6

Directed Ignoring

Inhibitory Regulation of Working Memory

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I. INTRODUCTION

Parents of teenage children suffer inordinately at the hands of their children and a key component of this suffering is induced by the adolescent's ability to ignore a wide range of stimulation, from background music, to television noise, to a ringing telephone, to, most irritatingly of all, parental speech. These are all examples of a category of behaviors that we call *directed ignoring.* Sometimes, as for the teenagers of our example, the reason for ignoring information is an internally driven one (in this case, something like intense absorption in self-directed thought). Other times the reason for ignoring information is externally driven, as occurs, for example, when there is a change in topic or a sudden change in stimulation—formerly relevant information must now be ignored and new information attended in order to accommodate the change. The importance of directed ignoring for a coherent mental life and for organized behavior is considerable and in this chapter we begin to make this argument by providing a number of formal examples of internally and externally driven directed ignoring behaviors. We take as our central task, however, to demonstrate the role of an attentional mechanism—inhibition—in fostering or limiting the ability to engage in directed ignoring behaviors. To this end, we report research that compares college-age young adults (who are only a little older than the teenagers of our example) to individuals at the other end of the adult age continuum, old age, an age at which we believe directed ignoring becomes particularly impaired, an impairment which to a large extent can be attributed to a decline in the efficiency with which attentional inhibition operates.

We come at the issue of directed ignoring from a theoretical viewpoint which proposes that inhibitory attentional mechanisms play an essential role in the efficient operation of the cognitive system via their control over the contents of working memory (Hasher & Zacks, 1988). In this chapter, we briefly outline the theoretical framework, highlight some of the evidence that is consistent with the assumption that inhibitory control diminishes with age, and then describe some consequences for attention and memory of a reduced ability to control the contents of working memory, or to put it otherwise, the consequences of a diminished ability to ignore task-irrelevant information. The examples were chosen to demonstrate the fact that the larger theoretical framework itself has wide applicability to individual and group differences across a range of cognitive functions, including language comprehension, speech production, episodic memory, problem solving, and selective attention.

Building on models of attention that emphasize "selection for action" (e.g., Allport, 1989; Keele & Neill, 1978; Navon, 1989; Neumann, 1987), Hasher and Zacks (1988) proposed that there are two basic mechanisms of selective attention: activation and inhibition. Inhibition operates in the service of goals by hindering the access to working memory of goal-irrelevant information that may be activated in parallel with goal-relevant information. A similar argument has been made in a different context by Dagenbach and Carr (this volume), and by Carr et al. (in press). 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. We (Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993) have recently proposed that inhibition has the further function of preventing the return of attention to a previously rejected item, whether that item is an external stimulus event or a thought (a notion analogous to "inhibition of return" in visual search; Klein & Taylor, this volume; Rafal & Henik, this volume). In doing so, inhibition helps to maintain attention to selected information so as to enable the development of a coherent thought stream.

Our assumption, based on a close reading of the cognitive gerontology literature, is that older adults have deficient inhibitory mechanisms. Among the relevant findings are those indicating that older adults show increased rates of irrelevant and personalistic intrusions in speech (Gold, Andres, Arbuckle, & Schwartzman, 1988), increased rates of intrusion in free recall of sentences (Stine & Wingfield, 1987), and increased rates of repeating already produced responses (Koriat, Ben-Zur,

& Sheffer, 1988). Also, analysis of traffic accidents of older drivers (see Charness & Bosman, 1992) shows that they tend to have elevated accident rates primarily in situations where there are many potentially distracting stimuli, such as would occur when making turns at busy intersections or trying to enter a superhighway in heavy traffic. These actuarial data are consistent with self-reports of older drivers about the aspects of driving they find difficult (Kline et al., 1992), as well as with data from laboratory studies of selective attention which indicate that older adults are less able than younger adults to maintain the focus of attention on strictly task-relevant information and are often more easily distracted by the presence of irrelevant information in the environment (e.g., Cremer & Zeef, 1987; Rabbitt, 1965). Further, older adults, unlike younger adults, tend not to habituate to the presence of continuing distraction (McDowd & Filion, 1992). Taken together, this general pattern of findings is suggestive of a deficit in inhibitory attentional mechanisms in older adults.

The study of inhibitory processes in aging has recently become a focus of research in several laboratories, with the result that there is now substantial direct evidence of an age-related deficiency of inhibitory control over attention. For example, we and others (McDowd & Oseas-Kreger, 1991; Tipper, 1991) have found age differences in negative priming, currently taken as a key marker of attentional inhibition (Houghton & Tipper, this volume). The negative priming effect is seen in selective attention tasks when a stimulus that had served as an ignored or selected-against distractor on the preceding trial becomes the target on the subsequent trial. For young adults, responding to the target in this situation is slowed compared to a condition in which completely different stimuli occur on successive trials (e.g., Tipper & Cranston, 1985). Furthermore, we know that young adults show this effect across a range of materials, including letters, words, and pictures, and across different response modes and delays between one trial and the next (see Houghton & Tipper, this volume, for a review). By contrast, several studies have found that older adults do not reliably show the negative priming effect (Hasher, Stoltzfus, Zacks, & Rypma, 1991; McDowd & Oseas-Kreger, 1991; Stoltzfus et al., 1993; Kane, Hasher, Stoltzfus, Zacks, & Connelly, in press; Tipper, 1991). We note that this pattern of behavior is limited to situations in which the task requires response to the identity of the target, rather than its location (see Connelly & Hasher, in press, for indications that older adults show efficient inhibition when responding to target location rather than target identity). Thus, taken as a whole, the data on negative priming provide support for our assumption of reduced inhibitory attentional mechanisms in older adults.

Two aspects of inhibitory control over the contents of working memory are relevant to our concern with directed ignoring. The first centers on the ability to screen out irrelevant stimuli while attending to task relevant ones. The second centers on the ability to switch the focus of attention in response to changes either in goals or in the structure of information. Consider goals. When a particular goal is satisfied, the recent past may no longer be relevant and, if that is the case, then abandoning the sustained activation of ideas that were connected with the no longer relevant information becomes appropriate. Similarly, suppressing no longer relevant ideas is beneficial in situations in which there is a dramatic change in the structure of information. One such change occurs for "garden path" sentences or passages, in which an initial interpretation (either semantic or syntactic) proves to be incorrect and therefore irrelevant. Inhibition, as a key mechanism for influencing what is active in working memory, has a major role to play in such situations; its function is to eliminate from working memory those ideas connected to the satisfied goal or to the misleading information in the front end of a garden path sentence or passage. Basically, our argument is as follows: Inhibition plays a role in situations in which the recent past is no longer relevant. The appropriate response to this, in many situations, is to discontinue maintenance of activation toward that information or to ignore it. Inhibition is a key aspect of successfully ignoring, at least on a momentary basis, the no longer relevant past. Insofar as older adults are deficient at inhibition, disrupted patterns of learned ignoring should be seen.

In this chapter, we point to five lines of work that are consistent with an age-related reduction in the ability to optimize directed ignoring. We note that although in each case our comparison is between younger and older adults, there may well be circumstances in which younger adults also show such inhibitory deficits,[1] however this has not been extensively explored to date. In all the experiments we summarize here, the young subjects were college students and the old subjects were healthy, community-dwelling individuals with a mean age of 67–68 years. In addition, all the participants were given a vocabulary test; in the few cases where the two age groups differed in average vocabulary score, it was the older group who had the higher scores.

II. IGNORING CONCURRENT ENVIRONMENTAL DISTRACTION

The first line of research we consider is one that examines the ability to ignore stimuli that are presented along with target stimuli but which are explicitly designated as irrelevant. Certainly, the literature on aging

[1]Indeed, even adolescents may show an inability to ignore the recent past, even if relatively restricted to only those instances in which their parents have just said no.

contains many findings that are at least superficially consistent with our prediction about this situation. These come from studies on visual search, categorization, and Stroop tasks, among others. Although the size of age differences is dependent on many factors, the clear trend is for older adults to be more negatively impacted by a given amount of environmental distraction than younger adults. A recent study of ours will serve as an example.

In this study (Connelly, Hasher, & Zacks, 1991), subjects read aloud short texts which, in the experimental conditions, had distracting material interspersed among the text words. The target and distracting materials were in different fonts and subjects were instructed to read all the words in one font and to ignore all the words in the other font. In the first experiment of this study, the distracting material consisted of repetitions of four different words or short phrases that were meaningfully related to the texts. In the second experiment, three different types of distracting materials were used: strings of *X*'s, words and short phrases that were unrelated (on the basis of meaning) to the to-be-read passage, and, as in the first experiment, words and short phrases that were meaningfully related to the to-be-read passage. On average, and in irregular places, an interruption occurred every four to five words of the target text.

In both of the Connelly et al. experiments, reading time was increased by distraction for younger as well as older adults, but the effects were substantially larger for the older groups. Furthermore, in Experiment 2 (see Figure 1), whereas the young participants were equally slowed by text-unrelated and text-related irrelevant verbal material, the older participants were more affected by text-related verbal distraction than by text-unrelated verbal distraction. Consistent with a considerable literature, the two Connelly et al. studies indicate that older adults have more difficulty ignoring distracting material than do younger adults. This difference is particularly true for distraction of the same category as the target material (here, words), and is even more the case when those distracting words are meaningfully related to the target material. The fact that the age difference was largest in the text-related condition is consistent with attentional findings previously summarized indicating that it is the inhibition of distractor identity which is particularly affected by aging.

III. IGNORING TO-BE-FORGOTTEN MATERIAL: DIRECTED FORGETTING STUDIES

The next line of research explores the directed ignoring of recently presented stimuli that have been designated as irrelevant by being

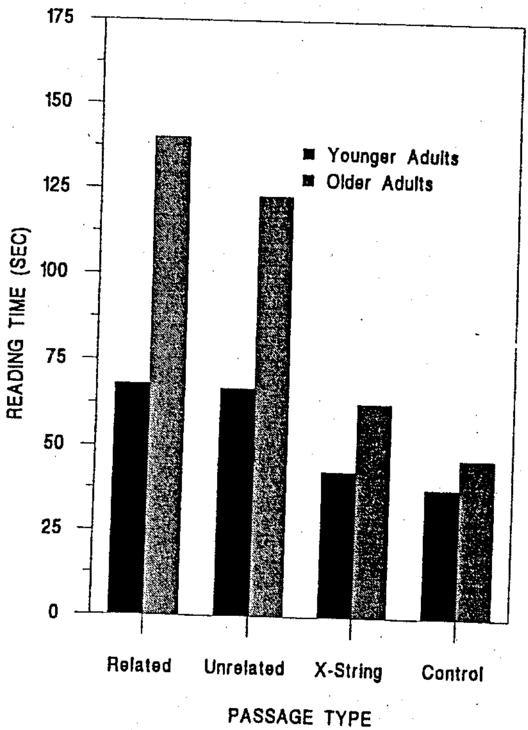

FIGURE 1

Reading times of younger and older adults as a function of different kinds of distraction. From "Age and reading: The impact of distraction" by S. L. Connelly, L. Hasher, and R. T. Zacks, 1991, *Psychology and Aging, 6*, 533–541, Figure 3. Copyright 1991 by the American Psychological Association. Adapted by permission.

marked as to be forgotten. Our reasoning here was that a diminished ability to comply with an instruction to ignore certain stimuli should be seen not only in relation to actually present stimuli, but also in relation to recently presented ones. To explore this idea, we have investigated directed forgetting in older adults (Zacks, Radvansky, & Hasher, 1993).

Research on directed forgetting is predicated on the intuition that active forgetting processes serve important functions. That is, it is frequently the case that being able to forget information that turned out to be wrong or that is no longer relevant is as important to attaining performance goals and maintaining emotional health as is being able to remember information that is correct and still relevant. Memory researchers have used a variety of procedures to study the ability to forget some inputs while remembering others presented in the same context and near the same time. The common feature of these procedures is that the cueing as to which items are to be remembered (TBR items) and which ones are to be forgotten (TBF items) occurs *after* the items have been presented for study, so that subjects cannot afford not to study each item as it is presented. The cueing can occur after each item, or after a group of items has been studied, or after the whole list has been presented. Regardless of the cueing procedure used, successful compliance with forget cueing is demonstrated by three phenomena. First, it can be seen in the absence of interference on the recall of TBR items from the inclusion of TBF items in the presentation list. That is, recall of TBR items is the same whether none, a few, or many TBF items have been presented prior to the TBR items. Second, successful directed forgetting is seen in the small number of intrusions of TBF items when subjects are instructed to recall only TBR items. Third and finally, successfully directed forgetting is seen in the poor recall or recognition of TBF items when, on a final memory test, participants are asked to recall or recognize all presented items. In general, young adults commonly show all these findings (see Bjork, 1989, for a review).

Current theories (Bjork, 1989; Geiselman & Bagheri, 1985; MacLeod, 1989) propose that multiple mechanisms underlie directed forgetting effects. These include stopping the rehearsal of an item following a forget cue, segregation of TBR and TBF items into distinct sets in memory, and inhibition of retrieval of TBF items. Together, these processes are thought to keep TBF items from interfering with the retrieval of TBR items on memory tests on which they *are not* to be retrieved and to produce low retrieval rates of TBF items on memory tests on which they *are* to be retrieved. It seems likely that attentional inhibition is centrally involved in these proposed mechanisms of directed forgetting effects, especially the first (ceasing to rehearse) and third (inhibition of retrieval); and so, our prediction was that older adults would be less successful in complying with directed forgetting instructions than younger adults.

We have completed several experiments on directed forgetting in older adults with fairly consistent results (Zacks et al., 1993). Here, we summarize the findings of two very similar experiments that used a procedure based on an experiment reported by Woodward and Bjork (1971, Experiment 2). In this procedure, subjects studied lists of 24 words, presented one at a time for 5 sec each. At the offset of each word, the subject was given a cue as to whether the *preceding* word should be remembered or forgotten. In each list there were 12 words of each type. Once the entire list had been presented, the subject tried to recall the remember words without intruding any of the forget words. This task was made harder by the fact that the 24 words in a list consisted of 4 words from each of 6 categories, presented in random order. And furthermore, within each category, forget cues were associated with 0, 1, 2, 3, or all 4 words, and remember cues with the rest. In one experiment, half of the items in each list were from exhaustive categories that have only four members each (e.g., north, south, east, and west), and half were high typicality members of nonexhaustive categories. In the other experiment, all the items were from nonexhaustive categories. In both experiments, following the presentation and immediate recall of six lists, participants attempted to recall all of the words, TBF words as well as TBR words. In the second experiment, this was followed by a yes/no recognition test for all TBR and TBF items on which the distractors came from categories that had been included on the presentation lists.

Performance on the immediate recall tests of both experiments is shown in Figure 2. Older adults recalled fewer TBR items than younger adults, but they *included* more TBF items in their recall (both differences are significant). On the final recall test (see Figure 3), younger adults outperformed older adults overall, and both groups produced more TBR than TBF items. One finding of particular interest is that the difference in recall of TBR and TBF items is smaller for the elderly as compared to the young subjects. To put this another way, especially in the second experiment, the older adults recall almost as many TBF items as the younger adults, but the older adults recall considerably fewer TBR items than the young. (In both experiments, the interaction between age and item type—TBR vs. TBF—is significant.) Similar findings were obtained on the final recognition test in the second experiment. This pattern of findings suggests that forget items receive more rehearsal at encoding and are less effectively blocked at retrieval for older, as compared to younger, adults. Taken together, the data from these directed forgetting studies and others we have done suggest that the elderly have a reduced ability to comply with the instruction to forget some of the presented items. This, we suggest, is due to deficient inhibitory mechanisms, mechanisms which, as Stoltzfus et al. (1993) suggest, ordinarily serve to cut off the past from continued consideration.

IV. IGNORING NO LONGER RELEVANT MATERIAL

A. Sentences with Unexpected Endings

Another situation in which we have studied older adults' difficulty suppressing no longer relevant information (Hartman & Hasher, 1991) involved the use of high-cloze sentence frames (e.g., *She ladled the soup into her* ______). Subjects read the sentence frames and tried to predict the ending for each. Because norms had established that each sentence frame elicited a particular ending with high probability, and because for

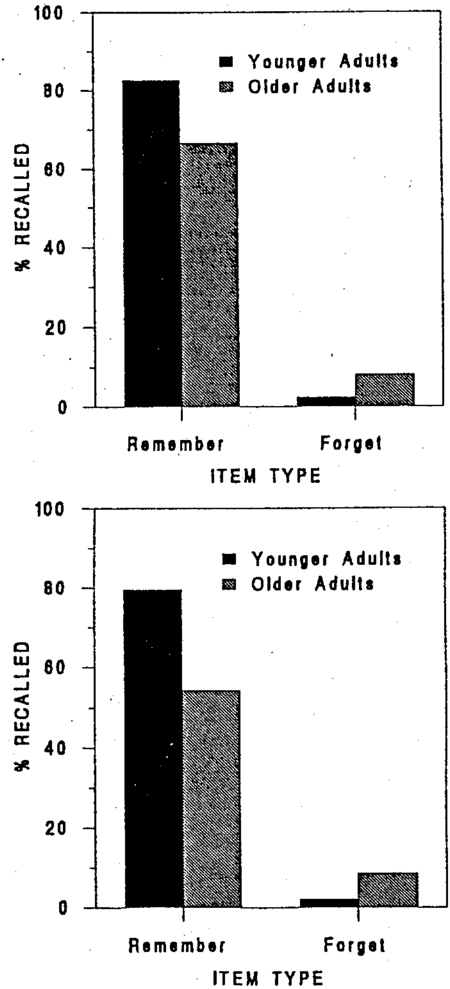

FIGURE 2

Younger and older adults' correct recall of TBR items and intrusions of TBF items on the immediate tests of two directed forgetting studies. The data in the top panel are from the experiment that used both exhaustive and nonexhaustive categories (Experiment 1); those in the bottom panel are from the study that used only nonexhaustive categories (Experiment 2). Both sets of data are from Zacks et al. (in preparation).

half of the frames (the filler items) the expected endings were confirmed, we assume that, for the most part, subjects predicted the high-cloze endings. For critical items, however, the predicted final word (*bowl*) was not shown. Instead, an unexpected but acceptable ending (*lap*) was provided as the target. Thus, in this task, subjects were asked to think of

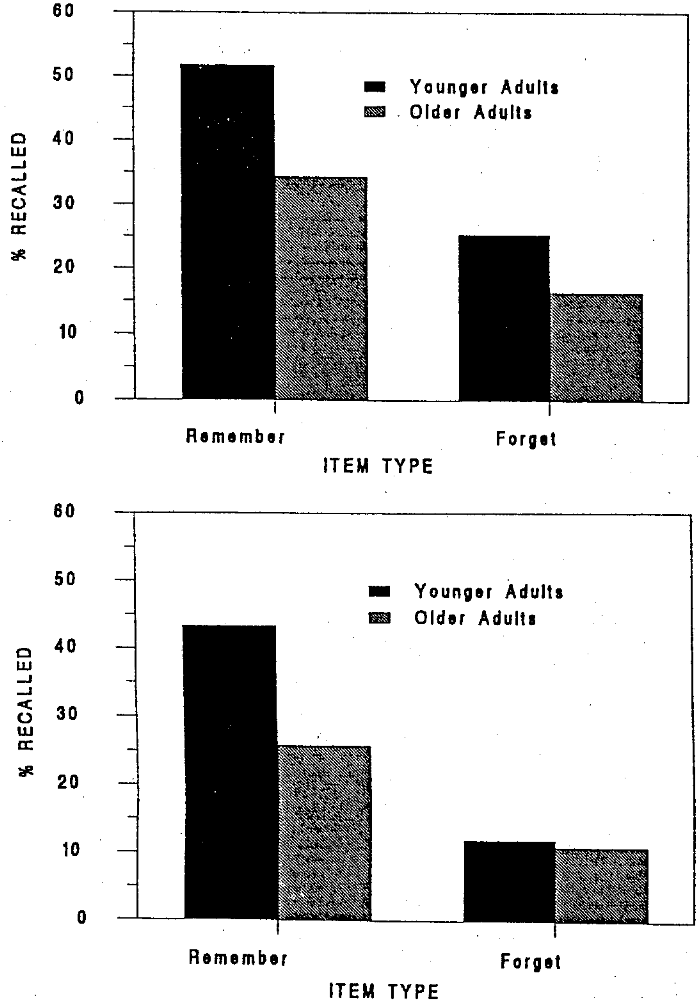

FIGURE 3

Younger and older adults' recall of TBR and TBF items on the delayed tests of two directed forgetting studies. The data in the top panel are from the experiment that used both exhaustive and nonexhaustive categories (Experiment 1); those in the bottom panel are from the study that used only nonexhaustive categories (Experiment 2). Both sets of data are from Zacks et al. (in preparation).

the last word of a sentence and then they were told the "correct," at least for experimental purposes, ending word. They were also told to remember the final words (the ones we provided) for a memory test of an unspecified sort.

The actual memory task (at least in the eyes of the experimenters, if not in those of most participants) was an indirect or implicit memory test in which subjects provided sentence completions for sentence frames of moderate cloze value. For each critical sentence in the first part of the experiment, there were two different frames included among the sentence completion materials: One of these was moderately predictive of the expected (but disconfirmed) ending (*bowl: Scotty licked the bottom of the* ______); the other was moderately predictive of the actual ending that had been presented (*lap: The kitten jumped on the owner's* ______). Control values for the probability of producing the experimental endings were obtained from subjects who had not been previously exposed to the relevant critical sentence. An increase from the control value for a particular test frame (i.e., a priming effect) was taken as evidence that the particular experimental word still had enhanced accessibility in memory.

The two test frames for each critical study sentence allowed us to assess memory for the ending that the subject had presumably originally thought about but should have suppressed when the correct one was given, as well as memory for the correct ending. The data were clear (see Figure 4): The young adults showed no priming effect for the disconfirmed endings; that is, *bowl* was no more accessible than if it had never been thought about in the context of the experiment. The older adults, by contrast, showed priming effects for both endings; that is, both *bowl* and *lap* were more accessible than if they had not been presented in the experimental context. Apparently, for older adults, being told that it was her *lap* not her *bowl* that "she" ladled her soup into does not result in the inhibition of *bowl*, whereas for younger adults, it does result in the inhibition of *bowl*. Another way to describe this situation is that older adults seem to have "richer" memory representations of the study sentences than do younger adults, in that they are more likely to maintain both the ending they initially thought about and the one given by the experimenter. In other words, older adults are not successfully ignoring endings that they generated but that proved irrelevant to the task.

B. Passages with Unexpected Twists

Another study (Hamm & Hasher, 1992) has implications similar to that of the Hartman and Hasher findings, but this time arrived at in the context of requiring participants to encode more elaborate texts, texts that again include garden path twists in the interpretation process. Thus, in this study, younger and older subjects were induced to encode material in a way that later turned out to be wrong. Here, too, a final

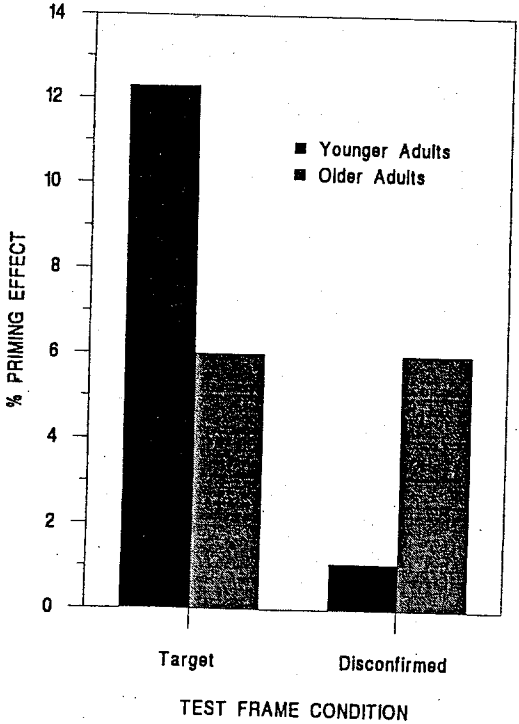

FIGURE 4

Priming effects shown by younger and older adults for the target and disconfirmed words. Data are from Hartman and Hasher (1991).

correct interpretation was arrived at, this time by the participants themselves. One interest in this study was in the ability of the two groups to access their initial interpretation (pre-garden-path twist) as well as their final interpretation.

This study used a set of paragraph-length narrative passages modeled on materials used in several earlier studies (Alba, 1984; Zacks & Hasher, 1988; Zacks, Hasher, Doren, Hamm, & Attig, 1987). Each passage has two versions which differ in the degree to which there is contextual support throughout the passage for the final correct interpretation of the central situation described in the narrative. In the *expected* version, the final interpretation is well supported from the beginning of the passage, whereas in the *unexpected* version, an erroneous initial interpretation is invited, and it is only after this interpretation has been established that information is given which shows it to be wrong (i.e., the unexpected versions are actually garden path passages). For example, in the expected version of "The Artist" passage, the opening sentences make it clear that the artist has been waiting for a telephone call from his doctor about which he is very concerned. Consequently, it is no surprise when toward the middle of the passage, the doctor tells him the bad news indicating that he only has "three more months" to live. By contrast, the opening sentences of the *unexpected* version of the artist passage omit any mention of the artist's concern about an awaited call from his doctor, and instead imply that he is concerned about finishing the painting he is working on. Consequently, the initial interpretation of the "three more months" mentioned in the telephone call is that this is the amount of time the artist has to finish his painting. It is only when the bad news from the doctor is described that there is a clue that the initial interpretation is wrong.

Our earlier research with these materials involved delayed memory tests following encoding of the passages under different presentation modes. Consider, for example, an experiment (described in Zacks & Hasher, 1988) in which young and old subjects read these passages, displayed one sentence at a time on a computer screen, at their own rate. At the end of groups of six passages, they were given a cued recall memory test for the preceding six passages. Included among the questions asked about each passage was one that tested the subject's interpretation and memory for the central situation in the passage. For "The Artist" passage, that question was *The artist was told he had three more months to do what?* The answer we were looking for was that the artist had three more months to live.

The major finding in this experiment (see Figure 5) was that there was an age difference (favoring the young adults) in retrieval of the critical information for the unexpected but not for the expected passages. Our original interpretation of these data relied on the notion that older adults have a reduced working memory capacity. We argued that the effects of being able to maintain only a reduced amount of information in working memory should be especially apparent when demands on working memory capacity are high. We thought that encoding of the unexpected passages qualified as a situation placing high demands on working memory because, to reach the final correct interpretation of one of these passages, memory for the preceding text had to be consulted and additional general knowledge might need to be activated. By contrast, because the expected passages provided redundant cueing of the correct interpretation and thus low demands on working memory, we felt that older adults would not necessarily be at a disadvantage on these passages.

However, an alternative account of these data is now available, an account consistent with an inhibitory frame. Older adults are especially disadvantaged with the unexpected passages because they are unable to suppress their original interpretation of the situation. Inferences and

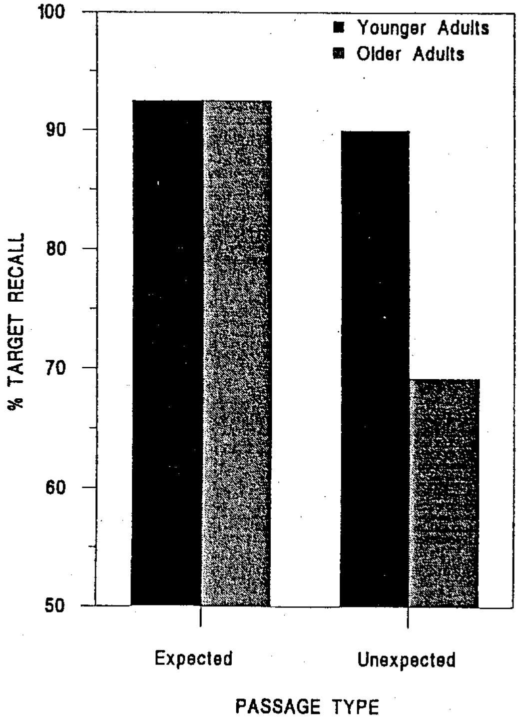

FIGURE 5

Younger and older adults' target recall for expected and unexpected passages. Data are from Zacks and Hasher (1988).

elaborations relevant to that interpretation remain activated and interfere with the encoding of a well-structured and coherent representation of the entire passage. The Hamm and Hasher (1992) study provides direct evidence for this new formulation.

Hamm and Hasher altered the basic procedure of our previous experiments with these passages by including a speeded judgment task which occurred either in the middle of a passage, before the first cue of the final interpretation in the unexpected passages, or at the end. The subjects had to judge whether each of a series of words was consistent with their *current* interpretation of the passage. Included among these words was one which referred to correct final passage interpretation (e.g., *live*) or one which referred to the original interpretation in the unexpected version (e.g., *finish*). When the test word was related to the final interpretation of the passage, the pattern of "yes" judgments was quite similar in younger and older adults (see Figure 6). The interesting data come from those trials in which the test word was related to the original inter-

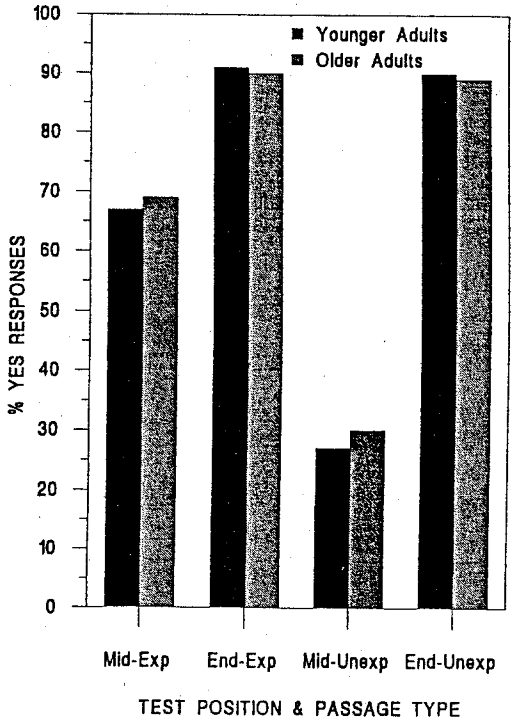

FIGURE 6

Percentage of "yes" responses given by younger and older subjects to test words consistent with the *final* passage interpretations. The results are shown for both the mid (Mid) and end (End) of passage test locations and for expected (Exp) and unexpected (Unexp) passages. Data from Hamm and Hasher (1992).

pretation of the unexpected passage (i.e., *finish*; see Figure 7): In three of four comparison points, older adults said yes to these words more frequently than young adults. That is, except at the midpoint of the unexpected passages, they more often said that *both live* and *finish* were consistent with their interpretation of the passage. For example, older adults' judgments at the end of the unexpected passages indicated that they maintained the original interpretation 48% of the time, although 88% of the time, they had also encoded the correct final interpretation. Another way to describe these data is that older adults were much less likely than younger adults to abandon their original interpretation of the unexpected passages; once they generate an interpretation, they tend to maintain it even in the face of subsequent contrary information.

Thus, in contrast to the idea of *less* information in working memory for older adults, these data suggest an *excess* of information in working

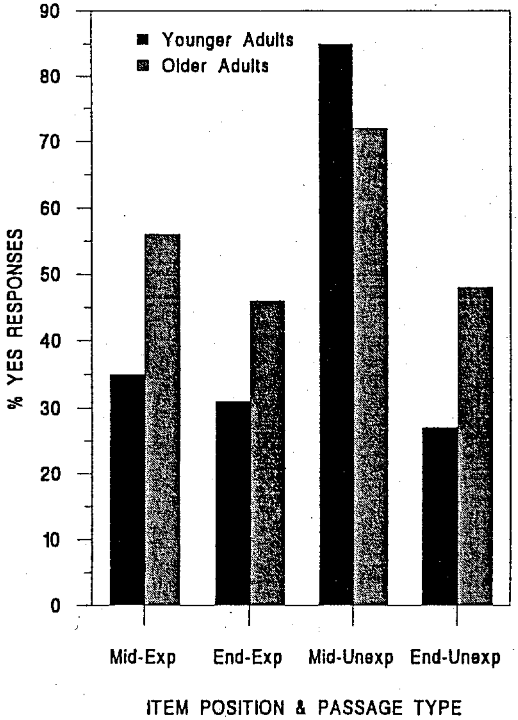

FIGURE 7

Percentage "yes" responses given by younger and older subjects to test words consistent with the *original* passage interpretations. The results are shown for both the mid (Mid) and end (End) of passage test locations and for expected (Exp) and unexpected (Unexp) passages. Data from Hamm and Hasher (1992).

memory, an excess that is the result of difficulty in suppressing original interpretations. One effect of maintaining both interpretations might well be a less coherent memory representation of the passage as a whole for older adults, and consequently poorer performance on a delayed recall test. The latter result was found in the experiment from Zacks and Hasher (1988), as already mentioned.

V. "ENRICHED" WORKING MEMORY CONTENTS AND RETRIEVAL FROM LONG-TERM MEMORY: THE FAN EFFECT

As we see it, the general pattern that emerges from these different lines of research is that older adults have a decreased ability to inhibit the processing of irrelevant stimuli and to quickly suppress irrelevant thoughts inadvertently activated by goal-relevant materials. The last research area we describe explores the impact that this relative inability to ignore irrelevant stimuli and thoughts might have on the speeded retrieval of information from long-term memory. Presumably, older adults' deficiencies in suppressing irrelevant information would operate both during attempts to encode information into long-term memory and also during attempts to retrieve the information from long-term memory, with predictable consequences at both stages. For encoding, one sort of consequence would follow from the notion that simultaneously activated thoughts tend to get associated with each other. With prolonged activation of irrelevant thoughts, more spurious associations between critical and irrelevant thoughts are likely to be stored; these spurious associations could later interfere with retrieval of task-relevant information.

This kind of reasoning led us to explore age-related differences in the "fan effect." In fan effect experiments (e.g., Anderson, 1974, 1983), subjects first learn a set of target facts, such as the following examples from Gerard, Zacks, Hasher, and Radvansky (1991): *The doctor took the car for a short test drive, The judge cut the apple pie into six pieces.* In a subsequent speeded recognition test, they are asked to distinguish between the target facts and unstudied foil facts constructed from repairings of the subject and predicate phrases of the target facts (e.g., *The doctor cut the apple pie into six pieces.*) The fundamental finding is that performance is tied to fan size: The more facts learned about a particular concept (e.g., *the doctor*), the longer it takes to retrieve any one of those facts and usually the more errors are made. This outcome is termed the "fan effect."

We predicted that the relative inefficiency of older adults' inhibitory mechanisms would result in their showing a larger fan effect than younger adults. Our reasoning went as follows: Because of compromised inhibitory attentional mechanisms, older adults should have increased difficulty in focusing on a single set of mental contents, both at learning and retrieval. Consider first what might happen during the learning of the experimental facts. Older adults will be less able to suppress irrelevant thoughts activated by the experimental materials. Such thoughts might include those tied to personal experience with the concepts (*their* doctor, *their friend*, the judge) and facts they are studying. Also, older adults may have a harder time constraining practice to a single experimental item. So when they are supposed to be studying *The doctor took the car for a short test drive*, they might also be prone to rehearse *The doctor danced the night away at the faculty ball.* In essence, the argument is that at any experimental or nominal fan size, the *functional* or *effective* fan size will be larger for older adults than for younger adults. This will then enable any single cue at retrieval (e.g., *the doctor*) to activate a larger number of connected ideas, thus slowing the retrieval of any particular target fact, and also setting the stage for more errors. At the time of retrieval, diminished inhibitory mechanisms will also create problems for older adults. They will be less able to focus their attention on the probed-for fact, because they will be less able to suppress the activation of any non-probed-for facts, whether experimentally related or self-generated.

In one of our fan effect experiments (Gerard et al., 1991), subjects learned lists of 18 facts having the form "The person (type of professional) performed an activity." Each person and each activity appeared in one to three facts. The critical items on the recognition test represented fan sizes 1-1, 2-2, and 3-3, where the first number indicates the number of facts for a particular person and the second the number of facts for a particular activity.

The recognition test reaction time data confirmed all our expectations (see Figure 8): Both groups showed a significant fan effect, which was larger for foil than for presented test items. Importantly, there was also a significant Age × Fan interaction, reflecting the fact that the difference

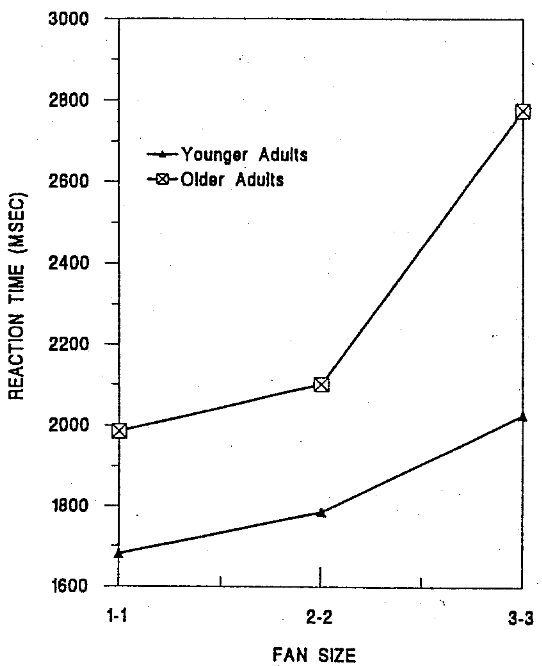

FIGURE 8

Younger and older adults' reaction times for correct recognition judgments as a function of fan size. Data are from Gerard et al. (1991).

between 1-1 and 3-3 fan sizes was almost twice as big for older as for younger adults. Because there were similar findings in the error data, the reaction time results do not reflect a difference between the two groups in speed-accuracy trade-offs.

What these data suggest to us is that the retrieval of well-learned memories can, for older adults, be slowed by the *enrichment* of target information with *irrelevant* associations. In the case of the fan paradigm, the enrichment stems from the older adults' difficulty in suppressing irrelevant associations to the probe concepts, both when they are memorizing the experimental facts and when they are doing the retrieval test. The latter type of effect can impair the retrieval of any well-learned information, with negative consequences for the many cognitive and social tasks that require timely access to information in long-term memory. Therefore, 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.

The picture may be quite different when the enrichment of target information involves primarily *relevant* or *situationally natural* associations. In such cases, older adults may look no different than younger adults, or may even look in some sense "better." Evidence regarding the first possibility is provided by a fan effect study (Zacks, Radvansky, Hasher, & Gerard, 1990, Experiment 2) using materials that readily evoke elaborations which permit nominally interfering associations to be integrated into unified representations based on mental models. Both younger and older adults showed equal benefit from the availability of these elaborations in the form of a reduced fan effect. One piece of evidence supporting the second possibility comes from a study by Boswell (1979) in which it was found that older adults' interpretations of metaphors were deemed by judges to be more integrative and synthetic than those of younger adults. This finding is consistent with the notion that metaphors activate a broader range of associations for older, as compared to younger, adults. Indeed, there is evidence that older individuals consider a broader range of candidates as completions for incomplete sentences than do younger individuals (Stoltzfus, 1992).

VI. BROADER IMPLICATIONS AND CONCLUSIONS

We believe that the several areas of research we have reviewed in this chapter are all consistent with our central assumption that as a consequence of a decline in the efficiency of inhibitory attentional mechanisms, older adults are less able than young adults to ignore stimuli and thoughts currently irrelevant to the task at hand. Because of this, such information is more likely to enter working memory and to remain there longer if it is does enter. Of course, no one of the experiments we have considered in this chapter is definitive, but taken together we feel the story they tell is quite compelling. This is especially true because the consistency in outcome comes from experiments involving a wide range of procedures, materials, and time frames over which processing is measured.

One general implication of our research relates to the repeated pattern of findings suggesting that older adults have "richer" interpretations and memory encodings of target material than do younger adults. This is particularly obvious in the Hartman and Hasher (1991) and Hamm and Hasher (1992) studies, but it is also quite consistent with the fan effect and directed forgetting data (e.g., the increased rate of intrusions of TBF items on the immediate recall tests). This pattern of findings is particularly of interest in relation to an alternate, widely held account of cognitive aging deficits, namely, an account that ties aging declines in cognitive performance to a decrease in the capacity of some central resource, frequently working memory capacity (cf. Light, 1991). Although this alternative view is appealing in some ways (note its consistency with Just & Carpenter's, 1992, recent account of individual differences in comprehension skill among young adults), and although as previously indicated we (Zacks et al., 1987) have held to this view in the past, our data suggesting that older adults hold more, not less, information in working memory than younger adults argue against such a view.

Of course, there are some data that seem to suggest that older adults do have less capacity for holding task-relevant information in working memory (e.g., Salthouse, Mitchell, Skovronek, & Babcock, 1989). However, such findings are not necessarily contrary to our view. We speculate that working memory sometimes *appears* to be reduced in older adults precisely because they have trouble eliminating from working memory information that is irrelevant to the task at hand. To the degree that measurement of working memory capacity taps only task-relevant information, capacity will be underestimated for older adults. That is, we make the tentative suggestion that a smaller measured working memory capacity may be a *result* of the underlying mechanisms of cognitive aging deficits not their cause.

Though highly speculative, this line of argument has the advantage of possibly being able to handle the divergence of results in studies relating working memory capacity to age-related differences in cognitive performance. For example, it has been reported both that older adults have lower average working memory capacities than younger adults (e.g., Light & Anderson, 1985) and that they do not (e.g., Hartley, 1988). Similarly, some data suggest that age differences in working memory capacity can account for the obtained age difference on the target task (e.g., Stine & Wingfield, 1987), whereas other results do not confirm such a trend (e.g., Light & Anderson, 1985; see Light, 1991, for a review). These conflicting findings would not be surprising if the tasks used to measure working memory capacity (e.g., Daneman & Carpenter, 1980) and the target tasks differed in the presence of distracting stimuli and in their potential for eliciting irrelevant ideas that older adults would have trouble suppressing. In addition, if valid, these conjectures would sidestep the thorny issues of how best to conceptualize working memory and to measure its capacity (Daneman, 1987), and the issue of whether working memory capacity is even the most important central resource to consider in accounting for cognitive aging declines (Light, 1991).

In closing, we note that theoretical views quite similar to ours have been offered in a number of different areas, including as accounts of cognitive developmental changes in children (Bjorklund & Harnishfeger, 1990; Dempster, 1992) and of individual differences in language comprehension skill among young adults (Gernsbacher & Faust, 1991). There have also been tentative claims that deficient inhibitory attentional mechanisms may account for some of the cognitive symptoms associated with certain psychopathologies, including schizophrenia (Beech, Powell, McWilliams, & Claridge, 1989). At the least, the increasing popularity of the general viewpoint, and the associated growing body of evidence it has generated, encourage us to continue exploring the impact on cognitive performance of differences in the ability to inhibit the processing of task-irrelevant information, or in other words, differences in the efficiency of directed ignoring.

ACKNOWLEDGMENTS

Much of the research reported in this chapter was supported by a series of grants from the National Institute on Aging (#RO1 AGO4306). We gratefully acknowledge this support. We are also indebted to the many students and colleagues who contributed in numerous ways to this work.

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