johnson-Laird, 1980) provides additional evidence that linguistic context constrains semantic processing in a similar way for young and older adults. In this paradigm, sentences biased specific properties of words: Immediately after reading, The oranges rolled off the uneven table, young and older adults were faster to verify a property of oranges relevant to the sentence, e.g., Oranges-Round?, than to verify a property that was irrelevant, e.g., Oranges-Juicy?, suggesting that the relevant meaning was activated during sentence processing. Similarly, after reading, The oranges quenched the thirst of the hot children, a decision involving the relevant property, Oranges-Juicy? was faster than Oranges-Round? (Burke & Harrold, 1988). If older adults activate more irrelevant meanings than young adults, or are less able to suppress irrelevant meanings once activated, they should produce a smaller difference between the time to verify relevant and irrelevant properties. Burke and Harrold, however, found no age effect on the difference in verification time between relevant and irrelevant properties.

Similarly, immediately after reading a sentence such as, The insect in the clover stung the professor, both young and older adults made faster category decisions for a sententially relevant instance, e.g., bee—insect?, than for an irrelevant instance, termite—insect? (Light, Valencia-Laver, & Zavis, 1991). Light et al. also varied the typicality of the category instances. In the example above, the typical insect bee is relevant to the sentence, whereas for The insect in the woodwork concerned the professor, the atypical insect termite is relevant. Of particular importance for ID theory is the condition in which a sentence instantiated a low typicality instance, as in the case of the woodwork sentence instantiating termite. Here, the high typicality instance bee is strongly associated with insect, but irrelevant to the sentence. If older adults are impaired in suppressing meanings that are irrelevant to the sentence or if they prefer easily accessed information, then they should show less facilitation of the relevant compared to the irrelevant instances, particularly when the irrelevant instance is a typical, easily accessed instance of the category. Contrary to these predictions of ID theory, Light and colleagues found constant effects of typicality and relevance of the instance across age.

A similar approach to measuring activation of meaning online during sentence processing involves presentation of a target stimulus for word recognition in sentence contexts that are semantically congruent (e.g., The accountant balanced the BOOKS versus less congruent (e.g., The train went over the CLOUDS; Madden, 1988). Inasmuch as older adults are less able to suppress activation of information that is irrelevant to a sentential context, they should show less benefit from semantic congruency between sentence and target. That is, under ID theory, older adults are less able to inhibit meaning irrelevant to the linguistic context, so that these competing irrelevant responses slow their latency in the semantic congruency condition. Many studies have shown, however, that facilitation from congruent sentence contexts is at least as large for older as for young adults (Burke & Yee, 1984; Cohen & Faulkner, 1983; Hutchinson, 1989; Madden, 1988, 1989; Nebes et al., 1986; Stine & Wingfield, 1994; Wingfield, Aberdeen, & Stine, 1991; Wingfield, Alexander, & Cavigelli, 1994).

The experimental paradigm of Stine and Wingfield (1994) is especially informative for evaluating ID theory.
They presented sentence fragments completed by a gated (i.e., acoustically abbreviated) word target as a completion and measured the recognition threshold (i.e., duration) for the gated word as a function of its probability as a completion. They also manipulated whether or not there was a high probability competitor for completing the sentence. For example, time is a high probability completion for All the guests had a very good dinner (completion probability = .83) and has no strong competitor, whereas dinner is a low probability completion (completion probability = .03) with a high probability competitor (time). Two possible outcomes would support ID theory. If older adults retrieve more semantic information during sentence processing because they are unable to suppress irrelevant or low probability responses, then they should show a smaller difference than young adults between recognition thresholds for low versus high probability completions. If older adults do not differ in activation of meaning based on context, but are impaired in suppressing a high probability but incorrect completion, they should be relatively slower than young adults to recognize a low probability target with a high probability competitor. Neither of these predicted outcomes was observed: High probability targets were easier to recognize than low probability targets, and a high probability competitor increased recognition threshold, but both effects were the same across age. Thus, there was no age difference in the ability to ignore the irrelevant high probability competitor (e.g., time when recognizing dinner), contradicting the basic prediction of ID theory that older adults are more susceptible to competition at encoding or retrieval (e.g., Stoltzfus et al., 1996).

Selection of the contextually appropriate meaning of words with multiple meanings (e.g., homophones) is an important paradigm for investigating comprehension processes, and one specifically cited by Hasher and Zacks (1988) as sensitive to inhibitory deficits. When a homophone is presented in a context biasing a particular meaning, either a single word context (e.g., ink-pen) or a sentential context (e.g., The ink leaked from the pen), word recognition is faster for a word related to the contextually appropriate meaning of the homophone pen (e.g., write) than for an unrelated word or a word related to the contextually inappropriate meaning (e.g., pig). Within ID theory, the contextually inappropriate meanings are suppressed so that only the appropriate meaning is activated; age-linked inhibitory deficits should make inappropriate meanings more available for older adults. Recent studies, however, using variations of this paradigm, consistently find equivalent disambiguation of homophones by single word or sentence contexts for young and older adults, with faster latency for contextually appropriate related words than for contextually inappropriate related words whose latency is slower or the same as that of unrelated words (Brady, Balota, & Faust, 1996; Herman, Kellas, Vu, Martin, & Yehling, 1996; Hopkins, Kellas, & Paul, 1995; Paul, 1996; see also Balota & Duchek, 1991). Particularly compelling is the finding of Hopkins et al. (1995) and Paul (1996) that only contextually appropriate related meanings were facilitated for young and older adults even when the appropriate meaning was the less frequent meaning of the homophone.

For example, after The pen broke and the animals ran out, latency was faster for the contextually appropriate meaning (target = pig) than for the inappropriate, suppressed meaning that was the dominant meaning of the homophone (target = write).

These studies consistently demonstrate age equivalence in the online selection of word meaning during language processing, an operation that requires inhibition of irrelevant meanings under ID theory. Interestingly, Paul (1996) reported an age difference when measuring naming latency for words that varied in their strength of association to a preceding sentence and varied in the length of the interval between the end of the sentence and target presentation. Strongly associated words, (e.g., dish for the sentence He dropped the bowl) produced faster naming latencies than unrelated words for young and older adults at all ISIs, and weakly associated words (e.g., cup) produced faster latencies than unrelated words at the shortest delay for young adults and at all delays for older adults. Paul rejects the interpretation that older adults are unable to suppress "low salient (but contextually appropriate) information" (p. 18) such as cup, because he found in a second experiment that older adults have no difficulty suppressing irrelevant meanings of homophones (see above). He favors the interesting idea that older adults may develop a more semiologically elaborated representation of the sentence than young adults because, although they exclude irrelevant information, older adults are less likely to exclude relevant information, an interpretation compatible with the findings of Hamm and Hasher (1992), as discussed below.

In sum, there is strong and consistent evidence for age constancy in retrieval of semantic information and semantic activation during language processing across a variety of tasks. Other reviews have concluded likewise: "Older adults do not seem to differ from young adults in rate, breadth, or amount of spreading activation, in likelihood of making inferences, or in use of context to particularize word meanings" (Light, 1991, p. 346; see also Kemper, 1992; Mitchell, 1989; Tun & Wingfield, 1993, for similar conclusions). There is no support for the ID theory predictions that older adults are deficient in suppressing contextually irrelevant meaning or that they activate more irrelevant semantic information than young adults or that they retrieve more high frequency, dominant, or typical information than young adults.

Experimental support for age-linked inhibitory deficits in comprehension. — How then, do we understand the age differences reported by Zacks, Hasher, and their colleagues (e.g., Zacks and Hasher, 1994) in a series of studies using three different experimental paradigms that they argue are sensitive to inhibitory processes in comprehension? The divergence of their results from previous findings of age constancy in comprehension processes calls for scrutiny of the experimental tasks to shed light on critical features.

In the widely cited experiment of Hartman and Hasher (1991), young and older adults read sentence fragments and tried to predict the missing last word. Then the actual word was presented, which participants were instructed to remember. The sentence fragments elicited high predictability
completions (in pilot work), but the last word that was actually presented, the target, was a low predictability ending. On a subsequent indirect memory test involving completions of new sentence fragments, young adults showed increased production (priming) of the target but not the distracter (the high predictability, rejected completion); older adults showed marginal and equivalent priming of both the target and the distracter. The authors suggested that older adults were less able to suppress the rejected completion so it was more accessible on the indirect test and that this caused “... less knowledge of the target stimuli” (p. 592).

A number of studies (see above) have demonstrated that older adults perform like young adults in online comprehension of low probability instances of a category or attributes of a noun (e.g., Mueller et al., 1980; Nebes & Brady, 1990) or an unexpected meaning of a sentence (e.g., Burke & Harrold, 1988; Light et al., 1991; Stine & Wingfield, 1994). Thus, rather than reflecting inhibitory processes involved in comprehension, the Hartman and Hasher (1991) results may depend on age differences in other mental operations not required in online comprehension tasks, for example, remembering which completion was read and which was generated, a necessary operation for learning the correct completion as instructed in this task. Older adults are less accurate than young adults in remembering whether words were read or generated (Rabinowitz, 1989) and are impaired, in general, in remembering source or contextual information (see Spencer & Raz, 1995). Indeed, in follow-up research, Hartman (1995) reported that young and older adults show the same pattern of priming for expected and unexpected targets presented as completions without distracters (e.g., rejected completions), and when targets were presented simultaneously with perceptually distinct distracters (Experiments 1 and 2). There was more priming for low than high predictability completions regardless of target-distracter status, contrary to the view that distracters are inhibited, thereby reducing their availability in the indirect test. Under conditions where differentiating the target and distracter was made more difficult (“learn the unexpected ending”), age differences in priming similar to Hartman and Hasher (1991) were observed. Hartman (1995) concluded that older adults have more difficulty selecting a target under adverse conditions but that this paradigm provides no evidence that their difficulty is related to inhibitory deficits: “... there was no evidence in either of these experiments that irrelevant information was ever suppressed even by young adults” (p. 667).

In the second experimental paradigm, young and older adults read garden path passages where initially implied information was not supported later in the paragraph (e.g., Hamm & Hasher, 1992; Zacks & Hasher, 1994). At the middle or end of the passage, participants were presented a series of words and made a speeded response of yes if a word represented a current interpretation or had appeared in the passage, and no if the word had not appeared in the passage. Young and older adults were equivalent in responding yes to the new target interpretation, but older adults produced more yes responses than young adults to the original, now competing, interpretation at the end of garden path passages and, after a delay, older adults recalled fewer target interpretations than young adults. The authors argue that older adults maintain additional interpretations because their inhibitory processes are deficient and these additional interpretations interfere with the recall of the target interpretation after a delay.

The finding that older adults maintain information that may be relevant to a passage longer than young adults is consistent with Paul’s (1996) finding, described above, that older adults show priming of low salience, relevant information at longer intervals than young adults. If this age effect, however, were the consequence of age-linked inhibitory deficits, then we would expect to see priming of irrelevant information in older adults as well, and as Paul (1996) points out, there is no evidence for this. Moreover, the garden path results of Hamm and Hasher (1992) may reflect age-linked episodic memory deficits rather than inhibitory deficits because the critical question was not simply about the correct current interpretation of the passage but also about memory for words that had been presented earlier in the passage: Correct “yes” responses to a new interpretation required the knowledge that it was the current interpretation, whereas correct “no” responses to the original, competing interpretation required knowledge that it was not the current interpretation and that it had not been presented earlier in the passage. Older adults’ episodic memory declines would reduce their retention of what had been explicitly stated earlier in the paragraph, inflating yes responses for competing interpretations because they incorrectly remembered that they appeared in the passage. Consistent with this interpretation of an effect of age-related memory declines independent of inhibitory deficits, older adults made significantly more “yes” responses to new words (false alarms), particularly at the end of the passage. Indeed, the influence of episodic memory in the Hamm and Hasher task is suggested by their report that when young and older adults were free to refer to the passages while answering inference questions, their understanding of the passages was equivalent.

A third experimental paradigm testing comprehension (and summarized above) involves reading text interspersed with visually disrupting material. This slows reading and increases comprehension errors with larger effects for older than young adults, particularly when the interspersed material is related to the target text (Carlson et al., 1995; Connelly et al., 1991). The ID explanation is controversial here as well. Dywan and Murphy (1996) demonstrated that on a surprise recognition test for the interspersed material, young adults’ performance was superior to older adults’, contrary to the view that young but not older adults inhibited the material, thus excluding it from working memory. Dywan and Murphy argue that the availability of target and interspersed material in memory was the same across age and that older adults make more errors on comprehension questions because of reduced memory for the correct source for familiar information, a well established deficit in old age (e.g., Spencer & Raz, 1995). This, of course, does not explain why older adults’ reading is slowed more by related than unrelated interspersed material. The Connelly et al. explanation, however, of “a greater breadth of spontaneous activation during reading of text for older than young
adults” (p. 539) is contrary to the well established findings in semantic priming studies we reviewed earlier.

In sum, these three experimental paradigms suggest some interesting age differences, but the contribution of inhibitory deficits to these differences is controversial at best. Overall, the review shows that age differences are absent in most online tasks where responses do not require episodic memory. In off-line tasks, however, where retention is involved in correct responding, age differences are consistently found. This pattern suggests that the age deficit is in remembering comprehended text rather than in comprehension per se (e.g., Burke & Harrold, 1988; Light & Albertson, 1988). The fundamental mechanism impacted by age seems to be the formation of new connections in memory, including those that link comprehended material to spatial, temporal context, including its source (MacKay & Abrams, 1996; MacKay & Burke, 1990). In contrast, under ID theory, decline in memory for new information in old age is secondary to inhibitory deficits that impair memory by allowing greater interference from irrelevant information. If inhibitory deficits are primary, it remains for ID theory to specify why they are not visible in language tasks that do not require new memory.

Language Production and Aging

The studies reviewed thus far are primarily concerned with the nature of semantic activation during language comprehension. Although less research has focused on language production and aging, ID theory has interpreted two important aspects of production that change significantly in old age, namely, word finding and off-topic speech. First, word-finding ability declines in old age. Older adults complain of difficulty in producing well known names and words (Cohen & Faulkner, 1986; Sunderland, Watts, Baddeley, & Harris, 1986) and produce more ambiguous references and more pronouns in their speech, apparently because they are less able than young adults to retrieve the appropriate common or proper names (Cooper, 1990; Heller & Dobbs, 1993; Pratt, Boyes, Robins, & Manchester, 1989; but see Glosser & Deser, 1992).

Tip of the tongue states. — One of the most dramatic instances of word finding difficulty is the tip of the tongue (TOT) state, in which a person is temporarily unable to produce a word although absolutely certain that they know the word. TOTs were highest in older adults’ ratings of expressive language problems (Ryan, See, Mener, & Trovato, 1994), and performance is consistent with these complaints: Both naturally occurring and experimentally induced TOTs increase with age (Burke, MacKay, Worthley, & Wade, 1991; Maylor, 1990b; Rastle & Burke, 1996).

Word finding deficits in old age are well supported; what is more controversial is the mechanism that causes them. Under ID theory, the mechanism is a decreased ability to suppress irrelevant associations or competing words during word retrieval: “...our claim would be that older adults might have trouble when trying to remember the names of acquaintances to make introductions, not because of the loss of access to the relevant memories, but because irrelevant ones are likely to be activated as well, which slows retrieval of the target memories” (Zacks & Hasher, 1994, p. 259; see also Hartman & Hasher, 1991; Hasher & Zacks, 1988). The empirical evidence, however, does not support this claim. People often report alternate competing words that come to mind spontaneously and repeatedly during a TOT; but older adults report fewer alternate words than young adults during TOTs in either the laboratory or everyday life (Burke et al., 1991; Cohen & Faulkner, 1986; Maylor, 1990a). If older adults suffer more TOT experiences because of greater competition from alternate words, we would expect them to report more, not fewer, alternates. Instead, older adults in the threes of a TOT report less information of any kind and say that their mind goes blank (Burke et al., 1991; Cohen & Faulkner, 1986). The inhibition explanation of TOTs is also inconsistent with findings that processing competitors, that is, words semantically and/or phonologically related to a TOT target, improved rather than hindered retrieval (James & Burke, 1996; Meyer & Bock, 1992). This pattern of findings for TOTs is more consistent with age-linked deficits in transmission of priming: Older adults have more TOT experiences and access fewer alternate words or partial information about the target because of deficits in the transmission of priming in the phonological system (see Burke et al., 1991; MacKay & Abrams, 1996; MacKay & Burke, 1990).

Fluency. — Another manifestation of word-finding difficulty in old age is performance on fluency tests in which participants produce in a limited time interval as many words as possible beginning with a designated letter or letters, or in a designated category. Older adults usually produce fewer words than young adults (e.g., Howard, 1980; Nyberg, Backman, Erngrund, Olofsson, & Nilsson, 1996; Riegel & Birren, 1966). In the context of ID theory, older adults’ production is slowed by interference from previous responses or irrelevant associates that are inhibited in young adults. Patients with frontal lobe lesions also produce fewer words on fluency tests (e.g., Janowsky, Shimamura, Kritchovsky, & Squire, 1989), and older adults’ fluency scores correlate with performance on other “frontal” neuropsychological tests thought to reflect inhibitory processes, namely the Wisconsin Card Sorting Test (WCST) and the Trailmaking Test (Arbuckle & Gold, 1993). This has led to the suggestion that impaired frontal lobe function may cause older adults’ inhibitory deficits (e.g., Arbuckle & Gold, 1993).

The mechanisms underlying fluency, however, appear to be complex. For example, there are typically sex differences in fluency (Cattell, 1971; Nyberg et al., 1996), but it seems unlikely that sex-linked inhibitory deficits cause men’s lower performance. Moreover, “frontal” tests such as fluency, WCST, and Trailmaking do not simply reflect functioning of discrete neuroanatomical structures or single cognitive processes such as inhibition (e.g., Corcoran & Upton, 1993; Grafman, Jonas, & Salazar, 1990; Hartman, Bolton, & Sweeney, 1996; Salthouse, 1993b; Salthouse, Fristoe, & Rhee, 1996). For example, fluency shares a high percentage of its age-related variance with performance on block design, a speeded visual-spatial test with no known relation to inhibitory processes. Moreover, controlling for
age differences in speed eliminates the age effect on fluency (Nyberg et al., 1996; Salthouse et al., 1996) and reduces the age variance in WCST and Trailmaking by more than 75% (Salthouse et al., 1996). Thus, the correlation between fluency and “inhibitory” tests (Arbuckle & Gold, 1993) may simply reflect the importance of perceptual speed for both (Salthouse et al., 1996).

Older adults are also slower than young adults to produce word associations (e.g., Burke & Peters, 1986; Riegel & Riegel, 1964), and parsimony would suggest that the explanation for this is the same as the explanation for their slower production in fluency tests, especially given the similarity of the requirements of fluency and word association tasks. Older adults’ word association responses provide no evidence that they are impaired in suppressing competing inappropriate responses (e.g., Burke & Peters, 1986; Howard, 1979), and thus there is no basis for inhibitory deficits as a cause of slower word association responses. Furthermore, over the duration of a fluency test, older adults’ rate of producing words increases until it approaches the rate of young adults (see Riegel & Birren, 1966), a finding incompatible with the claim that older adults are impaired in suppressing recently activated but no longer appropriate responses. In sum, considerable research remains to be done to show that a single cognitive factor (i.e., inhibitory deficits) causes, or even contributes to, age differences in fluency. Given the strong influence of speed on fluency performance, it seems a difficult testing ground for other mechanisms hypothesized to contribute to age differences in word retrieval.

Stroop effects. — Stroop interference effects in color naming, another word retrieval task, are widely and frequently cited as support for age-linked inhibitory deficits. In the Stroop task, naming the ink color of an incongruent color word is slower than naming the ink color of an unrelated word, letter string, or color patch. This slowing is generally greater for older than younger adults, under ID theory, because older adults have greater difficulty inhibiting irrelevant information, in this case the baseword, which interferes with color naming (e.g., Stoltzfus et al., 1996). Correlations linking greater Stroop interference effects to poorer language performance in older adults have been interpreted as support for the role of inhibitory deficits in age differences in language (Hartman & Hasher, 1991; Kwong See & Ryan, 1995). Interpretation of Stroop interference effects as support for ID theory is problematic, however. Older adults are typically slower than young adults in baseline color naming so that the larger absolute difference between baseline and interference conditions in older adults would be expected based on their slower naming (Hartley, 1992). Indeed, there is considerable evidence that age differences in Stroop interference effects are attributable to age-related general slowing (Park et al., 1996; Salthouse, 1996; Salthouse & Meinz, 1995; but see Kwong See & Ryan, 1995; Spieler, Balota, & Faust, 1996). Consistent with this, a recent meta-analysis demonstrated that the effect size for Stroop interference did not differ significantly for older and young adults (Verhaeghen & De Meersman, in press; see Kieley & Hartley, 1997, for other problems in the ID interpretation of Stroop).

Off-topic speech. — A second aspect of language production that changes in old age and has been attributed to age-linked inhibitory deficits is the frequency of off-topic speech. Arbuckle, Gold, and their colleagues have demonstrated that the speech of older adults more often lacks focus or strays from the current topic of conversation (e.g., Arbuckle & Gold, 1993; Gold, Andres, Arbuckle, & Schwartzman, 1988; see also Glosser & Deser, 1992). Under ID theory, older adults’ reduced ability to inhibit irrelevant information causes their speech to wander off the topic and become littered with extraneous personal observations and inappropriate information (Arbuckle & Gold, 1993; Zacks & Hasher, 1994). Arbuckle and Gold (1993; Gold & Arbuckle, 1995) reported evidence supporting this explanation of increased off-topic speech: A composite score of neuropsychological tests believed to measure inhibitory processes, namely WCST, Fluency, and Trailmaking, predicted the frequency and extent of off-topic speech.

Under ID theory, older adults’ off-topic verbosity reflects a decrement in using higher-level contextual constraints in discourse to select relevant speech topics and suppress irrelevant topics. This contrasts strikingly with the lack of age differences in using contextual constraints in the language processing studies we reviewed earlier. Why should age-linked differences in suppressing irrelevant responses emerge during language production at the discourse level, but not at the lexical or sentence level? A clue to the answer lies in three sets of findings relevant to the mechanism underlying off-topic verbosity. First, age differences in off-topic verbosity appear to be specific to certain conditions, as they have not been found in some studies (Cooper, 1990; Gould & Dixon, 1993). As Gold, Arbuckle, and Andres (1994) point out, older adults do not consistently talk more than young adults (e.g., Cooper, 1990; Kemper, Kynette, Rash, Sprott, & O’Brien, 1989). Second, older adults do not report more “mind wandering” or intrusions of irrelevant thoughts in laboratory tasks or everyday life (Giambra, 1989; Grodsky, Corder, Huie, O’Brien, Vesteich, & Giambra, 1992; Kramer et al., 1994; see also Salthouse, 1993a). And third, psychosocial functioning, such as high extroversion, poor health, and unsatisfactory social support, also predicts off-topic verbosity (e.g., Arbuckle & Gold, 1993; Gold et al., 1988).

These findings suggest that off-topic verbosity may reflect a speech style that older adults select in specific social contexts, rather than a cognitive decrement that produces inappropriate thoughts in all speech and nonspeech situations. Considerable evidence indicates that speakers select from a repertoire of speech styles based on their construction of the social situation (e.g., Giles & Coupland, 1991; Kemper, 1994; Labov, 1969). Within this framework, older adults choose off-topic verbosity as an interactional strategy because their restricted social interaction and, in some cases, decreased mobility lead them to place greater value on talk, particularly about their own lives. Giles and Coupland (1991) argue, “Rather than approach elderly discourse from the traditional decremental perspective, we interpreted it as a series of coping strategies, given the life circumstances of the elderly people involved” (p. 188). This hypothesis is consistent with the findings that lower
satisfaction with social support and higher extroversion predict verbosity, and with the lack of age differences in the intrusion of irrelevant information in nondiscourse situations (e.g., Giambra, 1989). This interactional strategy hypothesis contrasts with the decremental approach of the ID theory by linking off-topic verbosity to pragmatic principles that apply to conversational discourse, but not to experimental tasks involving single word or sentence processing. Older adults may construct the Gricean maxim for conciseness differently from young adults, but still produce coherent speech with high communicative value. The decremental approach, however, emphasizes cognitive impairment that obstructs communication by allowing production of irrelevant information that normally would be suppressed.

To address these issues, James, Burke, Austin, and Hulme (1997) collected speech samples from young and older adults and obtained ratings of their communicative value. Participants spoke on autobiographical topics (e.g., describe your education) and described a picture (e.g., an art work). Older adults demonstrated significantly more verbosity than young adults on the biographical topics, replicating the findings of Arbuckle and her colleagues, but not on the picture descriptions, replicating Cooper (1990). A second sample of young and older adults read verbatim transcriptions of the speech on the biographical topics and rated how interesting it was, how informative, and how clear and easy to follow. Older adults' speech received more positive ratings than young adults' in every category, including a category of overall quality of the story.

Thus, contrary to the decremental approach, older adults' verbosity was associated with increased communicative value. This finding is difficult to reconcile with the view of off-topic speech as a cognitive error resulting from an impaired mental operation. Rather, we think that older adults emphasize communicative value more than young adults because they hold different pragmatic goals for conversations, and that this explains age differences in the choice of information to include in the conversation. Wingfield, Tun, and Rosen (1995) make a similar argument in explaining why older adults produce more reconstructions than young adults as they recall passages: Reconstructions preserve coherence and communicative value of a text.

When Does Behavioral Inhibition Entail Theoretical Inhibition?

Inhibition is used in two different senses in cognitive psychology. Behavioral inhibition refers to decreased speed and accuracy of responses because of competition from other stimuli or cognitive operations, and is often interchangeable with interference. Theoretical inhibition is a process in interactive activation models that reduces activation of representational units, either through a spreading process among units or through self-inhibition of a unit (e.g., MacKay, 1987; McClelland & Rumelhart, 1981; Stemberger, 1985). Predictions for age-related changes typically focus on behavioral inhibition, and greater behavioral inhibition in older adults is assumed to reflect age-linked deficits in the theoretical process of inhibition. Behavioral "inhibition," however, may or may not entail the theoretical mechanism of inhibition (see, e.g., Anderson & Bjork, 1994; Dell & O'Seaghdha, 1994; Eberhard, 1994; MacKay, Miller, & Schuster, 1994; Wheelton & Monsell, 1994). Moreover, deficits in theoretical inhibition can reduce interference (e.g., reduce negative priming as in Hasher et al., 1991) or increase interference (e.g., from interspersed material during reading as in Connelly et al., 1991). Thus, the success of ID theory in making new testable predictions requires distinguishing between inhibition at the behavioral and theoretical level, and specifying the nature of behavioral inhibition. Predictions for age-related increases in behavioral inhibition, however, are often not based on well-specified models of the underlying processes; as a consequence, a prediction of increased behavioral inhibition in older adults may be inconsistent with age-linked inhibitory deficits at a theoretical level.

To illustrate this, consider competitor effects on word retrieval in which semantically related words compete for retrieval in production and form-related words compete for retrieval in perception. In language production, older adults' increased word-finding deficits have been explained under ID theory as a consequence of their reduced ability to inhibit irrelevant words (competitors) that impair retrieval of the target (e.g., Zacks & Hasher, 1994). However, within well-specified inhibitory models of word retrieval, inhibition emitted from a node is inversely proportional to its level of priming so that transmission of lateral inhibition between competitors and a target is bi-directional (e.g., Humphreys, Riddoch, & Quinlan, 1988; McClelland & Elman, 1986; McClelland & Rumelhart, 1981; Stemberger, 1985). The inhibition at the behavioral level, namely the failure of target retrieval, is a consequence of the transmission of inhibition from competitors to the target word. Older adults' inhibitory deficits would reduce the target word's inhibition of competitors, as has been predicted, but it would also reduce the effect of the competitors on target activation, thereby weakening the source of retrieval failure. Thus, deficits in theoretical inhibition would cause older adults to experience fewer word retrieval failures, not more. Predictions of behavioral effects of deficits in theoretical inhibition require careful analysis within a well-specified model of the behavior.

Now consider the effect of form-related competitors on perception of a target. Spoken word recognition is more difficult for words with many sound-similar neighbors (competitors) than for words with few such neighbors (e.g., Luce, Pisoni, & Goldinger, 1990). Sommers (1996) recently reported that older adults' spoken word recognition is negatively affected more than young adults' by targets with many competitors. Under ID theory, these results are explained by older adults' reduced transmission of theoretical inhibition to competitors. Inasmuch as inhibition is bi-directional (e.g., McClelland & Rumelhart, 1981), however, the reduction in theoretical inhibition would also modify the effect of competitors on the target. Thus, age-linked inhibitory deficits would diminish the behavioral inhibition of the target, contrary to the observed result (see Eberhard, 1994).

Conclusions

This review reveals a pattern of aging effects on language processes that must be explained by any general the-
ory of cognitive aging. The empirical evidence does not support the hypothesis that inhibitory deficits in old age increase the breadth of activation of information during language comprehension or production so that more irrelevant or inappropriate information is retrieved. This conclusion has implications for the inhibitory deficit account of aging effects on other cognitive functions besides language — for example, on episodic memory, inasmuch as retrieval of irrelevant information is the cause of age-linked declines in that function. In contrast to the remarkable age constancy reported for on-line comprehension, Hasher, Zacks, and their colleagues report age differences in language tasks requiring retention, or forgetting, of material once it is comprehended. The role of inhibition in these paradigms is controversial, and there is no explanation under the theory of why inhibitory deficits appear in some language tasks and not in others. Age deficits in a different mechanism, namely, forming new connections in memory, does explain why age differences are found primarily in off-line semantic tasks, which require retention of new information, rather than online tasks that are relatively free of retention. The pattern of age differences, especially in language production, however, may well reflect multiple explanatory mechanisms, both cognitive and social in nature. This is hardly surprising given the inherently social nature of language’s communicative function, and the evidence that language is both individually and situationally determined (e.g., Giles & Coupland, 1991).

In conclusion, ID theory has stimulated the introduction of new and interesting experimental paradigms in language and aging research (e.g., Hartman, 1995; Hartman & Hasher, 1991; Sommers, 1996). ID theory also promises to enhance the development of theory in cognitive aging by highlighting the distinction between empirical and theoretical levels of explanation, a requirement for understanding behavioral inhibition. A revised ID theory that is consistent with the pattern of age effects in language processing outlined in this article would represent a major theoretical advance in cognitive aging.

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Address correspondence to Dr. Deborah Burke, Department of Psychology, 550 Harvard Avenue, Pomona College, Claremont, CA 91711. E-mail: dburke@pomona.edu

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