The effects of age and expertise on discourse processing

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THE EFFECTS OF AGE AND EXPERTISE
ON DISCOURSE PROCESSING

BY

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ABSTRACT

THE EFFECTS OF AGE AND EXPERTISE ON DISCOURSE PROCESSING

by

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The paradoxical nature of adult development is that it is marked by a decline in processing capacity but an increase in knowledge. A specialized formulation of increased knowledge that can occur throughout the lifespan is expertise. Because discourse processing is both a method of acquiring domain expertise and is facilitated by domain expertise, the nature of this interrelationship is central to successful aging. However, the processes through which expertise facilitates discourse processing are virtually unexplored within the cognitive aging literature. Four experiments investigating this issue are presented. The first experiment investigated age differences in on-line reading strategies of readers with high and low recall using passages in which expertise was "induced" by giving "high-knowledge" subjects titles to passages that were otherwise incoherent. In Experiment 2, age differences in parsing mechanisms underlying discourse processing of high- and low-knowledge listeners were examined using speech segmentation methodology. Experiment 3 was conducted to examine age differences in the effects of task demands on the reading strategies of high- and low-knowledge adults. Lastly, in Experiment 4, age differences in discourse processing strategies were investigated in the real-world domain of cooking.
INTRODUCTION

The last few decades of aging research have seen a shift from the notion that there are inevitable and global declines in cognitive abilities with age to the understanding that there are some processes that remain intact or increase with age (cf. Baltes, Dittmann-Kohli, & Dixon, 1984). This perspective is embodied by a life-span developmental framework which assumes that there are a wide variety of developmental paths that are influenced by the normative, non-normative, and historical contexts in which we live (Baltes, 1987; Baltes, Cornelius, & Nesselroade, 1979). According to this framework, aging is a dynamic process between factors of growth and decline such that any area of development is influenced by the individual's health and past experiences, and environmental factors (Baltes & Schaie, 1976; Rowe & Kahn, 1987). To the extent that an individual has made choices throughout his or her life that maximize strengths while at the same time minimize areas of weakness (called "selective optimization"), the individual is aging successfully. Successful aging is also said to occur when an individual is able to excel in some areas through compensation for unavoidable areas of decline (Baltes & Baltes, 1990).

For example, many older adults experience age-related declines in certain areas of intellectual functioning. In particular, abilities related to fluid intelligence are thought to be strongly linked to neurological changes and therefore to aging (e.g., Horn & Donaldson, 1976). Fluid intelligence refers to the underlying mechanics of intellectual ability, that is, raw processing capacity that is content-free and is evident, for example, in the ability to perform a multiplication problem "in your head." Age-related declines in fluid intelligence have been documented in both longitudinal (e.g., Hertzog & Schaie, 1988) and cross-sectional (e.g., Stankov, 1988) studies. For example, Stankov (1988) found age-related declines in measures of fluid intelligence as assessed with a battery of 36 tests given to 100 adults between the ages of 20 and 70.

Against this backdrop of diminished cognitive capacity, knowledge, as a form of crystallized intelligence, is an example of how selective optimization can promote successful aging. Because knowledge is often acquired via discourse processing, this area of cognition was selected for investigation. In order to consider the effects of knowledge on discourse processing among the elderly, two topics will be
provided as background. First, the mechanisms underlying age-related declines in cognitive abilities will be
explored to establish areas in need of compensation. Second, models of discourse processing will be
described in order to provide background for research surrounding age-related cognitive declines in
discourse processing. After this, three areas will be explored: 1) mechanisms underlying performance of
high-knowledge individuals 2) age differences in the effects of knowledge, and 3) the central question of
how knowledge affects discourse processing among older adults.

Age-Related Processing Capacity Declines

Age-related declines can be considered in terms of a model of diminished processing resources
(Cerella, Poon, & Williams, 1980; Salthouse, 1988a). Whether the concept of processing resources refers
to the amount of available mental energy, rate of propagation of energy, or capacity of working memory (a
computational/memory system) is subject to debate (cf. Salthouse, 1988a), however the basic notion is that
there are age-related decrements in the amount of information an individual can attend to, or process, at any
one time. This approach assumes that there are relatively few factors responsible for most of the observed
age-related declines in cognition. In contrast, other models of cognitive aging represent an attempt to
localize deficits to specific abilities (e.g., encoding processes, retrieval strategies). Smith (1980), for
example, used this approach in his review of research surrounding memory abilities and the relative
contributions of encoding, storage, and retrieval processes to age-related deficits in memory performance.

Craik and McDowd (1987) used a generalized approach adopting the energy metaphor. Their
research showed age-related declines in performance on a free-recall task but not on a recognition task that
included cues at encoding and retrieval. The researchers argued that recognition provides more assistance,
or environmental support, than does free recall and that this in turn reduces the demands on attentional
capacity. According to their viewpoint, age differences in memory performance should increase to the
extent that the attentional capacity of older adults (rather than changes inherent to encoding versus retrieval
processes) is reached and should decrease to the extent that environmental support is available. Thus, this
attentional resources (energy) approach explains age-related decrements in performance across a wide
variety of tasks in terms of the various types of environmental supports that mitigate demands on resources.
Another way of explaining processing resources is in terms of speed of processing (e.g., Cerella et al., 1980; Craik & Simon, 1980; Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1988b). Salthouse (1991), for example, argued that the processing resources approach is able to explain the observed age-related declines in tasks designed to tap different abilities (e.g., spatial, verbal, reasoning, and number) that vary systematically in task demands (i.e., complexity, cf. Cerella et al., 1980). Rather than concluding that there are greater deficits in some of these abilities relative to others, Salthouse suggested that age-related differences occur to the extent that the demands of the task are at the limits of one's capacity. For example, Salthouse, Mitchell, Skovronek and Babcock (1989) had subjects perform both tasks that tapped spatial skills (visual synthesis, paper folding) and tasks that tapped reasoning skills (verbal reasoning tasks). These tasks were then manipulated quantitatively by increasing, for example, the number of premises to be integrated in the analogy task. The slope of the lines representing error rate as a function of the hypothesized number of required operations (complexity) was computed within each age group for each task. In addition to finding steeper slopes for older subjects, they also found that the correlations between the slopes and age were similar for the reasoning task (.43) and the spatial task (.45). Therefore they concluded that a general model of processing resources could account for age differences in performance across tasks that tap various abilities.

Age differences in slowing of cognitive operations (cf. Cerella, 1985) can also be represented by plotting the older subjects' response times as a function of those of the young (a Brinley plot) where the slope of this line is greater than unity (cf. Salthouse, 1985). Slopes greater than unity can be interpreted to mean that older subjects require proportionally more time as task demands increase. Cerella (1985) estimated this index from several meta-analyses to be close to 1.46 for subjects over 60. Thus, this "generalized slowing" approach can also be used to account for age differences in performance across a wide variety of tasks and abilities.

The generalized slowing approach has gained some popularity recently and has even been used to account for findings of age constancy. Myerson and Hale (1993) suggested that speed of processing can be used to explain why age differences are rarely found within the area of lexical access. Lexical access is typically studied through a semantic priming paradigm. Semantic priming refers to the extent to which a
target word is identified more quickly when it is preceded by a semantically related word than when it is preceded by a nonrelated word. This paradigm relies on a semantic activation framework which proposes that concepts (i.e., knowledge) can be represented by nodes which are connected via neural networks such that related concepts are clustered together and are highly interconnected. In this way, neighboring nodes serve to activate (or lower the activation threshold of) neighboring nodes and mental energy thus spreads through the network. While some have argued that semantic priming reflects the extent to which an individual uses context to facilitate processing and is age insensitive (i.e., no age differences in the prime effect) (e.g., Burke & Harrold, 1988), Myerson and Hale (1993) argued otherwise. According to their meta-analysis, older adults tend to have larger prime effects which can be explained using a generalized slowing model. The prime effect, they argued, actually represents savings in terms of the processes that do not need to be executed in the presence of context (i.e., semantically related words). That is, the finding that older adults are facilitated by context to a greater extent than are younger adults is evident in the time saved by having the context provided (rather than to preservation of spreading activation). Thus, in this formulation of processing resources, a slowing factor of 1.5 describes the performance of older adults relative to the young without need to specify the type of processes that are sensitive or insensitive to age. Furthermore, this model is capable of handling multidirectional changes in performance across late adulthood.

In addition to the conceptualization of processing resources in terms of energy and speed, a third generalized approach to cognitive aging research relies on the metaphor of space. One instance of this approach that is widely used within the area of discourse processing is the concept of working memory (WM) capacity. According to Baddeley and Hitch (1974), working memory is a limited capacity system comprised of temporary storage components (an articulatory loop, a phonological store, and a visual store) as well as a central executive used for computational processes. When the locus of age effects within working memory is the focus of investigation, for example, whether storage or computational (i.e., processing) aspects are more or less age sensitive, this theoretical orientation begins to resemble a localization model (e.g., Engle, Cantor & Carullo, 1992). The level of specification is useful to the extent
that it provides testable hypotheses that contribute to improvements in the operationalization of a WM construct. Some of these are explored below.

The computational aspect of WM has been investigated using loaded span tasks in which subjects listen to a list of sentences and then recall the last word from each sentence (Daneman & Carpenter, 1980). Because subjects have to both read new incoming text while at the same time retaining the last word from each sentence, this task is thought to represent the short-term storage and the computational processes of working memory. Wingfield, Stine, Lahar, and Aberdeen (1988) found greater age differences in working memory capacity as measured by the loaded span task than by tasks that tap primary memory abilities such as digit span and simple word span. Digit and simple word spans presumably tap only the storage components of short-term memory.

However, the data are not all consistent. In another study, loaded span and simple word span were equivalent in their ability to account for age differences in recall performance (Stine & Wingfield, 1990). Similarly, Babcock and Salthouse (1990) manipulated the effects of task complexity on working memory through the use of a variety of tasks tapping both storage and computational aspects of WM. These researchers found that both components of WM were equally affected by age. In subsequent work, Salthouse and Babcock (1991) decomposed WM further into storage capacity, processing efficiency, and ability to coordinate tasks. Subjects performed simple digit-span and word-span tasks designed to assess storage capacity (scoring was based on the total number of items correctly recalled at each span level). Arithmetic problems and sentence comprehension tasks were designed to tap processing efficiency (i.e., scoring was based on the total number of correctly answered problems during a 20-second interval). Additionally, a coordination task, designed to assess the effectiveness of WM coordination, required subjects to solve visually presented problems while at the same time answer orally presented problems. Lastly, subjects performed two loaded-span tasks (presented orally) to index overall WM functioning. A computation span task required subjects to compute an arithmetic problem and remember the last digit in each problem while continuing on to the next problem (this process is similar to the Daneman and Carpenter task described earlier). Similarly, a listening span required subjects to comprehend a sentence, answer a specific question (e.g., for a sentence describing someone running, "who ran?")}, and retain the answer to
each as subsequent sentences were presented. The correlations between age and overall WM were
significant (ranging from -39 to -.52), however, after partialling out the hypothesized components
(efficiency, coordination, and storage), efficiency was responsible for the greatest attenuation of the age
correlations. In a parallel follow-up experiment, components of WM were decomposed into processing
efficiency, storage capacity, and speed of processing (indexed by two simple speeded comparison tasks) to
more directly investigate whether the benefits of the processing efficiency component were attributable to
speed. The speed component was found to be the strongest predictor of overall WM performance.
Therefore, these researchers concluded that speed mediates the relation between age and working memory.
Thus, the field of cognitive aging has not overwhelmingly adopted one approach over the others.
Regardless of whether age-related deficits are described in terms of energy, speed, or space and, further,
whether one component of working memory capacity can better account for age decrements in performance,
the results overwhelming suggest that age-related declines are indeed evident across a wide variety of tasks.
For the sake of simplicity, a working memory conceptualization of processing resources will be used here
because this approach is used extensively within discourse processing literature. Therefore, the role of
working memory in discourse processing will be addressed in the next section.

Discourse Processing

Models of Discourse Processing

Just and Carpenter (1980) described a process whereby text is transformed from perceptual stimuli
into meaningful information via a number of stages including word encoding (orthographic decoding),
lexical access (identifying word meanings), and thematic role assignment (whereby arguments are assigned
roles such as agent or recipient). In order to link letters into words and words into phrases, verbatim text is
held in a buffer-like system within working memory where productions retrieved from long-term memory
operate on the text (Just & Carpenter, 1980). For example, the visual input is decoded into orthographic
features (letter combinations) via orthographic productions and other productions similarly operate to form
words, word concepts, and propositions. Productions cause a concept to be activated and retrieved from
long-term memory (declarative and procedural knowledge, and specifically knowledge of syntax, semantics,
and schemas for topics) and inserted into working memory. As mentioned earlier, the notion of activation
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refers to the degree to which a word or concept is available for use in working memory and relies on the conceptualization of memory as a network of nodes (Anderson, 1983). One characteristic of this model is that the activation of one node spreads to neighboring (i.e., semantically related) nodes without deliberate effort. Thus, the automatic spreading of activation is one way in which the lower-level processes of discourse processing (e.g., word and lexical access) occur and is evident in the facilitative effects of context on related target words (cf. Simpson, 1994).

Kintsch (1988; Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975; Kintsch & van Dijk, 1978) proposed a different activation model of how meaning is derived from text through the construction of propositions. A proposition is comprised of a predicador and its arguments. The predicador relates arguments, or concepts that are stored in semantic memory, to each other. A network of related propositions forms a textbase, the theoretical representation of meaning derived from a particular text (Kintsch et al., 1975). The psychological reality of this theory is supported by findings that demonstrate reading time is positively correlated to the number of propositions in a text, as well as to the number of new arguments present when the number of propositions are controlled (Kintsch et al., 1975).

Kintsch and van Dijk (1978) suggested that because working memory is a limited capacity system, propositions must be processed in cycles. Support for the notion that text is processed within a limited system can be found in a study by Jarvella (1971) showing that verbatim recall of a sentence is high when subjects are interrupted at clause boundaries whereas verbatim recall for the previous sentence falls markedly when subjects are interrupted in midsentence. This would suggest that after a sentence boundary is reached, the surface representation is purged from working memory. The number of times a proposition cycles through working memory is dependent on its overlap with other propositions. Relations between propositions can be conceptualized in terms of a hierarchy (Kintsch & van Dijk, 1978), called a coherence graph, that represents details at lower-levels and main ideas at higher-level. Those that are higher in the coherence graph are cycled through working memory more frequently because they have more connections to other propositions. Evidence that propositions are organized hierarchically is found in research showing that recall scores are higher for superordinate propositions than for subordinate ones (Kintsch et al., 1975) suggesting that the higher-level propositions are processed more often in working memory.
Elements from both the Kintsch and the Just and Carpenter models can be combined when considering organizational processing of text. Organization of verbatim text and integration of word concepts and propositions, processes collectively referred to as "wrap-up," are thought to occur at syntactically significant points, specifically at clause boundaries and the ends of sentences (Aaronson & Scarborough, 1976; Haberlandt, 1984). Wrap-up can be inferred from increases in reading times at these points as a function of the number of new arguments in a clause (Haberlandt & Graesser, 1989) and sentence (Haberlandt, Graesser, Schneider, & Kiely, 1986). Wrap-up is also influenced by text demands such as resolution of inconsistency, search for referents, and construction of interclause relations (Just & Carpenter, 1980).

Beyond these processes that result in a textbase representation of discourse, an overall interpretation of the text is also constructed, called a situation model. A situation model is an abstract level of discourse processing that includes a representation of the discourse beyond the literal propositions of the textbase (cf. Johnson-Laird, 1983). Kintsch (1988) describes the situation model as the representation of what the text is about, resulting from an integration of the textbase with the reader's prior knowledge and is less connected to a particular text than to the reader's knowledge. For example, situation models explain why readers are likely to be unable to recall whether they read "the girl was given a complete pedicure at the podiatrist's" or "the girl was given a complete pedicure by the podiatrist" when they can discriminate between "the girl had her handbag stolen at the podiatrist's" and "the girl had her handbag stolen by the podiatrist." Even though both pairs of sentences have similar textbase representations, the second pair of sentences are easily distinguishable because of their distinct meaning (Garham, 1981).

To summarize, the processes underlying listening to and reading text can be described in terms of layers or levels (Stine, Soederberg, & Morrow, 1996). Lower-level processes include orthographical coding and lexical access. An intermediate level consists of sentential processes such as organization of text, integration of propositions, making inferences, and linking antecedents to their referents. The highest level of discourse processing, a global representation of the text is constructed and includes information not directly contained in the wording and is highly likely to contain knowledge possessed by the reader or
listener (Kintsch, 1988). These levels do not imply stages with a strict temporal order, rather these levels are thought to represent concurrent processes and are useful for descriptive purposes.

**Discourse Processing and Aging**

Research surrounding discourse processing and aging suggests that, in general, the lowest levels, for example, lexical access, remains untouched by aging as assessed by word-by-word reading times (Stine, 1990) and semantic priming tasks that assess the facilitative effects of a target word on a semantically related word (e.g., Burke, White, & Diaz, 1987; but see Myerson & Hale, 1993). This age constancy could be attributed to the highly automated nature of these low-level processes that do not place heavy demands on working memory. On the other hand, text-level processes, such as syntactic processing, integration, propositional encoding, and anaphoric referent identification, may be more vulnerable to the effects of aging. Evidence from studies assessing age differences in syntactic production and comprehension, for example, show detrimental effects of complex syntax on older adults performance (Kemper, 1986; Norman, Kemper & Kynette, 1992). Similar to other domains of cognitive aging (cf. Salthouse, 1991), the effects of aging on discourse processing are evident to the extent that the task taxes processing resources. For example, when the elderly are required to make anaphoric inferences (e.g., find the appropriate antecedent for pronoun), their performance deteriorates as the distance between the two constituents increases (Light & Capps, 1986).

The effects of aging on higher levels of discourse processing (i.e., a situation model) have received less attention. One example of this type of representation, the manner in which the emotions of protagonists are represented, appears to be age insensitive. Elderly and young adults represented the emotional characteristics of the protagonist similarly as evident in increased reading times for emotion words that are inconsistent with the text (Soederberg & Stine, 1995). Similarly, Garnham’s (1981) demonstration that two similar textbases can have very different situation models, was replicated showing age constancy (Radvansky, Gerard, Zacks, & Hasher, 1990).

Further evidence of age constancy in the construction of situation models has been found in a study assessing the extent to which older adults focus on the narrative protagonist in terms of a spatial representation. Morrow, Leirer, Altieri, and Fitzsimmons (1994) had subjects memorize the spatial layout
of a building in which a subsequent story takes place. Subjects read target sentences followed by probes about objects that ranged in proximity to the protagonist. Although older adults were slower and made more errors than did younger adults, both older and younger adults had similar probe patterns indicating that they too used a situation model that focused on the protagonist's location. Similarly, older adults had no difficulty recognizing facts that could be integrated into a coherent situation model, even though there were age differences when the facts were unrelated (Radvansky, Zacks, & Hasher, 1996).

The nature of situation models in the elderly was investigated through the presentation of inconsistencies in global aspects of text representation. Older and younger adults had similar on-line reading times for inconsistent information suggesting that they detected the anomaly in their situation model, however, only the younger subjects showed an advantage in recall associated with this increase (Hakala, Rizella, Stine, & O'Brien, 1994). Therefore, although the bulk of the data suggest age invariance in the construction of situation models, some evidence suggests that this construction may be more vulnerable to inconsistency than those of the young.

In sum, the evidence reviewed above suggests that the lowest (e.g., lexical access) and highest (e.g., situation models) levels of discourse processing remain relatively intact with age whereas the middle level (e.g., comprehending sentences with complex syntax) is more age sensitive. The data also suggest that age differences are most pronounced when the tasks exceed the processing resources of the elderly (cf. Salihouse, 1991).

Age differences in discourse processing can be conceptualized in terms of resource allocation. For example, differences between younger and older adults' reading strategies can indicate how cognitive resources are allocated to minimize age-related WM declines. The resource distribution hypothesis (cf. Stine, 1995; Stine-Morrow, Loveless, & Soederberg, 1996) asserts that an aging cognitive system maintains high levels of performance by allocating resources in a fashion that minimizes age-related cognitive deficits. For example, elderly subjects with high-recall scores used a different reading strategy from those of their low-scoring counterparts and younger subjects (Stine, Cheung, & Henderson, 1995; Stine, Loveless, & Soederberg, 1996). To maintain high levels of performance, older readers allocated more time on words at the ends of clauses rather than at sentence-final words (Stine et al., 1995). Thus it appears that an effective
strategy for older subjects who have diminished resources involves the allocation of time to organizational processes in smaller units than entire sentences.

**Age-Related Declines in WM and Discourse Processing**

The link between working memory and discourse processing is well established. For example, Kintsch and van Dijk (1978) suggested that a larger WM capacity can contribute to comprehension through an increased ability to make more referential connections among propositions and across sentences, draw more inferences, and to process complex syntax. Within cognitive aging research, the ability to produce complex syntax (average number of clauses within an utterance and number of left-branching clause) has been found to be linked to WM (digit span) (Norman, Kemper, Kynette, Cheung, & Anagnopoulos, 1991). In a study addressing the effects of syntax on reading comprehension, Kemper and her colleagues found that WM capacity (digit and sentence span) was significantly correlated to performance on a syntax test and concluded that WM capacity affects comprehension of complex syntax (Norman et al., 1992). Similarly, Stine and Wingfield (1990) had subjects listen to and recall passages that varied in propositional density and length and found that working memory capacity accounted for age differences in recall performance on simple texts. A link between WM and language processing ability is not consistently found, however. Light and Anderson (1985), for example, found that the correlation between age and a composite score of fact recall and anaphoric inference was not significantly reduced after partialling out scores on a sentence-span task. It is possible that the sentence-span index of WM may be an inadequate representation of working memory capacity when particularly complex sentence processing is demanded (Stine & Wingfield, 1990). However, it is also possible that a slight variation in the loaded-span task itself may be responsible for this finding; Daneman and Carpenter included a true/false component that insured subjects processed the sentence in its entirety whereas Light and Anderson did not.

In sum, age-related declines in working memory have been implicated in a variety of language abilities. The data suggest that age differences are most pronounced when demands on WM are high. After reviewing expertise and its underlying mechanisms, the effects of knowledge and expertise on discourse processing will be addressed.
Expertise

If successful aging involves selectively optimizing strengths and minimizing weaknesses through compensation (Baltes & Baltes, 1990), then one form of successful aging could entail the development of specific domains of performance that are attained in spite of declines in processing resources and enable older adults to circumvent heavy demands on working memory. An example of selective optimization is expertise in which expert performance is defined as exceptionally high competence within a particular domain. Because expertise occurs with deliberate and concentrated practice (Ericsson & Charness, 1994), it is an excellent example of how an individual concentrates his or her skills in some areas at the expense of others.

Theoretical Approach

According to Ericsson and Charness (1994), the origins of the study of outstanding, exceptional performance can be traced to the works of Galton who attempted to show, by tracing family trees of individuals with exceptional intelligence, that genius was an inherited talent. Many researchers still acknowledge the importance of genetic predispositions (e.g., Gardner, 1983). Ericsson and Charness (1994), for example, considered the importance of psychological predispositions. They suggested that motivational factors, which could be inherited, are more likely to be influential in attaining high levels of performance than are any particular physical or cognitive ability. This, they point out, is not a new idea in that Galton and Darwin identified motivation and effort as being important factors of exceptional performance.

However, in general, there is little support for genetic factors associated with exceptional performance. For example, in a review of heritability and expert performers, Ericsson and colleagues (Ericsson, Krampe, & Tesch-Romer, 1993) found little support for heritability of expert abilities. Additionally, the researchers found that most of the studies that emphasize genetic influences on exceptional performance included random samples of individuals from the general population. They argued that this sampling procedure is inappropriate because expert performance depends on a select range of environmental effects and therefore should include more restrictive sampling procedures. The remaining
studies failed to support genetic influences and sometimes indicated that availability of training could
account for familial relations.

Thus, while the pursuit of innate causes of exceptional performance has not disappeared in
contemporary literature, the evidence suggests that genetic predispositions play a minor role relative to
experiential factors in the development of expertise. Not surprisingly then, current researchers appear to be
interested in environmental factors that contribute to high levels of performance (Ericsson & Charness,
1994). Next, research addressing the correlates of expert performance and possible mechanisms
responsible for exceptional levels of performance are considered.

Mechanisms Underlying Expert Performance

Two of the most influential studies addressing the mechanisms underlying expertise were done by
de Groot (1965) and by Chase and Simon (1973) who empirically investigated expert performance in the
game of chess. De Groot (1965) explored the differences between expert and novice chess players and
found no differences between the two groups in superficial processes such as number of moves considered,
heuristics, and depth of search. Rather, he found that experts were able to identify good moves very
quickly, perhaps through advanced perceptual abilities. Evidence for this was found in experts’ superior
ability to recall meaningful chessboard configurations. Importantly, these abilities did not carry over to
randomly placed chess pieces; experts and novices scored the same when asked to reconstruct a board
comprised of meaningless configurations. The researchers reasoned that since short-term limitations were
evident in both groups, experts must be using their perceptual abilities to organize information into
meaningful chunks to circumvent the widely accepted short-term memory limitation of 7 plus or minus 2
(Miller, 1956).

This work, however, did not address the precise nature of these chunks (e.g., their boundary limits,
the interrelations among different chunks). To gather more information on the nature of the chunks used by
experts, Chase and Simon (1973) used a perceptual task in which chess players reconstructed pieces on a
board that was within view, and a memory task similar to the one de Groot used that required subjects to
reconstruct configurations from memory. In both tasks, piece configurations were taken from middle game,
end game, and random placements. In the perceptual task, the time it took subjects to place pieces after one
glance at the board (roughly two seconds), was thought to represent the time required to produce a chunk. In the memory task, successive time intervals between piece placements, reflecting what they called clustering, was used to infer chunking in output processes. Further, for both tasks, five chess relations were coded for within-chunk as well as between-chunk organization, reflecting the nature of the relationship between the last piece and the present piece. These relationships included common type (e.g., pawn, knight), attack (in which one piece is in a position to attack the other), and proximity (the piece is placed on one of the adjacent eight squares). Within-chunk relations were found for all five of their relation measures, however, between-chunk relations were less clear, which they attributed to the presence of more abstract relational properties than those they identified.

As they predicted, the researchers found that the more experienced players were faster and had larger chunks. Because they found that roughly two seconds were needed to produce a chunk, the researchers proposed that experts used markers to facilitate recall from long-term memory. That is, rather than storing the contents of the chunk in short-term memory, a marker allowed the chunk to be located in long-term memory and retrieved quickly.

Thus, Chase and Simon's (1973) research suggests that one mechanism underlying expertise is the ability to represent information in meaningful units. Their work suggests that these chunks need not be stored in long-term memory but rather their rapid recall could be attributed to some sort of label or index that is stored and later accessed for efficient retrieval of chunk information.

Research following that of de Groot (1965) and Chase and Simon (1973) has confirmed and extended these data. For example, researchers have described the specific knowledge advantages of experts that facilitate perceptual, encoding, and retrieval functions (e.g., Chi, Feltovich, & Glaser, 1981; Lesgold, Glaser, Rubinson, Klopfer, Feltovich, & Wang, 1988). Other work has specifically focused on the nature of the expert's knowledge base itself.

A knowledge base refers to an organized set of propositions within a particular domain. Gobbo and Chi (1986) investigated the knowledge base of children who were experts about dinosaurs and, based on how children categorized familiar dinosaurs, concluded that experts had larger and more highly organized knowledge structures than novices. Further, when asked questions about unfamiliar dinosaurs,
experts were better able to make inferences and reason about these dinosaurs. For example, when reasoning about unfamiliar dinosaurs, experts made consistent use of more abstract categories (e.g., type of diet) in contrast to novices who used less consistent criteria and relied on superficial, directly observable information (e.g., size).

Similarly, the ability of physics experts to represent a problem at a high level was attributed to their superior knowledge base which included knowledge of how to use physics principles. This in turn allowed them to quickly search a problem space and arrive at a solution (Chi et al., 1981). Novices, on the other hand focused on the superficial, surface features of the problem. Thus, it appears that an expert knowledge base contains a highly organized and interconnected set of concepts which enables experts to represent problems at a complex level. This network also allows experts to reason on an abstract level and to make inferences about novel instances.

Other researchers have emphasized the interaction between the expert's knowledge base and processing ability (cf. Ericsson & Pennington, 1993). Specifically, Glaser (1987) states that “the nature of this organization determines the quality, completeness, and coherence of the internal representation, which in turn determines the efficiency of further thinking” (p. 84). The expert's knowledge base is thought to facilitate performance through greater automaticity of certain task features (e.g., use of labels as suggested by Chase and Simon, 1973) which frees up available capacity that can then be used for other facets of the task (Chi, Glaser, & Farr, 1988). This "savings" may be reflected in the increases in speed associated with expertise (e.g., Chase & Simon, 1973).

Another way in which an expert achieves high levels of performance resides in the procedural aspects of the knowledge base, that is, the use of knowledge or strategies of knowledge application. In contrast to an increase in efficiency of processing through automaticity, experts garner advantages in performance through their ability to apply processing resources, monitor the solution, or to be responsive to feedback (Glaser, 1987; Salthouse, 1984). Salthouse (1984), for example, found that expert typists were better able to monitor errors than were novices.

Ericsson and Kintsch (1995) have recently proposed the notion of long-term working memory to explain how expertise can influence performance. These researchers suggest that experts have a long-term
working memory system that enables them to attain exceptional levels of performance. With this extended working memory, they can build a system of retrieval cues, called retrieval structures, that allows them to rapidly encode and organize new information. Long-term working memory allows experts to hold and manipulate large amounts of information for lengths of time that exceed those found in traditional notions of working memory. Thus, expert performance has been linked to a superior knowledge base which not only allows for higher levels of reasoning, inferencing, and strategy use but also facilitates an increase in efficiency of processing through automaticity, strategy application, and retrieval structures.

Regardless of the precise way in which this occurs, the sophisticated knowledge base of experts, however, is typically limited to their domain of expertise. There is extensive research showing that expert performance in one domain does not translate into high levels of performance in other domains. Recall, for example, that Chase and Simon (1973) found that expert chess players had superior recall for meaningful chessboard configurations over novices but that this advantage disappeared for random configurations. Furthermore, the superior domain-related abilities of experts cannot be attributed to higher general intellectual abilities as has been shown within the domain of typing (Salthouse, 1984) and football (Yekovich, Walker, Ogle, & Thompson, 1990). The domain specificity of expertise has also been found in the child development literature. For example, child experts in chess have been found to have higher recall for chess pieces than adults with greater digit spans (Chi, 1978). child experts in the domain of emotions have been found to be superior to their novice counterparts at reasoning about emotional situations even after removing differences in general intelligence (Soederberg & Mebert, submitted), and child soccer players have been found to have superior recall of soccer knowledge this is independent of digit-span performance (Schneider, Korkel, & Weinert, 1989). Thus, expertise is specific to the domain in question; it does not necessarily generalize to other domains or to general intellectual abilities.

Expertise differences are not always found within a domain, and sometimes expertise has its costs. Experts were no better than novices in making medical predictions (Camerer & Johnson, 1991). Furthermore, experts lose the details of their memory representations (Adelson, 1984) and made more frequent plausible false alarms (Arkes & Freedman, 1984). Given the findings reported above that experts have a highly organized knowledge base which enables them to rely on retrieval structures to facilitate
processing, it is not surprising that experts may make schemata-consistent errors (i.e., top-down processing overpowers bottom up) and that the detailed, less relevant information is lost. Thus, a complete theoretical model of expertise would need to account for both the benefits and costs associated with expertise.

The data surrounding the predictors of expertise are rather mixed. For example, in a review of research Camerer and Johnson (1991) found that experience (i.e., years of experience) predicted, and level of training did not predict, problem-solving performance among clinical psychologists. On the other hand, other research has shown that both clinical knowledge (experience) and principled knowledge (education) predicted expert performance among x-ray technicians (Lesgold et al., 1988). Thus, caution is needed when generalizing across domains of expertise in terms of the relative contributions of formal education and experience.

In general, the evidence surrounding the origins of, and possible mechanisms underlying, expertise suggests that experts, through deliberate and extensive practice, acquire a highly organized procedural and declarative knowledge base that allows them to circumvent limits on working memory. Because this may be particularly important in the later part of the life span as age-related declines in WM increase, it is important to understand to what extent practice and experience within a domain can improve performance among the elderly. Evidence of cognitive plasticity in the elderly is reviewed below as a means of offering some insight into the potential for expert-level performance in the elderly.

Age and Expertise

Given the data suggesting that experts can circumvent WM limitations (e.g., Ericsson & Kintsch, 1995), one way in which expertise could be developed or maintained in later life is through a moderation of age-related declines in processing resources. In order for this to occur, cognitive abilities need to be modifiable in later adulthood.

Cognitive Plasticity. Cognitive plasticity has been demonstrated using intervention techniques designed to increase skills underlying various abilities. Research by Willis, Schaie, and colleagues has found support for plasticity in attentional processes (Willis, Cornelius, Blow, & Baltes, 1983), figural relations (Willis, Bliezner, & Baltes, 1981), spatial orientation and inductive reasoning (Willis & Schaie, 1986). Schaie and Willis (1986), for example, investigated whether those who had declined over a 14-year
period in either inductive reasoning and spatial orientation ability could increase their performance to prior levels and whether those who remained stable over the 14-year period could increase their scores through training specific to that skill. Subjects who declined in either ability received training (five, 1-hour sessions) specific to that ability such that the other non-trained ability served as the control. Their results indicated that training improved performance of decliners and those who remained stable and that both abilities benefited from domain-specific training.

Baltes and colleagues investigated cognitive plasticity in later life through the use of a paradigm called testing-the-limits. The goal of their work was to study the potential range of performance under optimal conditions (i.e., training supports). For example, Kliegl, Smith, and Baltes (1989) trained subjects on the method of loci mnemonic to facilitate memory for word lists. Subjects using this memory aid visualized each target word with a landmark from Berlin. Whereas older adults could only recall 5-7 items on a word recall task (consisting of a list of common nouns), they were able to increase their recall by utilizing the method of loci mnemonic. This was true for younger subjects as well, however, such that older group was never able to match the performance of the younger group. Baltes and Kliegl (1992) extended this research by using additional and enhanced training sessions and found that substantial age differences still persist.

Thus, it appears that although short periods of training cannot eliminate age differences in performance, older adults can augment their performance levels. Therefore plasticity is possible even without years of deliberate, intense training that results in expertise.

Methodology and Empirical Findings. A correlational approach to exceptional performance provides real-world insight into the nature of expertise in late life. For example, some work assessing age and productivity demonstrated that although there is a small decline in the amount of output during later adulthood, the probability of a masterpiece is constant (Simonton, 1988). Similar research has been done to investigate the age at which performance peaks in a variety of athletic events (Schultz, Musa, Staszewski, & Siegler, 1994) and in chess performance (Elo, 1965). The data suggest that in domains where intense physical ability is required, peak performance occurs in the 20s and 30s and further that this depends on the amount of endurance required and whether the expert is male or female. For example, long distance runners
tend to peak by age 28 with females peaking earlier than males (Schulz & Cumow, 1988). Chess players, on the other hand, peak at age 36 but are still able to perform at the level of those in their mid 20s when in their early 60s (Elo, 1965). This is consistent with the finding that physiological declines (e.g., maximal heart rate) are associated with age, independent of levels of training (Ericsson et al., 1993). Thus, age-related declines in peak performance depend on the degree to which the domain relies on physical ability and indicate that cognitive domains such as chess show little decline in later life.

Another common approach to the study of expertise among older adults involves testing experts and novices of different ages on laboratory tasks. This experimental approach often selects experts by virtue of employment status such as pilot (e.g., Morrow, Leirer, Fitzsimmons, & Altieri, 1994) or medical laboratory technologist (Clancy & Hoyer, 1994) and involves the administration of tasks designed to tap domain-related abilities.

For example, Clancy and Hoyer (1994) investigated age differences in expertise in medical laboratory technology using a visual search task as a domain-relevant measure and a standard letter search as a control. For the skilled search task, the researchers presented a prime that was followed by a 3-panel display. Subjects had to determine whether or not this panel contained a target item. Targets were diagrams of bacteria and the primes were bacterial morphology words. Hoyer and Clancy assessed the effects of related, unrelated, and neutral primes on the visual search times of experts and novices. They predicted that the presence of related primes (words from bacterial morphology) would enhance the experts' encoding processes, thereby increasing the efficiency of the search process. Further, they hypothesized that this efficiency may offset age-related processing declines. That is, older adults may use related primes as a compensatory mechanism which would be evident in a differential benefit relative to other primes.

Contrary to their expectations, the effects of related primes on latencies was comparable for both age groups and both skill groups (although the authors note that power may be a limiting factor within their study). The relative benefits and costs of the primes were calculated (by subtracting and adding neutral prime RTs). Among experts, they found a benefit for related primes and no costs for neutral and unrelated primes for experts whereas among novices no differences in either benefits or costs were found. Age did not interact with these measures. There was evidence of compensation in that older experts showed declines in general
visual search performance but were still able to attain high levels of performance within their domain as indexed by facilitation from valid primes in the skilled search task.

In another study, Morrow and colleagues (Morrow, Leirer, Altieri, & Fitzsimmons, 1994) had younger and older experts (pilots) and novices (nonpilots) read air traffic control commands and then read them back as typically required when communicating with air traffic controllers. They found that expertise can partially offset age-related performance decrements; age differences were smaller for experts than for novices. However, other tasks requiring subjects to memorize a map and answer location probes, perform free recall on the routes presented, and complete a cued recall test of the map, failed to reduce age differences. The researchers suggested that these tasks were less related to actual piloting tasks than was the read-back task. Similarly, in an earlier study by Morrow, Leirer and Altieri (1992), pilots and younger adults comprehended and recalled aviation narratives better than nonpilots and the elderly. Again, expertise failed to mitigates age differences, perhaps because the tasks were too far removed from typical piloting activities.

The data relying on this approach point to some beneficial effects of expertise on an aging cognitive system. However, consistent with the evidence surrounding testing-the-limits and cognitive plasticity, these advantages are domain specific and fail to show older experts surpassing the performance levels of younger experts. The above studies, however, did not decompose elements of performance into component parts in order to identify the mechanisms responsible for older experts' performance. For example, Clancy and Hoyer (1994) failed to find underlying components of skilled search; that is, how older adults were able to use the related primes to circumvent age-related declines in basic visual search processes. It is possible that there are some components of the task that older experts do differently that serve to circumvent age-related processing declines.

One methodological approach well suited to investigating age differences in underlying mechanisms is molar equivalence/molecular decomposition (Charness, 1981). This approach involves decomposing a skill into its component parts to see whether different individuals use the same molecular skills to achieve similar levels of molar performance. In this way, individuals varying in age and performance level on some criterion task (such that age and skill are uncorrelated) are given a series of
tasks thought to represent the component parts of the molar task in question (e.g., typing). With this method, expertise is operationalized as performance on a criterion task rather than by employment status or educational degree. In this way, molar equivalence/molecular decomposition seeks to address the mechanisms responsible for age-related compensation in expert performance.

Salthouse (1984), in his formulation of this procedure gave typists ranging in age (19-72) and in typing experience (0-600 months of at least part-time employment) a battery of typing tasks designed to assess the molar skill of typing (words per minute while typing standard text) and molecular skills (e.g., a serial choice RT task, typing words that have been reversed in letter order, tapping task, a typing task that varied in the amount of exposed to-be-typed material). Interkeystoke variability, ratio of two-hand:one-finger digrams, eye-hand span, and speed of alternate-hand tapping were all independently predictive of typing speed. Variables related to age included transposition errors, component process variables such as tapping speed (both negatively correlated), and eye-hand span (positively correlated). Because the correlation between speed (interkey interval) and age decreased for successively larger preview windows, a larger eye-hand span was thought to be responsible for compensatory processes. Larger previews presumably allowed the older expert to maintain high levels of typing skill despite decreases in underlying perceptual-motor abilities. Salthouse suggested that the larger span is a result of “rapid and efficient operation of parsing, translation, and execution processes” (1984, p. 367) that are driven by the demands of the material to be typed. Whether the compensatory mechanisms responsible for high levels of performance among older adults are primarily attributable to strategies that lessen the impact of age-related slowing remains to be seen. For example, looking farther ahead in the text gives the older typist more time to prepare for key-stroke patterns. It is also possible, however, that the elderly adults’ use of larger hand-eye strategies are derived from years of experience and, for example, knowledge of proper or meaningful typing chunks.

The molar equivalence/molecular decomposition methodology has also been used to explore compensatory processes underlying chess expertise. Charness (1981) investigated chess skills across adulthood and found, like Chase and Simon (1973), that chunking was related to skill level. More interesting was the finding that the number of chunks recalled per chessboard configuration decreased with
skill but increased with age. In other words, the chunks were larger as a function of skill, but smaller as a function of age. Also, on a task requiring subjects to choose the next move for an unfamiliar game, older experts took less time than younger experts to choose an equally good move. Thus, older experts are able to circumvent limits on working memory by processing smaller chunks and retain high levels of performance by efficient encoding processes as indicated by their ability to quickly scan a problem and select the next move.

As illustrated above, there is some evidence showing that aging experts retain their recall and comprehension abilities within their domain even given age-related declines. For older typists, it seems a larger hand-eye span is crucial to attaining high levels of performance despite decreases in perceptual-motor abilities (Salthouse, 1984). For elderly chess masters, the ability to efficiently search a problem space seems to be central to expert performance despite cognitive declines in encoding and retrieval (Charness, 1981).

Expertise and Discourse Processing

Assuming that one way in which experts develop and maintain expertise is through reading domain-related material, it is important to understand the differences between experts and novices in how they process discourse. The next section explores the effects of expertise on discourse processing, possible mechanisms underlying these effects, and then the effects of expertise on older experts' text processing.

Effects of Expertise on Discourse Processing

The evidence reviewed earlier supports the notion that an expert's knowledge base is a key factor in achieving high levels of performance. The evidence from the discourse processing literature further suggests that the relation between the text and an individual's knowledge is crucial. Therefore, it is not surprising that the literature on the effects of knowledge on reading suggests that expertise facilitates discourse processing within that domain (Kintsch & van Dijk, 1978; Kintsch, 1988). For example, Voss and colleagues had subjects listen to an account of a baseball game and found that subjects who possessed a high level of baseball knowledge had higher overall recall and higher recall for significant propositions than did novices (Spilich, Vesonder, Chiesi, & Voss, 1979). The authors interpret these results in terms of a superior goal structure representation that allows the expert to maintain crucial information within working
memory. A goal structure is a theoretical account of the action sequences used in baseball and is operationalized by the order in which actions occur in a text. In a series of similar experiments examining the effects of baseball knowledge on cognitive performance, Chiesi, Spilich and Voss (1979) found that high-knowledge individuals were better able to: detect new versus already-read information particularly when the information was more significant to the goal structure; detect the difference between old and new information given less of the information; to recall baseball text information particularly when the text was comprised of long sequences; produce more overall actions to continue the baseball situation and in particular, more probable actions; and to recall baseball sentences when they were presented with context (other related sentences) even though the context sentences were not provided at recall. According to the researchers, these data suggest that knowledge allows a reader to efficiently encode text (e.g., require fewer words for comprehension) in an organized manner (e.g., making connections among sequences) which in turn facilitates learning (e.g., comprehending a novel game) and remembering text (e.g., more overall and more significant propositions) (Chiesi et al., 1979).

Further research suggests that the beneficial effects of expertise is similar for comprehension and recall processes (Voss, Vesonder, & Spilich, 1980). Using a problem-solving framework, Voss and colleagues studied the effects of knowledge on text processing by having high- and low-knowledge individuals produce baseball narratives and giving these narratives to new high- and low-knowledge subjects for reading and recall. They found that high-knowledge subjects produced narratives that were more detailed in content representation (sequences of actions and state changes) which, the researchers argued, made them more memorable for high-knowledge readers. Voss et al. (1980) proposed that content representations mark the steps required for the solution path which in turn facilitated integration of action sequences necessary for high levels of recall. Whereas high-knowledge individuals had higher recall scores for narratives that were generated by high-knowledge individuals, low-knowledge individuals had higher recall for texts generated by low-knowledge subject (which contained more non-baseball related information). The researchers attributed these findings to the superior ability of high-knowledge subjects to represent a problem space and to better monitor the solution path (e.g., through the use of sequential information present in high-knowledge narratives).
These conclusions are not unlike those from the expertise literature discussed earlier suggesting that the benefits of expertise are attributable to an increased ability to represent the problem space (e.g., Chi et al., 1981; Charness, 1981). Both of these approaches (goal structures and representations of problem space), are congruent with the work of Ericsson and Kintsch (1995) who proposed that retrieval structures can be used in long-term working memory. This type of memory may underlie the expert's superior recall performance. This model is presented in greater detail below.

**Mechanisms Underlying Experts' Text Processing**

The bulk of the evidence suggests that one way in which expertise contributes to higher levels of performance in discourse processing is through a superior ability to represent the problem space in question (Chi et al., 1988) in such a way as to facilitate an understanding of the goal path and to use this to monitor the progress of the narrative (Voss et al., 1980). One way that a reader or listener may be able to achieve this is through long-term working memory (Ericsson & Kintsch, 1995). As mentioned earlier, long-term working memory is a portion of long-term memory that is used to extend working memory capacity. Ericsson and Kintsch (1995) suggested that retrieval structures available to high-knowledge individuals facilitate processing by allowing greater amounts of information to be processed at one time. These structures consist of an elaborate system of retrieval cues that make information available in long-term working memory which can then be used to handle larger amounts of text and facilitate rapid recall from long-term memory.

With this conceptualization, experts would not necessarily have a larger domain-specific processing capacity than novices but rather have a more efficient encoding and retrieval system. Consistent with this is the finding that expert performance is accomplished without a change in processing capacity. Fincher-Kiefer, Post, Greene, and Voss, (1988) had high- and low-knowledge subjects perform domain-related and neutral reading spans comprised of sentences that varied in connectedness. They found that high-knowledge individuals had higher spans for domain-related sentences but not for neutral sentences thus suggesting that expertise does not entail a change in raw capacity. These researchers attributed their findings to the experts’ ability to construct an organizational structure which guides recall. However, this
advantage only occurred when subjects were required to recall the sentences (as opposed to simply reading them) suggesting that experts' performance is dependent upon task demands.

In contrast to the idea that expertise lightens processing load, some researchers suggest that the use of knowledge is resource-consuming. In order to assess availability of resources, Britton and Tesser (1982) measured performance on a secondary task that required subjects to monitor the presentation of clicks while performing a primary task. High-knowledge individuals were defined as those who had read prior related text and low-knowledge individuals were those who had not. The researchers found that high-knowledge readers performed more poorly on the secondary task than did low-knowledge readers, suggesting that knowledge is resource-consuming. It is possible, however, that the reading manipulation failed to provide a sufficient base of knowledge and therefore the high-knowledge readers may have been expending resources to learn the relatively new material. That is, knowledge is not more resource-consuming but rather having more (relatively unfamiliar) information to integrate is.

Research addressing the effects of knowledge on on-line reading has also shown benefits associated with knowledge. Sharkey and Sharkey (1987) had subjects read short stories, frame-by-frame, on a computer at their own pace where each frame contained either the first half or the second half of a sentence. The passages ended with a sentence that either contained a word that was highly suggested by the previous text or was not (based on a previous study). To determine whether facilitation occurs before the sentence end or at the sentence end, the researchers manipulated the frame in which the target word appeared. The researchers also assessed two intrasentence locations by placing target words at midsentence or at the end of a clause and found that facilitation of knowledge occurred only at the ends of sentences.

Thus the evidence, although far from conclusive, suggests that expertise may have advantageous effects on discourse processing through the following route: easier access to concepts in long-term memory facilitates the construction of a high-level representation (e.g., retrieval structures) of text which, in turn, guides the interpretation and later recall of text. Specifically, knowledge facilitates encoding by decreasing the demands of wrap-up processes, for example, text integration, referent search, and ambiguity resolution (Kintsch & van Dijk, 1978).
Aging Experts and Discourse Processing

Given the evidence to suggest that expertise facilitates discourse processing, the next question is whether or not these advantages change in later adulthood. One way to consider how the effects of knowledge may differ for old and young experts is in terms of age differences in the use of schematic information. Hess (1990; see also Light, 1992) reviewed research on schemas, defined as "organized mental representations of generic knowledge concerning specific domains or classes of events" (p. 104), and their impact on age-related differences in memory performance. In his review of the literature, Hess evaluated the effects of schemas in terms of meaningfulness (the degree to which the information is salient to the schema) and integration (the extent to which schematic information is integrated into a memory trace) and concluded that the meaningfulness of stimuli facilitates memory of young and old to a similar extent, and that both age groups tend to integrate schematic information into memory traces to similar degrees. However, Hess also found evidence to suggest that age negatively affects memory for information that is novel or irrelevant to the schema and suggests that the processing resources of younger adults, unlike those of the elderly, are ample enough to integrate this type of information into the schema. This inability to integrate new or irrelevant information suggests that older adults rely more heavily on schemas to process information than do younger adults (Stine-Morrow et al., 1996; Wingfield, Aberdeen, & Stine, 1991).

Further evidence suggesting that older adults benefit from prior knowledge can be found in a study assessing the effects of familiarity on text processing (Hultsch & Dixon, 1983). Hultsch and Dixon (1983) had older, middle-aged, and younger adults read biographical sketches about famous entertainers who were either well-known within their generation, not well-known to individuals within their age group, or well-known across generations. Younger adults outperformed the older groups in the number of proposition recalled for the across-age story and the "young" story. However, the older adults recalled more from the "old" story than the other two groups indicating that pre-experimental knowledge is an important factor in immediate text recall.

In sum, the research reviewed above suggests that knowledge helps to preserve discourse processing skills in later adulthood. The following experiments are designed to investigate the extent of this
preservation, possible mechanisms underlying the beneficial effects of knowledge, and possible strategy shifts that enable older adults to compensate for their declining working memory capacity.
EXPERIMENTS

Four experiments are presented. In Experiment 1, the effects of knowledge, as manipulated by the presence of passage titles, on on-line reading strategies of young and older readers were explored, as was the quality of that processing as assessed by gist recall performance. In Experiment 2, the effects of knowledge were explored via a listening paradigm that more specifically addressed the chunking mechanisms underlying young and older adults' discourse processing strategies. In the third experiment, the effects of task demands on the benefits of knowledge were investigated. Lastly, in Experiment 4, the generalizability of these findings to an instance of real-world expertise within the domain of cooking was investigated.

Experiment 1:

Effects of Age and Knowledge on On-line Reading Strategies

One form of knowledge that can aid in discourse processing is a situation model (or schema) of text that guides encoding and facilitates recall (Ericsson & Kintsch, 1995). In this experiment, the availability of this schema, and hence, knowledge was manipulated by supplying the title of an ambiguously written text as originally done in a study by Bransford and Johnson (1972) (see also Moravcsik & Kintsch, 1993; Arbuckle, Vanderleck, Harsany, & Lapidus, 1990; Alba, Alexander, Hasher, & Caniglia, 1981). Bransford and Johnson investigated the effects of schemas on encoding and retrieval processes by presenting passages that were comprised of vague, seemingly disjointed sentences when the title of the passage was not provided. However, when the title was provided, the passages were coherent. For example, a portion of one passage was "It is important not to overdo any particular endeavor. That is, it is better to do too few things at once than too many. In the short run this may not seem important, but complications from doing too many can easily arise." in reference to the process of washing clothes and separating laundry into appropriately-sized loads in order to avoid damaging the washing machine. The researchers found that the schematic knowledge provided by the titles significantly increased comprehension and recall. This technique was used in the present study to assess the benefits of this type of knowledge on the reading and recall performance of young and older readers.
If knowledge provides retrieval structures that facilitate encoding and retrieval (Ericsson & Kintsch, 1995), then passage titles should lighten the processing load of reading and enable participants to achieve higher levels of recall than those without titles. For example, the knowledge provided by passage titles should enable readers to more easily and accurately assign referents, resolve ambiguity, and integrate and organize propositions into meaningful units of text. To illustrate, the knowledge that the above passage refers to washing clothes would facilitate assigning "attempt to clean a load of laundry" to "endeavor." As Sharkey and Sharkey (1987) found, the effects of knowledge should be evident on on-line reading strategies such that those who read passages with titles, "high-knowledge (HK) readers" should have dampened wrap-up peaks than would "low-knowledge (LK) readers." Older LK readers should be at a particular disadvantage without a situation model to guide processing (cf. Hess, 1990) and thus would show even more exaggerated peaks because of their reduced working memory capacity. Additionally, the presence of retrieval structures should enable readers to spend less time early on in the passage to set up a situation model. The effects of knowledge on contextual facilitation would be evident in a dampened serial position effect which reflects the relative change in reading rate across the passage. An informative way to consider these age-related changes in reading strategy is in terms of resource allocation.

Resource Allocation and Outcome

While the time readers allocate to text is commonly used to investigate the processes involved in reading, this methodology relies on the assumption that readers press the "continue" button only when they have understood the word. Just and Carpenter (1980) refer to this as the eye-mind assumption. Because the accuracy of these reading times is less certain than are those associated with reaction times from a lexical decision task, for example, it is informative to include a measure of outcome to index the effectiveness of reading. Therefore, the present experiment included a recall measure to investigate differences between those who were more or less successful readers (cf. Stine, 1990).

Interesting age differences in the reading strategies have been found, particularly when subsequent recall performance is considered. For example, Stine et al. (1995) found that older adults with high recall spent more time integrating concepts at intrasentence boundaries than did either their low-recall counterparts or younger readers. The researchers suggested that this pattern of pausing after shorter
segments of text reflects an adaptive shift in reading strategy that places fewer demands on working memory than would one involving larger segments (i.e., sentence boundaries). Thus, if a lack of knowledge is particularly challenging for older adults, LK older readers may adopt this strategy.

There are also differences in the serial position effect which, as described above, reflects the tendency to read more slowly at the beginning of a passage than at the middle or end. This variable reflects the reader's attempt to establish a situation model early in the passage, which then facilitates subsequent reading. In general, this effect has been found to be more pronounced among older adults, however, it is even more pronounced among successful older adults (Stine-Morrow et al., 1996). It seems likely that, in general, knowledge would decrease the time necessary to build a situation model. If older adults are capable of benefiting from this knowledge, younger and older adults should show similar decrements in the serial position effect.

Thus, the effects of knowledge on both conceptual integration and contextual facilitation were explored among readers who were either above or below average in subsequent memory performance. The overall predictions were that (1) knowledge would have beneficial effects on reading in terms of faster reading rates overall, less time performing wrap-up, and less time setting up a situation model; (2) to the extent that knowledge can mitigate processing declines (Clancy & Hoyer, 1994; Morrow et al., 1994), older adults would be expected to take particular advantage of knowledge as would be reflected in differentially larger wrap-up peaks among successful older readers lacking knowledge; (3) to mitigate demands on WM, conceptual integration should be most evident at intrasentence boundaries among older adults as these locations represent smaller units of text; (4) to the extent that older readers are able to take advantage of knowledge in situation model construction, they should show the same contextual facilitation (serial position effect) as the young.

Methods

Subjects. Fifty elderly subjects (ages 60-81, M=70.2) were recruited from the Seacoast community of New Hampshire and from among university alumni and 50 younger subjects (ages 17-35, M=19.0) were recruited through the university introductory psychology laboratory subject pool. As is representative of this region of the country, the vast majority of participants were Caucasian. The older
volunteers were paid $10 for participation and the younger subjects were given class credit. All subjects were screened for health-related limitations such as stroke, Parkinson's disease, and cataracts. Subjects were first administered individual-difference measures consisting of the digit span (forward and backward) and the vocabulary subscales of Wechsler Adult Intelligent Scale (WAIS) and reading and listening versions of a Daneman and Carpenter (1980) style sentence-span measure (Stine & Hindman, 1994) which were averaged to yield a single index of working memory (WM) capacity, called average sentence span.

Subjects within each age group were randomly assigned to either an HK group that was given the topic of the passage or to a LK group that was not. To verify that randomization produced Knowledge groups that were otherwise equivalent, each individual-difference measure was entered into an Age x Knowledge ANOVA. Neither the main effect of Knowledge nor the interaction of Age x Knowledge was significant, therefore only the Age effects are reported. For both the forward and backward digit spans, the effects of Age were nonsignificant, F<1, for both. However, older adults had an advantage in terms of years of education (M=13.6, SE=0.1; M=16.0, SE=0.3 for young and old respectively), F(1,94)=60.24, p<.0001, and WAIS vocabulary (M=51.3, SE=1.0; M=60.9, SE=0.1 for young and old respectively), F(1,94)=55.88, p<.0001. Younger adults performed significantly higher on average sentence span (M=4.9, SE=0.1; M=4.3, SE=0.1 for young and old respectively), F(1,94)=9.26, p<.01.

Materials. Two passages (one describing a man serenading a woman from the foot of a high rise and the other describing the procedure of washing clothes) were taken from Bransford and Johnson (1972) and two passages (one describing Columbus' discovery of America and one describing the first space voyage) were taken from Dooling and Lachman (1971). In order to have four experimental passages and one practice passage (the "serenading" story), a fifth passage (describing how to drive a car), written in style similar to the others, was included (see Appendix A).

Experimental materials ranged in length from 77 to 157 words. A text-base representation (Kintsch & van Dijk, 1978) for each was constructed; passages ranged from 36 to 51 propositions, and the total number of propositions for the four texts was 179. Syntactic analyses were performed to identify linguistic constituents. Intrasentence boundaries were defined as words at the ends of clauses as well as prepositional, adjectival, adverbial, verb, and noun phrases and were often marked by the presence of a
comma. These boundaries were defined at the smallest phrasal unit possible (i.e., lowest in the tree diagram) providing they consisted of more than one word.

**Procedures.** All subjects read the same four passages, using the "moving window" method (Just, Carpenter & Wooley, 1982) through MacLaboratory (Chute, 1994) computer software. In this way, subjects read passages word-by-word such that one word at a time appeared on the screen (i.e., all previous words disappeared) and the subject paced the rate of word presentation by pressing a key on the keyboard. The first word of each passage was preceded by a fixation point to guide the subject's gaze prior to the presentation of the text. Reading times were measured on-line (in milliseconds) for each word. Subjects were instructed to read the passages "at a normal reading rate" and told that they would be asked to recall each passage immediately after reading it. At the end of each passage, subjects were prompted to recall aloud as much as they could from the preceding passage (verbal protocols were chosen because they required less effort than would written protocols). Recall protocols were tape-recorded and later transcribed. Prior to the test trials, subjects were given a practice passage (with or without the title depending on whether they were in the HK or LK condition) to help them become comfortable with the procedure. Subjects took roughly 50 to 75 minutes to complete the experiment.

**Results**

**Recall Performance.** Recall protocols for each passage were scored for number of propositions using a gist criterion (Kintsch et al., 1975; Turner & Greene, 1978). Twenty protocols were randomly selected with the restriction that five were drawn from each the four age-knowledge groups for independent scoring. The correlation between the two scorers for total propositions recalled was .974.

The total number of propositions recalled across the four passages was entered into a 2(Age) x 2(Knowledge) ANOVA. As expected, HK readers recalled more (M=43.65, SE=2.61) than did LK readers (M=32.12, SE=2.63), F(1,93)=9.43, p<.01, however, there were no age differences in the number of propositions recalled (M=37.84, SE=2.60 versus M=37.32, SE=2.88, for young and old, respectively), F(1,93)<1, nor was there an interaction between Age and Knowledge, F(1,93)<1. These data indicate that the situation models available to HK readers facilitated subsequent recall and that this facilitation was similarly available to both young and elderly readers.
A qualitative assessment of recall was performed using relative memorability analyses in which each proposition was plotted in terms of the proportion of older readers who recalled the proposition relative to the proportion of the young who recalled the same proposition (Stine & Wingfield, 1988). The resulting slope coefficient is informative in that it reflects the relative degree to which older adults remember the more memorable units of text (as indexed by the young group) and hence to what extent older adults organize and select text propositions in memory in same way as the young. A slope of greater than unity indicates that older readers are recalling more memorable, and presumably more central, ideas and forgetting details; a slope of unity indicates that both age groups are recalling idea units similarly; and a slope of less than unity indicates that the older adults are recalling details at the expense of central ideas and thus are failing to effectively organize the text. Relative memorability analyses in this case yielded significantly different slope coefficients for HK (.81) and LK (.67) readers, t(177)=1.80, p<.05. These data show that although there were no quantitative age differences in recall, older LK readers recalled relatively more of the less memorable ideas and fewer of the more memorable ideas than did older HK relative to their younger counterparts. These qualitative analyses support the notion that knowledge among elderly readers provides retrieval structures with which to organize text.

Because one goal of the present study was to contrast the reading strategies of those who were more or less successful on subsequent memory performance, a median split (within knowledge group) on recall was calculated to determine whether those who scored high on recall differed in their reading strategies from those who did not. First, to determine whether these two groups differed on individual-difference measures as well, Age x Knowledge x Recall Group ANOVAs were performed on average sentence span, vocabulary, and education. High-recall subjects scored significantly higher than low-recall subjects on the average sentence span (M=5.06, SE=0.2; M=4.27, SE=0.1 for high and low-recall subjects, respectively), F(1,89)=20.48, p<.001, MSe=.80, and vocabulary (M=58.3, SE=1.1; M=54.1, SE=1.1), F(1,89)=14.33, p<.001, MSe=33.50. There was also an interaction between Knowledge and Recall Group on vocabulary, F(1,89)=9.33, p<.01, MSe=33.50, such that among HK individuals, those with high recall scored higher on vocabulary (M=60.3, SE=1.3), than did those with low recall (M=51.6, SE=1.4), however, among LK individuals, this difference was nonsignificant, (M=56.5, SE=1.6 for high recall and M=56.3,
Lastly, there were significant differences in years of education between the two recall groups (M=15.2, SE=0.3 for high-recall subjects; M=14.4, SE=0.2 for low-recall subjects), F(1,89)=5.21, p<.05, MSe=2.46. (To insure that these differences were not responsible for findings reported below, the analyses described below were also conducted with education, vocabulary and average sentence span as covariates; no differences in the pattern of findings for either covariate were found, therefore only the simpler analyses are reported.)

**Group Differences in Reading Strategy (Raw RTs).** Reading times (RT) less than 150 msec were removed from the data (a conservative estimate of invalid reading times, given simple RTs are at about 300 msec). Outliers that were five standard deviation units above the median for that word within each age-knowledge group were replaced with this maximum value. Medians for each subject were then calculated separately for intrasentence-boundary, sentence-boundary, and nonsentence-boundary words. However, due to excessive replacements of the data (greater than 25%), two elderly subjects were dropped from further analyses (having 39% and 63% of their data replaced). This resulted in an average of 3.2% of the data being dropped or replaced across all remaining subjects. The final sample used in all analyses (including the individual-difference measures reported above) included 24 young HK, 26 young LK, 23 older HK, and 25 older LK readers.

Reading times (msec) were analyzed in a 2(Age) x 2(Knowledge) x 2(Recall: high, low) x 3(Location: intrasentence-boundary, sentence-boundary, nonboundary) ANOVA with Location as a within-subjects factor and Age, Knowledge, and Recall as between-subjects variables. Figure 1 shows the median reading time at different locations as a function of Age, Knowledge, and Recall Group. As predicted, there was a main effect of Age (M=535, SE=18, and M=653, SE=35, for young and old, respectively), F(1,89)=6.32, p<.05, MSe=275,296.04, showing that, overall, younger adults read more quickly than older adults. Also, there were main effects of Knowledge, with LK readers taking longer to read than HK readers (M=619, SE=31, and M=564, SE=25, for LK and HK readers respectively), F(1,89)=7.79, p<.01, MSe=275,296.04, and for Recall Group, with high-recall subjects taking longer to read than low-recall subjects (M=663, SE=31, and M=526, SE=24 for high and low-recall subjects respectively), F(1,89)=26.74, p<.001, MSe=275,296.04. This suggests that LK readers were slower than HK readers...
because they lacked the facilitative effects provided by the title and a corresponding schema. Further, because those with higher recall scores took more time to read, it seems likely that it was in part this extra time that enabled them to produce high recall. This is particularly interesting in light of the fact that high-recall subjects were also supported by a greater WM capacity and higher verbal ability. Thus, even though these readers were presumably capable of fast and efficient processing at the componential level (Salthouse & Babcock, 1991; Stine & Hindman, 1994), these high-recall subjects allocated more time to reading, and not less, as would be predicted by a simple capacity notion of working memory (cf. Stine, 1995). In addition, there was one significant between-group interaction, Age x Recall Group, showing that older high-recall subjects allocated especially more time to the text as a whole, F(1,89)=5.67, p<.05, MSe=275,296.04.

Finally, there was a main effect of Location: on average, readers allocated more time to sentence-boundary (M=859, SE=64) than to intrasentence-boundary (M=676, SE=34) words and more time to both of these words than to nonsentence-boundary words (M=577, SE=19), F(2,178)=39.77, p<.001, MSe=54,417.79 (confirmed by post hoc analyses). This finding was as expected given that boundary sites are locations at which integration and organization of linguistic constituents occur.
Figure 1. Reading time allocation to sentence, intrasentence, and nonboundary locations as a function of recall group, knowledge, and age.

Low Recall

High Knowledge

Low Knowledge

High Recall

High Knowledge

Low Knowledge

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These main effects were moderated by several interactions. The interaction between Recall and Location was significant, $F(2, 178) = 24.07, p < .001$, $MSe = 54,417.79$, such that the boundary effects (the median reading times for sentence- or intrasentence-boundary words minus nonboundary words) for high-recall subjects (518 msec for Sentence Boundary, 171 msec for Intrasentence Boundary) were significantly larger than those of low-recall subjects (69 msec for Sentence Boundary, 32 msec for Intrasentence Boundary). Thus, high-recall subjects showed greater boundary effects at the ends of both clauses, $F(1, 89) = 13.66, p < .001$, $MSe = 17,435.21$, and sentences, $F(1, 89) = 25.68, p < .001$, $MSe = 97,252.30$. These data support the contention that high-recall subjects were engaged in organizational processing at boundary locations which later facilitated recall.

As predicted, the interaction between Knowledge and Location was also significant, $F(2, 178) = 7.41, p < .01$, $MSe = 54,417.79$, indicating that, overall, LK readers had larger boundary effects than did HK readers: while LK readers showed a 391 msec effect at sentence boundaries and a 128 msec effect at intrasentence boundaries, HK readers showed only a 163 msec effect and a 67 msec effect at sentence and intrasentence boundaries, respectively. This difference reached significance for sentence, $F(1, 89) = 7.84, p < .01$, $MSe = 97,252.30$, but not for intrasentence, $F(1, 89) = 3.72, p < .06$, $MSe = 17,435.21$, boundary effects. This finding is generally consistent with that of Sharkey and Sharkey (1987) who also found that knowledge facilitates text integration at sentence boundaries.

This two-way interaction was further moderated by Recall Group in a significant three-way interaction among Recall, Knowledge, and Location, $F(2, 178) = 4.54, p < .05$, $MSe = 54,417.79$, such that the Location by Knowledge interaction was exaggerated among good recallers. In fact, in post hoc analyses, the Knowledge by Location interaction was reliable for higher recallers, $F(2, 84) = 5.48, p < .01$, $MSe = 111,110.29$, but not for low-recall subjects, $F(2, 94) = 2.69, p < .10$, $MSe = 3,765.35$. Thus, it appears that high-recall subjects were more sensitive to text demands than were low-recall subjects.

Most interesting were the significant interactions with Age. First, the Age x Knowledge x Location interaction was significant, $F(2, 178) = 3.43, p < .05$, $MSe = 54,417.79$, suggesting that although young LK readers had to increase reading times at boundary locations, older LK readers had to do so to an even greater extent. When effectiveness of processing was considered, this trend was even more
pronounced. The Age x Knowledge x Recall x Location interaction (plotted in Figure 1), $F(2,178)=4.58$, $p<.05$, $MSe=54,417.79$, indicates that old LK readers who were high-recall subjects had exaggerated sentence- and intrasentence-boundary effects. Post hoc analyses within Recall Group indicated that for higher recallers, the Age x Knowledge x Location interaction was significant, $F(2,84)=3.70$, $p<.05$, $MSe=111,110.29$, whereas for low-recall subjects, it was not, $F<1$. For these proficient recallers, responsiveness of reading times to the text demands was most pronounced among the elderly LK readers. Thus, these results suggest that successful older adults take disproportionate advantage of knowledge in discourse processing such that the presence of knowledge enables older adults to perform similarly to younger adults. Without this support, on the other hand, successful older readers must spend more time relative to the young at these processing sites in order to achieve high levels of recall. This is consistent with the notion that knowledge can promote successful cognitive aging by circumventing age-related declines in working memory.

**Individual Difference in Reading Strategies.** The next set of analyses were conducted to explicitly test predictions surrounding age differences in (1) the location of the conceptual integration (older adults were expected to organize more frequently (i.e., at intrasentence boundaries) as a way of circumventing WM limits) and (2) contextual facilitation. Regression analyses were used to estimate how individual subjects allocated reading time to the different features of the text (Aaronson & Scarborough, 1976; Lorch & Myers, 1990; Stine et al., 1995; Stine-Morrow et al., 1996). This approach more directly enabled a test of the prediction surrounding age differences in conceptual integration since conceptual load can vary unsystematically across a text; regression analyses provided a more sensitive estimate of conceptual processing inasmuch as it controls other factors. This analysis also enabled an examination of the hypothesis that the serial position effect would be more pronounced among LK readers and that, providing older adults take advantage of knowledge, this pattern would be constant across age.

Each word ($n=451$) was coded in terms of: (1) number of letters (Ltrs), (2) word frequency (Thordike & Lorge, 1944) (Word f), (3) whether or not it occurred at the beginning of a new line (NewL), (4) the number of cumulative new concepts occurring at intrasentence boundaries (CCxInt), (5) the number of cumulative new concepts occurring at sentence boundaries (CCxSnt), and (6) serial position of the word.
within the passage (SP). Variables (1) and (2) were continuous variables representing the word-level processes of orthographic coding and lexical access, respectively, and (3) was dummy coded (to account for the variance associated with directing attention to the start of a new line). Since conceptual load is the primary factor affecting the time needed to organize and integrate text at boundaries (Haberlandt et al., 1986; Stine et al., 1993), variables (4) and (5) were interaction terms created by multiplying the cumulative number of new concepts introduced up to a given boundary by the dummy coded variable for whether the word occurred at the specified boundary (for this analysis, all sentence-final words counted as both an intrasentence as well as sentence boundaries to be consistent with X-bar syntax theory (cf. Napoli, 1993)). The interaction terms, CCxSnt and CCxInt, represent the extent to which wrap-up processes are demanded by the text (cf. Haberlandt et al., 1986), and were expected to show the effects of knowledge especially if knowledge involves the use of a retrieval structure to rapidly encode and organize new conceptual information (Ericsson & Kintsch, 1995). Variable (6), serial position, was a continuous variable representing how far along the word was in the passage, thus indicating the extent to which time has been allocated early in the passage to build a situation model (Haberlandt, 1984). This model significantly predicted reading times for all subjects except for one younger reader and three older readers.

These independent variables (Ltrs, Word f, NewL, CCxSnt, CCxInt, and SP) were entered (in the order listed, to represent a bottom-up model) into hierarchical regressions with each word's reading time as the dependent measure. These analyses were performed separately for each subject (Lorch & Myers, 1990). The criterion for entry was an alpha level of .05 and nonsignificant predictors were removed if they were no longer significant (p>.1) as new variables were added. The resulting significant coefficients reflected how much time each subject allocated to process various features of the text.

Table 1 presents the mean regression coefficients from the individual regressions. These coefficients, reflecting the relative time allotment to each feature of the text (in msec), were analyzed in a 2(Age) x 2(Knowledge) x 2(Recall Group) x 6((Reading) Process: Ltrs, Word f, NewL, CCxSnt, CCxInt, and SP) repeated-measures ANOVA to determine whether there were group differences in reading-time patterns. A nonsignificant coefficient from an individual regression was treated as a null value in this analysis inasmuch as nonsignificant predictors signify values that are not different from zero. Consistent
with the ANOVA on raw reading times, there were main effects of Recall, $F(1,89)=31.20$, $p<.001$, 
$MSe=2,218.16$, and Knowledge, $F(1,89)=21.28$, $p<.001$, $MSe=2,218.16$, however, there was no effect of 
Age, $F<1$. The within-subjects effect of Process, $F(5,445)=22.69$, $p<.001$, $MSe=3,225.61$, was significant 
simply supporting the observation (albeit not very informative) that resources were differentially allocated 
across features of the text. The Age x Process, $F(5,445)=7.34$, $p<.001$, $MSe=3,225.61$, Knowledge x 
Process, $F(5,445)=4.46$, $p<.01$, $MSe=3,225.61$, and Recall x Process, $F(5,445)=5.25$, $p<.001$, 
$MSe=3,225.61$, interactions were significant indicating that the pattern of reading time allocation varied as 
a function of Age, Knowledge, and Recall Group, respectively. Further, the Age x Knowledge x Process 
interaction, $F(5,445)=2.45$, $p<.05$, $MSe=3,225.61$, was also significant indicating that young and elderly 
readers used different reading strategies as a function of knowledge. The remaining interactions were 
nonsignificant.
<table>
<thead>
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<th>Low Knowledge</th>
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<td></td>
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<td>-0.75 (0.33)</td>
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<tr>
<td>NewL</td>
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<td>72.58 (28.76)</td>
<td>18.25 (10.30)</td>
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<td>13.02 (10.03)</td>
</tr>
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<td>141.35 (30.17)</td>
<td>43.51 (12.66)</td>
<td>97.03 (27.90)</td>
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<td>-0.55 (0.27)</td>
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<tr>
<td>**Old</td>
<td></td>
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To more specifically explore these interactions, post hoc 2(Age) x 2(Knowledge) x 2(Recall) ANOVAs were conducted on the regression coefficients of the six text features. Consistent with earlier work with extended expository texts (Stine-Morrow et al., 1996), there was no age effect for either word-level variable (Ltrs, Word f), nor did knowledge affect the time allocated to word decoding (Ltrs), F<1 for all three analyses. Interestingly, HK readers who could rely on their knowledge to understand lexical items showed a lower word-frequency parameter than did LK readers (M=.52, SE=.12; M=1.47, SE=.25, respectively), F(1,89)=12.24, p<.01, MSe=1.89. Presumably, low-frequency words required relatively less access time for HK readers because their knowledge schema rendered these words more familiar. High-recall subjects seemed to spend more time in word decoding than low-recall subjects, F(1,89)=6.36, p<.025, MSe=206.87, with high-recall subjects allocating 11.31 (SE=2.68) msec per letter and low-recall subjects allocating 4.10 (SE=1.32) msec per letter. High-recall subjects also spent more time accessing (and/or disambiguating) low-frequency words, as shown by the fact that they were more facilitated by word frequency, F(1,89)=4.25, p<.05, MSe=1.89, than were low-recall subjects (M=1.33 msec facilitation per log unit of word frequency, SE=.26, for high-recall subjects; M=.75, SE=.16, for low-recall subjects), suggesting that high-recall subjects were more fully elaborating word meanings (cf. Carpenter & Just, 1989). Not surprisingly, the new line variable (NewL) was not affected by Age, F<1, Knowledge, F(1,89)=1.18, or Recall level, F<1.

The 2(Age) x 2(Knowledge) x 2 (Recall) ANOVA on serial position, an index of situation model facilitation, as predicted, revealed a significant main effect for Knowledge, F(1,89)=5.72, p<.05, MSe=2.43, indicating that LK readers (M=1.49, SE=0.3) increased their reading rate to a greater extent than did HK adults (M=.75, SE=0.2). Presumably, the increase in time allocated at the start of a passage reflects the LK reader's attempt to construct a situation model out of the incoherent text. The main effect of Age, F(1,89)=7.60, p<.01, MSe=2.43, was also significant indicating that elderly subjects had greater contextual facilitation (M=1.59, SE=0.3) than did younger adults (M=.70, SE=0.2). This finding is consistent with past research showing that older readers are equally likely to form a mental model level of representation (Soederberg & Stine, 1995), but that they may require more time to do so (Stine-Morrow et al., 1996). There was also a trend for low-recall subjects (M=.89, SE=0.2) to invest relatively less time
early on in the passage than high-recall subjects (M = -1.46, SE = 0.3), but this main effect of Recall did not reach significance, F(1, 89) = 3.44, p = .07, MSE = 2.43. None of the interactions was significant, indicating that these situation model processes were not differentially affected by the combination of Age or Recall with Knowledge. Thus, these findings are consistent with the prediction that HK readers would differentially benefit from the contextual facilitation that their situation model provided and further indicates that HK older adults do not benefit more than their younger counterparts.

To specifically explore the prediction that older readers process text in smaller units and that this pattern would be more pronounced among LK older readers, a 2(Age) x 2(Knowledge) x 2(Recall) x 2(Location: CCxInt, CCxSnt) ANOVA on resource allocation to conceptual load was conducted. The dependent variable for this analysis represents the amount of time allocated per new concept at each of the two boundary sites (small/intrasentence and large/sentence boundaries) with the effects of other text features partialled out.

Collapsing across Location and Knowledge, there were no age differences, F < 1, suggesting that, overall, young and elderly readers allocated comparable amounts of time to process conceptual load. This is contrary to Stine et al. (1995) in which older adults, on average, showed less conceptual processing, and (unlike in the present study) a measurable deficit in quantitative recall. A more accurate comparison is between HK readers in this study and all readers in Stine et al. (1995). In this case; the data are consistent: older readers spent less time on conceptual processing relative to the young. The main effects of Knowledge, F(1, 89) = 22.70, p < .001, MSE = 5,071.56, and of Recall, F(1, 89) = 26.92, p < .001, MSE = 5,071.56, showed that LK readers (M = 140.20, SE = 20.9) spent more time than did HK readers (M = 48.53, SE = 11.2), and high-recall subjects (M = 151.06, SE = 22.8) spent more time than did low-recall subjects (M = 47.42, SE = 10.1) to process conceptual load. Consistent with the analysis on raw reading times, these data show that knowledge enabled readers to allocate less time to conceptual integration and that high recallers allocated more time to conceptual integration than did less successful readers.

A significant Age x Knowledge interaction, F(1, 89) = 7.15, p < .01, MSE = 5,071.56, showed that the Knowledge effect was more pronounced among older readers (M = 161.44, SE = 36.84, for older LK, and M = 23.95, SE = 9.66, for older HK readers) than it was among younger readers (M = 119.77, SE = 20.73, for
younger LK, and M=72.08, SE=18.97, for younger HK readers). Again, these data support the notion that knowledge differentially facilitates discourse processing for elderly readers. The Knowledge x Recall interaction, F(1,89)=6.56, p<.05, MSe=5,071.56, was also significant indicating that LK readers with high recall (M=221.77, SE=33.30) slowed to a greater extent than did those with low recall (M=67.69, SE=16.96) while this was not the case among HK readers (M=24.61, SE=8.04, for low recall, and M=73.92, SE=21.28, for high recall). Thus, in order to be a successful reader, particularly when faced with reading material outside of one's area, more time is needed to integrate concepts. Although the Age x Recall interaction failed to reach significance, F(1,89)=3.01, p<.09, MSe=5,071.56, the three-way interaction of Age x Knowledge x Recall, F(1,89)=5.48, p<.05, MSe=5,071.56, depicted in Figure 2, was significant. Among low-recall subjects overall, very little time was devoted to conceptual integration, however, among high-recall subjects, time allocation to new concepts was differentially greater for older relative to younger LK readers. These findings are consistent with the analysis of raw reading times in showing that older LK readers spend more time in organizational processing at boundaries, but expand on this finding by showing that this time is allocated specifically to conceptual processing; that is, while partialling our variance contributed by orthographic coding, lexical access, serial position, and beginning a new line.
Figure 2. Regression estimates of total time allocated (msec) per new concept as a function of age for low-knowledge and high-knowledge readers varying in recall level.

**Low Recall**

- **High Knowledge**
- **Low Knowledge**

**High Recall**

- **High Knowledge**
- **Low Knowledge**

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More to the point of the segmentation size, the Location variable assessed the relative differences in time allocated to the smaller units of text (at intrasentence boundaries) versus the larger units of text (at sentence boundaries). The Location effect was significant such that readers allocated more time to sentence boundaries than to intrasentence boundaries, $F(1,89)=7.84$, $p<.01$, $MSe=7,191.57$. However, the Knowledge x Location was nonsignificant; HK and LK did not differ in time allocated across Location. The Age x Location interaction, depicted in Figure 3, was significant, $F(1,89)=15.96$, $p<.001$, $MSe=7,191.57$, indicating that, collapsing across Knowledge and Recall, older readers spent more time per new concept at intrasentence boundaries ($M=55.1$, $SE=14.9$) than did younger readers ($M=7.0$, $SE=3.7$), and conversely, younger readers spent more time per concept at sentence boundaries ($M=89.8$, $SE=13.4$) than did older readers ($M=40.4$, $SE=14.8$). This finding, as predicted, suggests that older readers were "chunking" text into smaller units. This cross-over interaction was not different for LK readers and HK readers, $F(1,89)=1.26$, or for high and low-recall subjects, $F(1,89)=1.15$, $MSe=7,191.57$. Thus, the tendency for successful older readers to allocate resources more frequently to conceptual integration during on-line processing does not depend on knowledge or outcome. Thus, it appears that younger readers, presumably because of their larger working memory capacity (Wingfield et al., 1988), used primarily sentence boundaries for organizational processing of conceptual load whereas older readers used both intrasentence and sentence boundaries. This asymmetry did not depend on the presence of a retrieval structure or the level of subsequent memory performance.

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Figure 3. Regression estimates of resources allocated (msec) per new concept at sentence (CCxSnt) and intrasentence (CCxInt) boundaries as a function of age.
Predicting Recall from Reading Strategy and Individual Differences. Lastly, to determine the relative contributions of reading processes, individual differences, and age on recall, we regressed recall on all six reading-process variables, average sentence span and vocabulary, and age (in this order) for HK and LK readers. Only the conceptual integration variables (CCxInt and CCxSnt) predicted recall for LK readers (Adj. $R^2=.44$), however these variables dropped below significance for HK readers, leaving only vocabulary and age as the significant predictors (Adj. $R^2=.49$). Thus, it appears that reading strategy is most crucial for high recall among readers lacking requisite knowledge whereas individual differences are more important among HK readers.

Discussion

How Knowledge Facilitates Reading. These data show that knowledge facilitates wrap-up for both young and elderly readers which was evident in the reduced processing time at boundary sites by HK readers. Presumably, the retrieval structures possessed by HK readers allowed them a greater level of efficiency in integrating new concepts (Haberlandt et al., 1986), organizing constituents within sentences (Aaronson & Scarborough, 1976), and resolving the potential ambiguities (Daneman & Carpenter, 1980) that these materials were particularly likely to engender. In particular, successful older HK readers showed marked reductions in time to perform wrap-up processes at boundary locations relative to their LK counterparts. Thus, these findings add to the literature surrounding the effects of knowledge on text processing by (1) replicating earlier findings that show younger adults are facilitated by the presence of knowledge at sentence boundaries (Sharkey & Sharkey, 1987), and (2) showing that this facilitation is even greater among successful older readers.

In addition to facilitating conceptual integration, the effects of knowledge were also evident in two other aspects of on-line processing, lexical access and set-up time to construct situation models. First, the effects of knowledge on lexical access were evident in the larger word-frequency parameter of LK readers indicating that they had to spend differentially more time accessing low frequency words. This suggests that, for example, when LK readers encountered the low-frequency word "gems" while reading the passage about Christopher Columbus, they took more time to access the features of meaning for this word in this context than did HK readers who had the requisite knowledge active from the passage title. This is
consistent with research showing that the presence of scripts facilitates word recognition in lexical decision
tasks (Sharkey & Mitchell, 1985). It also seems likely that, due to the ambiguous nature of these passages,
the word-frequency parameter taps into processes associated with post-access integration in addition to
lexical access and is consistent with data showing that context reduces the effects of lexical ambiguity (cf.
Simpson, 1994).

Second, the effects of knowledge were apparent in the construction of situation model
representations as indexed by the serial position effect (the extent to which reading times increased at the
start of a passage relative to the end). The data showing that LK readers had a steeper serial position effect
than did HK readers, suggest that LK readers require more effort than do HK readers to construct a situation
model representation of the text. Consistent with past research, there were age differences in this set-up
time, suggesting that older readers are more likely than are younger readers to allocate time early on to
establish a situation model (Stine-Morrow et al., 1996). More importantly, older readers showed the same
effect of knowledge on this situation model construction.

How Reading Strategies Can Make a Difference in Memory. Another major point made by the
present study concerns the importance of assessing outcomes when investigating reading strategies. In
general, high-recall subjects were more sensitive to text demands as reflected in greater overall reading
times, greater reading-time peaks at boundary locations, and greater time allocation to process conceptual
load. These group differences were particularly evident when considering the effects of age and knowledge.
For example, whereas knowledge had little effect on the reading strategies of older adults with low recall,
older high-recall subjects appeared to adapt their reading strategy when faced with a challenging situation
(i.e., little knowledge to help process disconnected discourse). These older readers, who lacked relevant
background knowledge but were nevertheless able to produce high recall, appeared to be sensitive to text
demands and allocated the necessary resources to wrap-up processes at boundary locations. Conversely,
successful older HK readers spent relatively little time at these sites presumably because they possessed the
relevant retrieval structures (cf. Ericsson & Kintsch, 1995) that facilitated the integration of accumulating
concepts thereby allowing them to circumvent demands on working memory. These findings illustrate the

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high degree of sensitivity a reader must have to the multiple demands of text in order to encode it effectively and to the special role of knowledge in facilitation of discourse processing among the elderly.

Differences between high- and low-recall subjects were also found in lexical processing. High-recall subjects spent differentially more time than did low-recall subjects accessing the meaning of lexical items in context. This time could have been used to more fully elaborate word meanings (cf. Carpenter & Just, 1989), which presumably created a more distinctive memory trace which in turn facilitated subsequent recall. Thus, it seems that increased resource allocation to access (and disambiguate) word meaning is more likely among LK readers who lack relevant knowledge structures because they have to and more likely among readers who subsequently achieve high recall in service to a richer representation of the text.

How Older Readers Compensate for Declining Cognitive Resources. Evidence of compensation can be found by looking at the effects of age and knowledge on on-line discourse processing. Knowledge appears to offset processing declines by facilitating wrap-up processing. That is, although older readers had lower scores on WM measure, they were able to achieve levels of recall comparable to younger readers by allocating more time to overall as well as to process new concepts at the ends of important syntactic constituents. Additionally, older readers showed evidence of greater contextual facilitation (i.e., a stronger serial position effect) than did younger readers.

Another way in which older adults appear to compensate for processing declines is by pausing after smaller units of text (cf. Stine, 1990; Stine et al., 1995). Younger readers, on the other hand, allocated time to process conceptual load at sentence boundaries but spent virtually no time at the intrasentence boundaries. Although there were no effects of domain knowledge on this reading strategy shift, the more frequent pausing among the older readers could be an adaptive way to read given working memory capacity declines (Stine & Wingfield, 1990; Salthouse, 1991).

These data are inconsistent with past research that shows that older adults do not use sentence boundaries for wrap-up processes (Stine, 1990; Stine et al., 1995). Because, in the present study, sentence wrap-up effects were demonstrated primarily in LK older readers, it seems reasonable to attribute these reading strategy differences to ambiguous and incoherent texts. This suggests that chunking among older
readers is sensitive to text demands but that future research is need to determine the extent to which this
tendency is influenced by factors such as text coherence.

Furthermore, there are some older adults who are particularly successful in their ability to
compensate. These readers appear to do two things. First, they take more time overall to read a text, and
second they are sensitive to their lack of relevant domain knowledge. That is, this special group of older
readers who are faced with the challenge of trying to read material for which they lack the relevant
knowledge, allocate even more resources to organize text and process new concepts.

Conclusions. In sum, the present study adds to the literature by suggesting that knowledge
increases the efficiency of discourse processing by facilitating wrap-up, by increasing accessibility to word
meanings, and by reducing the set-up time required for situation model construction. These data also speak
to the importance of assessing outcome when investigating discourse processing in that the benefits of
knowledge were primarily evident for those individuals who had effectively encoded the text (as indexed by
subsequent recall). This finding suggests that sensitivity to text demands may lead to a more solid memory
trace which, in turn, produces better recall. Lastly, successful aging was evident in the finding that 1) the
facilitation of wrap-up processes afforded to HK readers was more pronounced among older readers with
high recall and 2) that older readers, who often have fewer cognitive resources available, allocated
relatively more time to smaller units to accommodate processing declines. These data suggest that one way
that we may age successfully as readers is to compensate for working memory declines by using strategies
in which we take greater advantage of our accumulated knowledge and parse text into smaller units. To
more thoroughly explore these ideas, the next experiment explored the effects of knowledge on chunking.

Experiment 2:

Effects of Age and Knowledge on the Spontaneous Segmentation of Speech

The data from Experiment 1 showed that knowledge facilitates discourse processing by decreasing
the time necessary to perform wrap-up processes at boundary locations and that this advantage was even
more pronounced among the elderly. Contrary to the expectation that knowledge would affect older adults'
use smaller units of text to perform wrap-up, the degree of conceptual integration at intrasentence
boundaries was comparable for both HK and LK older readers. In Experiment 2, chunking strategies were

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further explored in the context of speech processing using a task that is more sensitive to age differences in recall. A more sensitive outcome measure may show effects of knowledge on chunking strategies which might have gone undetected in Experiment 1. The present study investigated text input size and recall through a procedure called spontaneous segmentation (cf. Wingfield & Butterworth, 1984).

Spontaneous segmentation is well suited to the investigation of input size relative to processing effectiveness because it relies on verbatim recall of each segment of text that a subject chooses. Chunk sizes are therefore defined by the listener as opposed to boundaries defined by the experimenter. This task yields two types of data: recall accuracy and segmentation place, both of which can be informative about the effectiveness of parsing strategies. Additionally, speech can be accelerated, providing a more demanding test of subjects’ processing abilities. Thus, if older adults are required to process incoming speech that is ambiguous and incoherent and are also asked to do so under the more taxing conditions of accelerated speech, the presence of knowledge may then lead to age differences in chunking strategy.

This methodology was used originally to investigate parsing strategies in young adults. Wingfield and Butterworth (1984) instructed young adults to listen to connected speech and to interrupt the tape so as to recall verbatim what they had just heard. Because subjects tended to segment text at syntactically coherent boundaries, they concluded that listeners must be able to predict the end of the chunks in order to stop the flow of speech at meaningful locations that would accommodate WM limitations. Also, the researchers found that when speech was heard without its normal prosody, high performance was linked to smaller segmentations. More recently, listeners have also been found to segment text into smaller units when the speech is less predictable (Wingfield & Lindfield, 1995). Because subjects changed their segmentation strategy in relation to the content of speech, the authors saw this as support for the existence of an immediate conceptual memory trace that co-occurs with a phonological memory trace (Potter, 1993). The presence of knowledge structures could conceivably affect either or both levels of representation: (1) knowledge could enhance conceptual short-term memory which would facilitate parsing strategies; (2) knowledge could enhance phonological memory to the extent that retrieval structures provide top-down processing support when stimuli are degraded (cf. Cohen & Faulkner, 1983) as could be experienced by LK listeners.
Age differences in speech processing have been investigated with the spontaneous speech segmentation procedure by manipulating variables such as speech rate, which taxes the processing system, and prosody, which facilitates speech perception. Rapid speech has been found to decrease subjects' ability to segment text into recallable chunks and this is particularly true for older adults (Wingfield & Stine, 1986). Prosody, defined as a collection of features including contour, stress, timing, and absolute pitch, has been found to differentially facilitate the production of recallable chunks for elderly listeners (Wingfield, Lahar & Stine, 1989). Age differences in recall are even more pronounced under the difficult conditions of speech devoid of syntactic and semantic structure (Wingfield et al., 1989).

If, as in some studies involving reading (Stine et al., 1995) and chess (Charness, 1981), successful older adults compensate for declining working memory capacity by taking smaller meaningful chunks of information, then this might be evident in how older listeners, who lack the support of knowledge, segment the flow of text. Some data show that older adults segment text into the same sizes (number of words), on average, as do younger adults (Wingfield et al., 1989; Wingfield & Lindfield, 1995). On the other hand, when the linguistic quality of the segments (i.e., place of segmentation) is considered rather than simply the number of words selected, age differences appear. Under the difficult conditions of speech devoid of prosody, older adults tended to stop the flow of text at boundaries following smaller syntactic units (Wingfield et al., 1989), however, these age differences were not present when the support of prosody was available. Similarly, age differences occur when texts were low in predictability but not when they were high in predictability (Wingfield & Lindfield, 1995). Thus, it appears that under more difficult circumstances, older adults shift to a smaller chunking strategy and suggests that the absence of knowledge may also have this effect on older listeners.

Although the place of segmentation may show age constancy under normal listening conditions, recall accuracy is consistently below that of younger adults, and this is particularly true when texts are less than optimal (Wingfield et al., 1989; Wingfield & Lindfield, 1995). An informative way to assess recall accuracy is to plot the number of words correctly recalled within each segment size. The extent to which the slope of the resulting line is less than unity (i.e., perfect recall) reflects a deterioration of recall relative to the segment size selected. Because of the wide variability in selected segment sizes, this type of analysis

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is more sensitive to the effectiveness of segmentation strategies than is an analysis in which overall accuracy is evaluated without consideration to segment size (cf. Wingfield & Lindfield, 1995). Thus, the spontaneous segmentation procedure is sensitive to age differences in verbatim recall relative to segment size and, therefore, lends itself well to studying the effects of knowledge on chunking processes.

These data suggest that linguistic support, such as prosody, and semantic support, such as predictability, lessen task demands as indexed by older listeners' ability to accurately recall increasingly longer segments. Thus, knowledge may also provide support that would differentially benefit older listeners. This could occur in at least two ways. First, knowledge may facilitate the phonological memory trace of older listeners which would enable them to take a variety of segment sizes and to recall them well, even the larger segments. That is, as was the case in Experiment 1, knowledge would simply allow the older adults to behave like younger adults without accruing the associated costs experienced by older LK listeners. The effects of knowledge on spontaneous segmentation would be evident in the slope parameter representing recall as a function of segment size. If the retrieval structures provided by knowledge enable older adults to recall verbatim text like the young do, young and older HK listeners should have similar slope coefficients. Older LK listeners, on the other hand, should have smaller slope coefficients than their younger counterparts who have ample WM to deal with large chunks of text even when knowledge is lacking. Additionally, the retrieval structures provided by knowledge may facilitate the conceptual memory trace of older listeners by allowing them to predict more suitable stopping places. However, to the extent that a conceptual trace is resistant to the effects of aging (Wingfield & Lindfield, 1995), this facilitation may only be evident when task demands are increased by accelerating the rate of speech presentation. This prediction would be supported by older HK listeners using a parsing strategy that includes more syntactically-based stopping places than would their LK counterparts particularly when speech rates are accelerated.

In summary, if retrieval structures facilitate encoding and lighten the processing load of speech processing, knowledge should facilitate speech processing of older listeners. This could occur in at least two ways: 1) at the phonological level, knowledge could allow older adults to circumvent WM declines and select increasingly larger segments of text than their LK counterparts without corresponding recall.
decrements; 2) at the conceptual level, knowledge could provide top-down support which would guide the selection of more syntactically meaningful units of text. Both predictions are consistent with Wingfield and Lindfield (1995) who found that predictability differentially facilitated older listeners' verbatim recall and parsing strategies.

Methods

Subjects. Eighteen elderly subjects (ages 61-79, M=68.8) were recruited from the community and from among university alumni and 18 younger subjects (ages 17-29, M=19.0) were recruited through the university introductory psychology laboratory subject pool. Compensation was in the form of $10 for the older volunteers and laboratory credit hours for the younger subjects. All subjects were screened for health-related limitations. As in Experiment 1, the vocabulary test, and the forward and backward digit spans of the Wechsler Adult Intelligent Scale (WAIS) were administered and the average sentence span was computed from reading and listening sentence spans (Daneman & Carpenter, 1980). While younger adults scored significantly higher on average sentence span, F(1,31)=9.55, p<.01, (M=5.13, SE=0.2, for young; M=4.09, SE=0.2 for old), older adults had an advantage in terms of years of education, F(1,31)=11.92, p<.01, (M=13.3, SE=0.2; M=15.4, SE=0.6 for young and old respectively) and vocabulary, F(1,31)=47.8, p<.001, (M=48.8, SE=1.4; M=61.7, SE=1.2 for young and old respectively). There were no age differences in either the Forward, F(1,31)=2.54, p=.12, or Backward digit spans, F<1. This profile was similar to that of the first Experiment.

Materials. All four passages from Experiment 1 were used in the present study. Each was read aloud by the experimenter at a normal speech rate and with normal prosody and digitally recorded by SoundEdit PRO software (MacroMind, 1992) into a Macintosh Iici. In addition, each passage was time compressed to 60% of its original length, resulting in an accelerated speech rate (300 wpm) version of each passage. Four conditions were constructed by randomly pairing the four passages to create two blocks which were then counter balanced such that each appeared in both positions and at both speech rates.

Procedures. To parallel the procedures used in Experiment 1, both young and elderly subjects were randomly assigned to a Knowledge group which was manipulated by the presence of passage titles (presented on a sheet of paper). The general instructions followed traditional speech segmentation
methodology (cf. Wingfield & Butterworth, 1984) except that, in the present study, a gist recall task was included at the end of each passage to parallel Experiment 1. Subjects were first introduced to the dual tape recorder on which the passages were presented and were shown how to play the tape in order to listen to the recorded passages. Subjects were shown that the tape deck was already in the play mode and were instructed to press the play/pause toggle button in order to listen to, and pause, the passages. They were instructed to press the play/pause button to stop the tape at any place they wished in order to provide verbatim recall of the text they just heard. In this way, subjects only needed to press one button throughout the task. To minimize the occurrence of "shadowing," subjects were instructed not to begin recalling the passage until they had paused the tape. To help subjects become comfortable with the procedure, they were given one fast and one normal practice passage (with or without the title depending on whether they were in the HK or LK condition). Recall protocols were tape-recorded using a Gemini PMX-12A sound mixer to record both subjects' recall and the corresponding passage segments for ease of transcription. To be consistent with Experiment 1, subjects were also asked to perform a second recall task: to recall everything they could about the passage they just heard. In order to avoid competition with their primary, verbatim recall task, the overall gist recall task was referred to as a secondary goal.

Because the first two older subjects failed to follow the instructions (even though they performed satisfactorily during the practice), the experimenter sat in the experiment room with all subsequent subjects to monitor task performance (these two elderly subjects were replaced). This insured that subjects remembered to stop the tape before speaking and to produce their overall recall before continuing on to the next passage. Additionally, the data from one older subject was thrown out due to his serious difficulty with the task which resulted in three out of the four passages being skipped altogether (i.e., the subject failed to pause the tape until the end of the passage). Lastly, two protocols were incomplete (one out of four passages was omitted for one old and one younger subject) due to equipment failure (pause button failed to "catch." These data were treated as missing. The resulting sample consisted of 9 young LK listeners, 9 young HK listeners, 8 elderly LK listeners, and 9 elderly HK listeners.
Results and Discussion

Segment Size. The average segment size selected by each subject for fast and normal passages was entered into a 2(Age) x 2(Knowledge) x (Speech Rate) repeated measures ANOVA with Speech Rate as the within-subjects variable. Consistent with past research (Wingfield & Stine, 1986; Wingfield & Lindfield, 1995), the average segment size selected was similar for both young and older listeners as reflected in a nonsignificant effect of Age, F<1. This suggests that these older adults were not sensitive to working memory limits in that they were choosing similar segment sizes. Knowledge also had no affect on segment size, F<1, which was somewhat surprising given that text difficulty, as manipulated by syntactic structure, prosody (Wingfield et al., 1989), and predictability (Wingfield & Lindfield, 1995), all had an effect on the average segment size. This prior research suggests that LK listeners should have taken smaller segments on average than HK listeners. Perhaps, as one subject observed, LK individuals listened to more words believing this would clarify the meaning of the text. If this were the case, this should be evident in lower recall for the larger segments that exceed WM limitations, which (as discussed below) appeared to be the case. The interaction of Age x Knowledge was also nonsignificant, F(1.31)=2.22, ns. The effect of Speech Rate on average segment size was significant, F(1.31)=4.77, p<.05, MSe=2.40, with fast passages leading to larger segments (M=8.9, SE=.45) than normal passages (M=8.1, SE=.40). Presumably, this is because faster speech allowed less time to process information and make predictions about where to segment the text. These data are consistent with those showing that faster rates cause the selection of larger segments (Wingfield & Stine, 1986; but see Wingfield & Lindfield, 1995). The effects of Speech Rate were constant across Age and Knowledge as reflected in a nonsignificant Age x Knowledge x Speech Rate interaction, F<1. Thus, it is likely that accelerated speech interfered with subjects' ability to select recallable segment sizes and this was true across Knowledge and Age.

To explore the possibility that the effects of Knowledge differentially impacted Age and Speech Rate, posthoc ANOVAs were conducted separately for HK and LK listeners. In the LK analysis, Age was nonsignificant, F<1, as was Speech Rate, F<1. However, as depicted in Figure 4, there was a significant Age x Speech Rate interaction, F(1.15)=10.84, p<.01, MSe=.00, reflecting a tendency for the elderly to increase segment sizes for fast passages whereas the young remained constant. Thus, the performance of
older LK listeners appeared to fall apart when processing demands increased in that they selected larger segment sizes. In the analysis on HK listeners, Speech Rate once again had no influence, $F(1,16)=2.00$, and this true across Age, as shown by a nonsignificant Age x Speech Rate interaction, $F<1$. However, older adults took significantly smaller chunks ($M=8.08, SE=.66$) than did younger subjects ($M=9.20, SE=.98$), $F(1,16)=4.68, p<.05, MSe=.01$. These data suggest that knowledge serves to enhance short-term conceptual memory among older adults by enabling them to encode the meaning of a segment given less information which would be advantageous for older adults with diminished processing resources. Furthermore, this advantage held for fast, as well as normal, speech rates. This finding is reminiscent of research showing that, relative to their LK counterparts, HK individuals required less of the stimulus material to be able to detect the difference between old and new information (Chiesi et al., 1979).
Figure 4. Average segment size as a function of age and speech rate for LK individuals.
Passage Recall. Recall protocols were scored in terms of the number of propositions correctly recalled using a gist criterion (Turner & Greene, 1978) and the proportion of propositions recalled for each passage was computed. Subjects received two gist recall scores; the mean of two passages presented at the fast speech rate and the mean of those presented at the normal speech rate. The overall propositional recall levels were low, ranging from .00 to .24. Passage recall scores were entered into a 2(Age) x 2(Knowledge) x 2(Speech Rate) repeated-measures ANOVA with Speech Rate as the repeated measure. There was no effect of Age, $F(1,31)=2.58, p=.12$, however, there was an effect of Knowledge, $F(1,31)=6.30, p<.05$, $MSe=.01$, such that LK listeners ($M=.07, SE=.01$) had lower recall than did HK listeners ($M=.11, SE=.01$). Thus, consistent with Experiment 1, knowledge facilitated recall and this was constant across Age as reflected in a nonsignificant Age x Knowledge interaction, $F<1$. Speech Rate had an effect on passage recall, $F(1,31)=4.23, p<.05, MSe=.00$, with passages spoken slowly being more recallable ($M=.1, SE=.01$) than those spoken in accelerated speech ($M=.08, SE=.01$). As depicted in Figure 5, Knowledge and Speech Rate interacted, $F(1,31)=7.03, p<.05$. $MSe=.00$, such that a normal speech rate was helpful only for HK listeners; speech rate had no affect on LK listeners. However, there was no Age x Speech Rate interaction, $F(1,31)=1.72, p=.2$, nor was there an Age x Knowledge x Speech Rate interaction, $F<1$. Thus, the retrieval structures provided by schematic Knowledge augmented passage recall only when speech was presented at a normal speech rate and this was true across Age.
Figure 5. Passage recall as a function of knowledge and speech rate.
Segment Recall. The number of words correctly recalled was determined using strict criteria such that credit was given only for words recalled completely. That is, credit was given for an addition of a morpheme but not for an omission (e.g., "mechanisms" but not "mechanic" would receive credit for "mechanism"). The overall proportion of words correctly recalled by each subject for fast and normal passages was entered into a 2(Age) x 2(Knowledge) x (Speech Rate) repeated measures ANOVA, again with Rate as the within-subjects variable. This analysis revealed a significant main effect of Age, F(1,31)=5.90, p<.05, MSe=.04, indicating that older adults had poorer recall (M=.69, SE=.04) than did younger adults (M=.78, SE=.02). This is consistent with past research showing that older adults reported fewer words accurately than did younger listeners (Wingfield & Lindfield, 1995). Rate was also significant, F(1,31)=47.18, p<.001, MSe=.01, such that the fast speech rate resulted in poorer recall (M=.64, SE=.03) than did the normal rate (M=.80, SE=.02). Contrary to research showing older adults had more difficulty with accelerated speech (Wingfield & Stine, 1986), Speech Rate failed to have a more pronounced effect on the elderly than it did on the young as reflected in a nonsignificant Age x Rate interaction, F(1,31)=1.28. Unexpectedly, Knowledge failed to affect overall recall accuracy and this was true across Age, F>1 for both. This is inconsistent with research showing that predictability enhanced recall accuracy (Wingfield & Lindfield, 1995), however, it may be that this analysis was insensitive to subtle differences in recall relative to segment size.

Recall as a Function of Segment Size. In order to assess the degree to which age differences in recall changed across segment size, the proportion of words correctly reported out of the total number of words heard for each segment size (up to 14 words) was computed. For scoring purposes, correctly recalled words were assigned to the segment in which they were heard and subjects received credit for a correctly recalled word that was recalled in the subsequent segment if the word was the first word spoken in the next segment's recall.

To explore the prediction that knowledge would enable older adults to parse text into larger segments (i.e., those that young adults use) without a corresponding loss of recall accuracy, regressions were computed for young and elderly HK listeners and LK listeners. Using perfect recall as the regressor, mean recall accuracy for each segment size (ranging from 1 to 14 words) was entered into regressions to
obtain a slope parameter for each group. Thus, the extent to which the slope coefficient is less than unity (representing perfect recall), the data show a deterioration in recall performance. Presumably this decrease reflects a decrement in the ability to anticipate when to stop the flow of text in order to limit the amount of information in working memory. In this way, the slope is an index of the extent to which segmentation strategies reflect awareness of one's WM limitations (Stine et al., 1989). Based on the results of Experiment 1, if older adults are able to use knowledge to mitigate age-related declines in WM, then young and elderly HK listeners should show similar slope parameters. That is, knowledge should provide contextual support that will facilitate phonological memory, a particularly age-sensitive process (Wingfield & Lindfield, 1995). Older LK listeners, on the other hand, without the luxury of a situation model to guide encoding, would show performance decrements where younger LK listeners, with their greater WM capacity, would not.

In this analysis, means with fewer than 7 cases were not included because they were thought to represent spurious segment sizes. This resulted in an average 10 observations per data point. Consistent with the prediction that knowledge would enable older adults to recall verbatim text as younger adults do, the slope parameters of younger (.70) and older (.72) HK listeners did not differ, t(17) = .09, ns, indicating that knowledge can offset declines in recall associated with increased demands on WM (i.e., recall for the larger segment sizes). As shown in Figure 6, the slopes of the LK groups, however, were significantly different (.75 and .44 for young and old, respectively), t(17) = 3.89, p < .01, indicating that a lack of knowledge differentially affects the performance of older listeners. Thus, even though the analysis on overall recall accuracy failed to detect an interaction between Knowledge and Age, this finding suggests that knowledge does indeed provide contextual support that facilitates phonological memory by showing that older HK listeners were able to attain levels of recall comparable to those of the young across all segment sizes. To investigate segmentation strategies underlying this performance, place of segmentation was analyzed next.
Figure 6. The effects of knowledge on recall as a function of segment size for HK and LK adults.

**High Knowledge**

- \( y = 0.033545 + 0.72349x \quad R^2 = 0.996 \)
- \( y = 0.63424 + 0.69765x \quad R^2 = 0.98015 \)

**Low Knowledge**

- \( y = 2.3143 + 0.43964x \quad R^2 = 0.91876 \)
- \( y = 0.70524 + 0.75024x \quad R^2 = 0.99441 \)
Place of Segmentation. The segment sizes selected by participants (reported above) varied a great deal and probably reflect the listeners' tendency to stop text at linguistically meaningful points rather than after listening to a certain number of words (cf. Wingfield & Lindfield, 1995). Therefore, to explore the possibility that knowledge may differentially affect the parsing strategies of older listeners, age differences in the place of segmentation were analyzed. Prior work has shown that listeners tend to interrupt text more frequently at linguistically important locations, with relatively few interruptions occurring at nonboundary locations (Wingfield & Butterworth, 1984; Wingfield & Stine, 1986; Stine, Wingfield, & Poon, 1989; Wingfield et al., 1989; Wingfield & Lindfield, 1995). A relative preference for older HK listeners to use smaller chunks (marked by words falling at the ends of intrasentence boundaries) over larger chunks (those falling at sentence boundaries) would support the hypothesis that knowledge promotes a chunking strategy among older adults that entails segmenting text into smaller units. Therefore, the effects of knowledge on the quality of segmentation in terms of increased use of syntactic units was assessed as well as the size of the unit.

Verbatim recall protocols were thus scored in terms of the frequency of linguistic (falling at the ends of syntactic units) and nonlinguistic (falling in the middle of a phrasal units and in the middle of words) segmentation points. Linguistic interruptions were coded in terms of whether they occurred at the ends of 1) large (sentence) or 2) small (intrasentence) boundaries. As in Experiment 1, intrasentence boundaries included ends of dependent clauses and prepositional phrases. Also, nonsyntactic interruption points were coded in terms of whether they occurred 3) at nonboundary locations (e.g., those occurring between "the" and "procedure," or 4) in the middle of words ("splits") which presumably reflect parsing errors. The proportion of linguistically meaningful interruptions accounted for the majority (71%) of the segmentation sites, consistent with past research (Wingfield & Lindfield, 1995). Linguistically meaningful interruptions occurring at sentence boundaries and at intrasentence boundaries comprised 43% and 28% of the total, respectively. Nonlinguistically meaningful interruptions consisted of 11% nonboundary interruptions and 18% word splits. Figure 7 depicts the proportion of segmentation cites for younger and older listeners as a function of Knowledge.
Figure 7. Place of segmentation as a function of age and knowledge.
To determine whether there were age differences in the frequency with which older and young adults used various places of segmentation, the percentage of interruptions falling at each location was entered into four separate repeated-measures ANOVAs with Age and Knowledge as between-subjects variables and Speech Rate as the within-subjects variable. The ANOVA on intrasentence boundaries explored the extent to which older adults, and HK older adults in particular, used a parsing strategy that entailed more frequent pauses after smaller syntactically meaningful segments. Although neither Age, $F(1,31)=1.08, p=.31$, nor Knowledge, $F<1$, was significant, the Age x Knowledge interaction was as predicted, $F(1,31)=4.46, p<.05$, $MSe=.01$. Older listeners made more use of intrasentence boundaries when background knowledge was present relative to younger listeners, but both age groups used similar amounts when knowledge was lacking. Younger and older listeners also used different parsing strategies as a function of speech rate as reflected in a significant Age x Speech Rate interaction, $F(1,31)=7.78, p<.01$, $MSe=.01$. A post hoc ANOVA within Knowledge showed that this Age x Location effect was significant only among LK listeners. While young LK listeners used more intrasentence boundaries when passages became more difficult by accelerated speech, LK older adults used fewer. It appears that, when older adults lacked background knowledge, their parsing strategy deteriorated under the difficult conditions of accelerated speech. Younger adults, on the other hand, appeared to make use of smaller syntactic units when faced with these same challenges. Thus, these data suggest that knowledge can preserve parsing strategies of older adults when WM demands are increased.

The other three ANOVAs were somewhat less informative. The ANOVA on sentence boundaries showed a trend for an increase in the use of sentence boundaries for faster speech rates, $F(1,31)=3.97, p<.06$, however, no other effects were significant. Thus, although older adults used more smaller chunks when parsing the flow of speech, the prediction that they would also use fewer larger chunks was not supported. The ANOVA on word splits showed only a trend for older adults to use more split words than did the young, $F(1,31)=3.97, p<.06$, and a trend for LK listeners to use more split words than HK, $F(1,31)=3.14, p<.09$, however, no effects reach significance. In the ANOVA on nonboundary locations, Rate had an effect, $F(1,31)=6.64, p<.05$, $MSe=.01$, such that a normal speech rate engendered a higher frequency of these than did a fast speech rate.
Predicting Segment Recall from Strategy and Individual Differences. To explore whether segmentation strategies differentially affected verbatim recall across Age and Knowledge, four regressions were conducted predicting verbatim recall from individual difference measures (average sentence span, vocabulary, age) and strategy variables (frequency of intrasentence boundary use, frequency of sentence boundary use, and average segment size used). None of these variables predicted verbatim recall of passages spoken at a normal speech rate for any of the four groups. Regressions predicting recall of the fast speech rate passages, on the other hand, showed different patterns for Knowledge and Age. Among LK young listeners, none of these variables predicted recall, however, for HK young listeners, average sentence span alone significantly predicted recall, accounting for 60% of the variance. This suggests that, for younger listeners, knowledge together with WM capacity produced higher levels of recall. For older adults, however, the pattern was different. Among older LK listeners, parsing strategy in terms of frequent use of syntactically meaningful segmentation sites produced higher recall; intrasentence and sentence boundaries together accounted for 82% of the variance. None of these variables predicted the performance of older HK listeners, however. Thus, it appears that WM capacity alone leads to high verbatim recall among young adults with requisite schematic knowledge and strategy is inconsequential. Conversely, strategy variables are important to recall performance among older adults who lack the requisite background knowledge. However, it is unclear from these variables what leads to high recall among older HK listeners.

In general, then, the results of Experiment 2 showed that knowledge enabled older listeners to take increasingly larger segments of text and recall them as accurately as did younger adults. Although the performance of older HK listeners appeared to parallel that of the young in terms of their ability to recall even the larger segments, examination of place of segmentation revealed qualitative differences in segmentation strategies (cf. Figure 7). Older HK listeners adopted a strategy of using more intrasentence boundaries than did their younger counterparts under conditions of accelerated speech. Thus, it appears that knowledge lightens the processing load of the elderly by making larger segments recallable and by making it easier to predict when to stop the flow of text at more meaningful locations.

Conclusions. The data from the present study provide some new insight into the effects of knowledge on an aging discourse processing system in two ways. First, older adults appeared to
differentially benefit from the presence of knowledge during speech processing. In this experiment, older HK listeners were able to maintain recall levels comparable to those of young adults even as their segment size increased. The young adults, presumably due to sufficient working memory capacity, were able to attain high levels of recall independent of their level of knowledge. Thus, these data suggest that knowledge differentially facilitated the elderly by enhancing a phonological memory trace which allowed them to circumvent working memory limitations and handle a wider range of segment sizes. It appears then that Experiments 1 and 2 provide a source of convergent validity of the benefits of knowledge in both reading and speech processing among the elderly.

Second, the way in which older HK listeners attained high levels of verbatim recall differed in terms of parsing strategy. In particular, under the demanding conditions of accelerated speech, knowledge enabled older listeners to adaptively switch to a smaller chunking strategy, not required by their younger counterparts. Thus, when WM is taxed, it appears that the presence of knowledge facilitated short-term conceptual memory of older listeners which enabled them to make better predictions as to how to chunk the rapid flow of speech into recallable portions.

This interpretation is consistent with the notion that an immediate conceptual trace of speech is resistant to age-related declines (Wingfield & Lindfield, 1995). Wingfield and Lindfield have suggested that age differences in verbatim recall accuracy reflect decrements in phonological memory traces which rely heavily on WM. Conversely, the ability to parse a stream of text into meaningful segments relies more on a conceptual memory trace which is less sensitive to the effects of aging. Age constancy in the ability to make syntactically meaningful segmentations is taken as support of this hypothesis and is supported by the finding that text predictability, independent of syntax, influences segmentation performance (Wingfield & Lindfield, 1995). These data suggest that knowledge differentially facilitates phonological memory for older listeners but also provides support to a conceptual memory trace by helping them find smaller syntactically meaningful places to parse text when the task becomes demanding.

In summary, the first two experiments show that the benefits associated with knowledge are evident in performance on passage recall after reading and segment (and passage) recall after listening. Further, older adults appear to differentially benefit from the presence of knowledge structures in that older
HK listeners are able to parse text into increasingly larger units without penalty. The question remains, however, as to whether these benefits are specific to difficult tasks involving recall. The next question is whether task demands in the form of instructions can affect the observed effects of Knowledge during reading.

**Experiment 3:**

**Effects of Task Demands and Knowledge on Reading Strategies**

Research suggests that reading strategies differ when reading with the goal of comprehending a text than when reading with the goal of reproducing the text (i.e., free recall). Aaronson and colleagues (Aaronson & Scarborough, 1976; Aaronson & Ferres, 1984; Aaronson & Ferres, 1986) used on-line methodology to determine how readers allocated time to features of text when subjects read for comprehension in contrast to recall. Recall instructions engendered reading-time patterns that showed increases in time spent at boundary locations (wrap-up peaks), whereas comprehension instructions did not show pronounced wrap-up peaks. Thus it appears that, when reading for comprehension, less time is required to integrate and organize text. These researchers argued that subjects who were reading for recall were attending to the linguistic content of the text so as to reproduce it later. On the other hand, when instructed to comprehend the text, readers do not need to attend to the structural content and can instead concentrate on the meaning.

It is possible, then, that the effects of knowledge found in Experiment 1 were attributable to task demands and that without the added burden of producing free recall (cf. Craik & McDowd, 1987; Craik & Jennings, 1992), these benefits would not be evident. Research among younger adults indicates that the benefits of knowledge are dependent upon task demands. Fincher-Kiefer et al. (1988) gave baseball experts a word-span task that used either a baseball theme (sentences that together formed a baseball story), or a non-baseball theme. When subjects were not told that they would have to recall the sentences after performing the span task, there were no differences in performance between the two groups; the benefits of knowledge were not present for HK readers. However, when subjects were asked to recall the sentences after performing the span task, HK individuals outperformed LK individuals on the span task. Thus, if the
task demands are made easier by simply asking readers to complete a comprehension task rather than to reconstruct the entire passage, the effects of knowledge on on-line reading strategies disappear.

To specifically explore this possibility, the present experiment used the same materials and procedures as in Experiment 1 but with a different set of instructions and a different outcome measure. Rather than asking subjects to recall the text, they were instructed to comprehend the text; rather than asking subjects to perform a free recall task after each passage, they were asked to answer ten multiple-choice questions at the end of each. Thus, the current experiment sought to replicate Fincher-Kiefer et al.'s (1988) finding that young experts do not "call forth" their knowledge unless required to do so by the task and, further, explores the effects of task difficulty on on-line reading strategies.

Because this multiple-choice task still required subjects to "understand" the story (i.e., pay more attention to content than was required in Fincher-Kiefer et al., 1988), HK readers were still expected to outperform LK readers on the comprehension task. However, the question remained as to whether HK and LK readers would show different reading strategies. LK readers may not need to work as hard to organize and integrate text as they did when attending to structural content as in Experiment 1. Also, since multiple-choice questions provide more retrieval support than does free recall (Craik & Jennings, 1992), age differences in reading strategy may not be evident. That is, without the added demands of attending to linguistic content, the comprehension task may not require older LK readers to allocate extra time organizational processing.

Comprehension itself involves various levels of understanding and the influence of knowledge, therefore, can depend on the level of comprehension required. Kintsch (1994) suggested that knowledge can facilitate certain types of comprehension but not others. Comprehension levels range from superficial representations of the text to higher-level representations that draw on the reader's situation model. According to this viewpoint, high-knowledge individuals will outperform low-knowledge individuals on questions tapping a situation model representation. The reverse is also true: low-knowledge readers will outperform high-knowledge individuals on textbase questions. Thus, if knowledge does facilitate comprehension even under relatively easy task demands, it may be specific to questions that tap the reader's situation model of the passage.
If reading for comprehension is places fewer demands on wrap-up processes than does reading for
free recall, then this easier task may not require LK readers to allocate more time (1) to words at boundary
locations and (2) to conceptual load processing as they did in the first experiment. Furthermore, with the
decreased demands associated with these instructions, older adults may not need to rely more heavily on
knowledge. That is, since attention to the structural information is not required, old LK readers may not
show increased resource allocation to boundaries. This would be evident in a failure to find significant Age
by Knowledge interactions in terms of raw reading times and conceptual processing. Furthermore, if
knowledge facilitates situation model comprehension relative to textbase comprehension, then HK and LK
readers should differ in terms of their relative performance on the two types of comprehension questions:
HK readers should outperform LK readers on situation model questions, whereas LK readers should
outperform HK readers on textbase questions.

The change in instructions, however, should not affect the chunking strategy used by older adults
in Experiment 1 since that effect was independent of knowledge. That is, the finding that older adults used
more intrasentence boundary locations than did the young in Experiment 1 for conceptual integration should
be replicated in this experiment.

Methods

Subjects. Thirty elderly subjects (ages 59-80, M=69.3) were recruited from the community and
from among university alumni and 30 younger subjects (ages 18-23, M=19.0) were recruited through the
university introductory psychology laboratory subject pool. The older volunteers were given $10 for
participation and the younger subjects received class credit. All subjects were screened for health-related
limitations. To parallel Experiment 1, subjects were first administered individual-difference measures
consisting of the vocabulary and digit-span subscales of Wechsler Adult Intelligent Scale (WAIS), and
reading and listening versions of a Daneman and Carpenter (1980) style sentence span measure (Stine &
Hindman, 1994) were averaged to form an overall index of working memory (WM) capacity. To insure
that the randomization procedure produced comparable groups, an Age x Knowledge ANOVA was
performed on each of these measures. There were no main effects of Knowledge, nor were any Age x
Knowledge interactions significant, therefore only Age effects will be described. Older adults had an
advantage in terms of years of education \((M=13.4, SE=0.1; M=14.8, SE=0.4\) for young and old respectively), \(F(1,54)=10.60, p<.01\), and WAIS vocabulary \((M=51.5, SE=1.3; M=59.4, SE=1.1\) for young and old respectively), \(F(1,54)=21.06, p<.001\), however, younger adults outperformed older adults on average sentence span \((M=5.2, SE=0.2; M=4.0, SE=0.2\) for young and old respectively), \(F(1,54)=15.66, p<.001\). Neither the forward nor the backward digit-span analyses yielded any significant effects.

### Materials
All four passages from Experiment 1 were used. This experiment, however, included four comprehension tests (presented in Appendix B) constructed by the experimenter. Each test consisted of 10 multiple-choice questions, half of which were intended to tap a text-based representation of each passage and the other half were constructed to test the situation model representation of the passage (Kintsch, 1994). Because only two judges were used to determine the type of question, these two groups are intended as a general index of textbase and situation model comprehension and therefore provide a weak test of Kintsch's (1994) notion of knowledge on various levels of comprehension.

### Procedures
As in Experiment 1, subjects within each age group were randomly assigned to either a "high-knowledge" (HK) group that was given the topics of the passages or to a "low-knowledge" (LK) group that was not. Subjects read passages in the same manner as in Experiment 1. At the end of each passage, however, rather than performing a free-recall task, subjects completed the multiple-choice test on the passage they just read. Again, subjects were given a practice passage to become comfortable with the procedure. Subjects took roughly 50 to 75 minutes to complete the experiment.

### Results and Discussion

#### Comprehension Performance
The total number of correctly answered for textbase and situation model questions (20 each) were summed to form a two comprehension scores to investigate the notion that knowledge might differentially benefit performance on situation model questions relative to textbase questions. A \(2(Age) \times 2(Knowledge) \times 2(Question Type: textbase, situation model)\) ANOVA was performed on the two types of questions as the repeated measure. These data showed that HK readers \((M=30.4, SE=1.0)\) outperformed LK readers \((M=19.6, SE=0.9)\) on all questions, \(F(1,54)=64.28, p<.001, MSe=13.01\). Also, there was a main effect of Question Type indicating that readers scored higher on textbase questions \((M=13.2, SE=0.5)\) than they did on situation model questions \((M=11.4, SE=0.6)\) and this
was moderated by Knowledge as indicated by a significant Knowledge x Question Type interaction, F(1,54)=6.95, p<.05, MSE=3.91. HK readers performed better on situation model questions relative to textbase questions (M=14.6, SE=0.6 for textbase; M=15.6, SE=0.4 for situation model) and LK readers performed better on textbase questions than on situation model questions (M=11.2, SE=0.6 for textbase; M=8.3, SE=0.5 for situation model), consistent with Kintsch's (1994), notion of a lower level of comprehension (confirmed by posthoc analyses). However, there were no effects of Age, F<1, nor did Knowledge differentially benefit older adults as reflected in a nonsignificant Age x Knowledge interaction, F<1. Additionally, the benefits of knowledge on situation model comprehension were constant across Age as reflected in a nonsignificant Age x Knowledge x Question Type interaction, F<1.

Group Differences in Reading Strategy (Raw RTs). As in Experiment 1, reading times (RT) less than 150 msec were removed from the data and outliers greater than five standard deviations above the median for that word were replaced with this maximum value. This resulted in a loss of two elderly subjects (27% and 25% lost/replaced data) and an average of 3.6% the data being dropped or replaced across all remaining subjects. Also, due to equipment failure, one younger HK reader's data were lost. The final sample used in all analyses (including the individual-difference measures reported above) included 14 young HK readers, 15 young LK readers, 14 older HK readers, and 15 older LK readers.

Medians for each subject were calculated separately for intrasentence-boundary, sentence-boundary, and nonsentence-boundary words. Reading times (msec) were analyzed in a 2(Age) x 2(Knowledge) x 3(Location: intrasentence-boundary, sentence-boundary, nonboundary words) ANOVA with Location as a within-subjects factor and Age and Knowledge as between-subjects variables. Unlike in Experiment 1, there were no main effects of Age on raw reading times, showing that comprehension instructions engendered similar overall reading rates of young and older readers alike, F<1. Similarly, the main of effect Knowledge found in Experiment 1 failed to reach significance here as did the Age x Knowledge interaction, F<1 for both. Thus, as predicted, the easier task of comprehension did not require subjects to utilize different reading strategies when they lacked the requisite knowledge. There was a main effect of Location: readers allocated more time to sentence-boundary (M=614, SE=35) and intrasentence-boundary (M=529, SE=34) words than to nonsentence-boundary words (M=497, SE=16), F(2,108)=18.41,
p<0.001, MSe=11,494.90 (confirmed by post hoc analyses). This finding was as expected given that boundary sites are locations at which integration and organization processing occurs. The Age x Location interaction was significant, $F(2,108)=4.51$, p<.05, MSe=11,494.90, showing that older adults spent more time performing wrap-up at intrasentence boundaries (M=567, SE=29) than did the young (M=491, SE=27) and both spent comparable amounts of time at sentence boundaries (M=600, SE=42 for old, M=628, SE=56 for young) (confirmed by post hoc analyses). Thus, these data are consistent with Experiment 1 in that older adults paused longer at intrasentence boundaries than did the young.

Interestingly, the effects of knowledge on wrap-up appear to occur only when the task demands such knowledge application, as indicated by a nonsignificant Knowledge x Location effect, F<1, and this held across Age, as reflected in a nonsignificant Age x Knowledge x Location interaction, F<1. That is, it appears that comprehension instructions did not require LK subjects to allocate resources to organizational processes in an attempt to build a coherent situation model of the passages and thus they did not suffer from the lack of titles.

**Individual Difference in Reading Strategies.** To determine whether comprehension task demands also diminished the effects of knowledge on individual reading strategies, individual regression analyses were conducted as in Experiment 1. Specifically, if the benefits of knowledge are specific to tasks requiring subjects to produce subsequent recall, then time allocated to conceptual integration and contextual facilitation should be similar for HK and LK readers. Again, each subject's reading strategy was determined by decomposing each one's reading times into time allocated to various features of text (cf. Table 2). With the exception of one younger reader, this model significantly predicted reading times for all subjects. In this way the surface features were partialled out to provide a more sensitive estimate of subjects' responsiveness to processing load and serial position.
Table 2.

**Means (and Standard Errors) of all Text Features, Experiment 3**

<table>
<thead>
<tr>
<th>Feature</th>
<th>High Knowledge</th>
<th>Low Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young</td>
<td>Old</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ltrs</td>
<td>11.75 (2.57)</td>
<td>15.11 (5.76)</td>
</tr>
<tr>
<td>Word f</td>
<td>-38 (0.24)</td>
<td>-.24 (0.17)</td>
</tr>
<tr>
<td>NewL</td>
<td>38.50 (12.67)</td>
<td>50.98 (19.84)</td>
</tr>
<tr>
<td>CCxInt</td>
<td>3.59 (3.59)</td>
<td>8.39 (5.29)</td>
</tr>
<tr>
<td>CCxSnt</td>
<td>29.91 (11.14)</td>
<td>6.81 (4.63)</td>
</tr>
<tr>
<td>SP</td>
<td>-0.29 (0.15)</td>
<td>-.69 (0.22)</td>
</tr>
</tbody>
</table>

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First, all six regression coefficients were entered into a 2(Age) x 2(Knowledge) x 6(Reading Process: Ltrs, Word f, NewL, CCxInt, CCxSnt, SP) repeated-measures ANOVA to determine if there were group difference in overall read-time patterns. There were no main effects of Age or Knowledge, nor did these two variables interact, F<1, for all three effects, suggesting that reading strategies were constant for young and old, and were not dependent upon the presence of knowledge. The within-subjects effect of Reading Process was significant, however, which suggests only that readers were sensitive to the demands of text, F(5,270)=18.62, p<.001, MSe=993.72. Reading Process failed to interact with Knowledge or with the combination of Age and Knowledge, F<1 for both, suggesting once again, that the effects of knowledge are minimal when reading for comprehension and this is true for both young and old. As was the case in Experiment 1, an Age x Reading Process interaction indicated that young and older adults differed in how they allocated time to the different features of text, F(5,270)=4.30, p<.01, MSe=993.72. Four individual post hoc 2(Age) x 2(Knowledge) ANOVAs on Ltrs. Word f, NewL, and SP, and a post hoc 2(Age) x 2(Knowledge) x 2(Location: CCxInt, CCxSnt) repeated-measures ANOVA were conducted to take a closer look at these age differences. Consistent with the pattern of findings in the first experiment, there were no significant Age effects in the Ltrs, Word f, or NewL ANOVAs. Unlike the first experiment, however, Knowledge failed to have an effect on the word-frequency parameter. The analysis on contextual facilitation showed that older adults had greater contextual facilitation than did the young as indicated by a significant Age effect in the ANOVA on SP, F(1,54)=6.31, p<.05, MSe=2.54, which is consistent with Experiment 1 and with previous research (Stine-Morrow et al., 1996). This analysis showed that Knowledge failed to have an effect on contextual facilitation, F(1,54)=2.40, p<.13, indicating that, consistent with the analyses on raw reading times above, comprehension instructions failed to engender differences between HK and LK readers. The Age x Knowledge interaction was also nonsignificant, F<1, (as was the case in the first experiment).

To determine whether there were age differences in time allocated to conceptual integration and, specifically, in the location at which this occurs, a post hoc 2(Age) x 2(Knowledge) x 2(Location: CCxInt, CCxSnt) repeated-measures ANOVA was conducted. The pattern of findings was somewhat different from those of Experiment 1 in that in the present study there was a main effect of Age, F(1,54)=5.31, p<.05,
MSe=945.01, indicating that older adults allocated less time overall than did the young to conceptual integration (see also Stine et al., 1995). Thus, older adults might be more likely than their younger counterparts to allocate fewer resources when the task demands allow it. The Age x Location effect, depicted in Figure 8, indicates that older adults spent more time than did younger adults integrating concepts at intrasentence boundaries and also that younger adults spent more time than did older adults integrating concepts at sentence boundaries, F(1,54)=14.91, p<.001, MSe=880.54. As addressed in the next section, however, these means are markedly lower than those reported in Experiment 1.
Figure 8. Regression estimates of time allocated (msec) per new concept at sentence (CCxSnt) and intrasentence (CCxInt) boundaries as a function of age.
Conceptual Integration in Experiments 1 and 3 Combined. The pattern of findings described above suggests that task demands have a striking effect upon the benefits of knowledge during reading. That is, when asked to read for comprehension rather than for recall, subjects exhibited very different reading strategies which are most evident when considering time allocated to conceptual integration. To more specifically explore these differences, a 2(Task Demands: recall, comprehension) x 2(Age) x 2(Knowledge) x 2(Location: CCxInt, CCxSnt) ANOVA, was conducted by combining the data from Experiments 1 and 3. This analysis showed that subjects in the present study allocated less time overall to process each new concept (M=31.6, SE=5.9 for comprehension; M=96.2, SE=13.0 for recall), F(1,148)=14.81, p<.001, MSe=4,869.49, suggesting that comprehension is requires less organizational processing than does recall (e.g., Aaronson & Ferres, 1984).

More importantly were the between-subjects analyses contrasting HK and LK readers. There was a main effect of Knowledge, F(1,148)=10.60, p<.01, MSe=4,869.49, showing that LK readers allocated more time to conceptual integration than did HK readers (M=38.32, SE=8.76 for LK; M=24.35, SE=7.84 for HK). Further, this effect was moderated by Task Demands as indicated by a significant Task Demands x Knowledge interaction, F(1,148)=5.77, p<.05, MSe=4,869.49. As depicted in Figure 9, these data suggest that LK readers who did not have the added burden of encoding linguistic structure, failed to allocate more time than did HK readers to conceptual integration. To be sure, LK individuals in the present study still showed poorer performance on the outcome measure relative to HK readers, however, these data suggest that the lighter task demands rendered a more effortful reading strategy unnecessary. Furthermore, this resource-allocation pattern was true for young and old LK readers alike, as indicated by a nonsignificant Task Demands x Knowledge x Age interaction on conceptual integration time, F(1,148)=2.62, p=.11. Apparently, the comprehension task was not taxing enough for LK older readers to allocate differentially more time to wrap-up. Thus, it seems that under these easier wrap-up conditions, older adults are not as constrained by WM limitations as is the case when reading for recall. Lastly, across both Task Demands, the Location effect was significant, indicating that both young and old readers spent more time overall at sentence boundaries relative to intrasentence boundaries, F(1,148)=10.03, p<.01, MSe=4,725.47, as was the Age x Location effect, F(1,148)=18.58, p<.01, MSe=4,725.47. Thus, collapsing
across both Experiment 1 and 3, older adults used relatively more intrasentence boundary locations than did younger readers as places to organize and integrate text and this was independent of the effects of knowledge.
Figure 9. Regression estimates of total time allocated (msec) per new concept as a function of task demands.
Conclusions. The present study replicated some general age differences found in the first Experiment. First, older adults, regardless of the availability of requisite knowledge, allocated more time to intrasentence boundaries relative to the young. This finding that older adults rely more on smaller units of text input suggests a strategy shift among older readers that serves to mitigate WM constraints (Stine et al., 1995). Second, older adults allocated more time in the beginning of each passage presumably to establish a situation model of the text early on which then facilitated subsequent text processing. Again, this finding is independent of knowledge. Thus, regardless of whether reading for recall or reading for comprehension, older adults, relative to the young, prefer intrasentence boundaries as locations for text wrap-up and invest greater amounts of time at the beginning of passages.

It appears, then, that whenever Knowledge had an effect on reading strategy in Experiment 1, it failed to do so in the present study and, further, that if Age had an effect in the first experiment, it was replicated in this study. An exception to this complete agreement in age differences between the two was in terms of total time allocated to conceptual integration. Age differences occurred in Experiment 3 but not in Experiment 1 (but failed to materialize in a significant Task Demands x Age effect on total conceptual integration time when the two experiments were combined). Total time spent on conceptual integration was constant across age group in Experiment 1 but in the present study, older adults allocated less time to process conceptual load at boundaries than did the young (see also Stine et al., 1995). These data suggest a trend for older adults to allocate extra resources to conceptual integration only when pushed by task demands. Thus, although the benefits of knowledge were evident on the comprehension outcome measure, they were not apparent on reading strategies and this was true for young and old readers alike.

With a clearer picture of the underlying mechanisms involved in knowledge across adulthood, it is now necessary to apply these findings to a real-world domain of expertise. If expertise does indeed provide retrieval structures (Ericsson & Kintsch, 1995) that act somewhat like schematic knowledge, then the effects of expertise on discourse processing should be consistent with the findings from the studies reported above.
Experiment 4:
Effects of Domain-Knowledge on Discourse Processing: Evidence from Cooking Expertise

The present experiment extended the findings of the prior three experiments involving artificial, laboratory-controlled domains of expertise to instances of real-world expertise. This experiment was designed to assess reading strategies of old and young cooking experts in both domain-related and nondomain-related text relative to young and old control subjects ("non-cooks"). If real-world cooking knowledge translates into the benefits of knowledge found in the first experiment, then older experts should be differentially facilitated by the presence of knowledge which would be evident in dampened wrap-up peaks relative to their novice counterparts. In this way, knowledge would appear to enable older experts to circumvent working memory limitations by allowing them to achieve high levels of recall while investing relatively little in wrap-up, a resource-consuming process. On the other hand, if the effects of knowledge are relevant to only extreme cases such as expertise and the manipulation of schematic knowledge as in Experiment 1, then these benefits may not materialize.

Methods

Subjects. Fifty (ages 60-75) elderly and 50 younger subjects (ages 18-30) were recruited from the community. Older volunteers were paid $10 for participation and younger subjects received course credits. All participants from the community and from university alumni records were screened for health-related limitations. As was the case in Experiments 1 and 3, subjects were administered individual-difference measures consisting of the forward and backward digit spans and vocabulary subscales of the WAIS as well as reading and listening sentence spans (Daneman & Carpenter, 1980) which were averaged to form a composite of WM capacity. One-way ANOVAs on each measure as well as on years of education indicated that older adults had an advantage over young adults in terms of years of education, (M=16.2, SE=0.3 for old; M=13.2, SE=0.1 for young), F(1,95)=87.1, p<.001, and vocabulary (M=61.2, SE=0.7 for old, M=49.1, SE=1.0 for young), F(1,95)=103.3, p<.001. However, young adults (M=5.1, SE=0.2) scored higher on average sentence span than did older adults (M=4.0, SE=0.1), F(1,95)=27.2, p<.001. There were no age differences in either the forward or backward digit spans, F<1, for both. This subject profile is consistent with the previous three experiments.
Cooking Test. One hundred items about cooking practices and cooking knowledge were administered to 9 experts and 20 novices in cooking in order to determine which questions most effectively discriminated between experts and novices. The cooking experts were non-paid volunteers recruited from a local monthly meeting of the American Culinary Federation as well as through a cookbook publisher. Although 40 requests were distributed, only 9 experts returned the test. Novices were 20 students from the University who received course credit for taking the test. Participants were also given a short questionnaire on their cooking experience in order to confirm their expertise status; all participants in the expert group reported significant exposure to cooking practices whereas those in the novice group had very little or no cooking experience. Responses were computer scored both independently for experts and novices so as to select items on which experts scored higher than novices on all items and together as one group. Test items were then selected based on their biserial correlations and the percentage of participants who correctly responded to the item. Biserial correlations of \( \geq +.40 \) were selected because these represented items that were strongly correlated to overall test performance. A range of 40-60 percent of participants passing the item was selected to ensure future responses would yield maximum information (Anastasi, 1982). This screening process yielded 20 test items (see Appendix C). Alphas conducted on the entire test (.93) and the short version (.88) indicated that the test was reliable in both forms.

Materials. Three experimental passages were adapted from texts on cooking (Axler, 1969; Donovan, 1996; Gorman, 1984; Lunberg & Kotschevar, 1965) and three expository control passages were borrowed from a previous study (Stine-Morrow et al., 1996) (see Appendix D). Passages were comparable in terms of length, propositional density, and style (see Table 3).

Procedures. Procedures used in this experiment were similar to those used in Experiment 1, with the addition of the cooking quiz which was administered after subjects completed the reading portion of the experiment. As in Experiment 1, subjects read passages word-by-word on a computer and were told they would be asked to recall each passage after reading it. Subjects paced the onset of the next word's presentation by pushing a marked key. Subjects were given a practice passage to help them become comfortable with the procedure. At the end of the passages, subjects performed a free recall task which was tape recorded for later transcription.
Table 3.

**Passage Characteristics, Experiment 4**

<table>
<thead>
<tr>
<th></th>
<th>Number of Words</th>
<th>Number of Props</th>
<th>Number of New Concepts</th>
<th>Propositional Density (props/word)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cooking Passages</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baking</td>
<td>213</td>
<td>81</td>
<td>29</td>
<td>.38</td>
</tr>
<tr>
<td>Spring Lamb</td>
<td>256</td>
<td>103</td>
<td>26</td>
<td>.40</td>
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<tr>
<td>Sauces</td>
<td>266</td>
<td>102</td>
<td>18</td>
<td>.38</td>
</tr>
<tr>
<td><strong>Control Passages</strong></td>
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</tr>
<tr>
<td>Jumping Beans</td>
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<td>86</td>
<td>24</td>
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<tr>
<td>Swordmaking</td>
<td>239</td>
<td>79</td>
<td>43</td>
<td>.33</td>
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<tr>
<td>Whales</td>
<td>204</td>
<td>78</td>
<td>24</td>
<td>.38</td>
</tr>
</tbody>
</table>
Results and Discussion

Cooking Test. The cooking test was scored in terms of the number of correct responses out of 20 questions. Scores ranged from 2 to 18, however, the ranges were considerably different for young and older adults and for males and females, as indicated by significant effects of Age, $F(1,93)=115.4$, $p<.001$, Gender, $F(1,93)=5.39$, $p<.05$ and Age x Gender, $F(1,93)=7.22$, $p<.01$ (such that gender differences were present for older adults only), in an ANOVA on test scores. Because older adults ($M=11.8$, SE=0.5) knew more about cooking than did the younger adults ($M=5.4$, SE=0.3), a median split within Age seemed to be a misleading way to identify expertise. Therefore, the analyses on reading strategy presented below will depart from those presented in the previous analyses.

Recall Performance. Recall protocols for each passage were scored in terms of the total number of propositions correctly recalled using a gist criterion (Kintsch, Kozminsky, Strebby, McKoon, & Keenan, 1975; Turner & Greene, 1978). Twenty recall protocols were randomly selected from among the old and the young subjects for independent scoring. The inter-rater reliability analysis yield a correlation of .897 between the two scorers. The proportion of propositions correctly recalled for all six passages was computed and then a composite recall score was computed for the cooking and control passages by averaging the scores within each condition. Reliability analyses showed that for both the cooking ($r=.79$) and the control ($r=.82$), recall scores showed fairly good internal reliability ($r=.86$ across all six).

To determine whether there were age differences in recall, a 2(Age) x 2(Passage Type: cooking, control) repeated-measures ANOVA was conducted on recall scores for the two types of passages. Age was nonsignificant, $F<1$. This finding is somewhat surprising since older adults had significantly more cooking knowledge than did they young. Thus, the WM of younger readers appears to offset these knowledge benefits. Despite efforts to equate passages in terms of propositional and conceptual density, the control passages ($M=.34$, SE=0.01) appeared to be easier to recall than were the cooking passages ($M=.22$, SE=0.01), as indicated by a significant effect of Passage Type, $F(1,94)=232.22$, $p<.001$. This trend was constant across Age as indicated by a nonsignificant Age x Passage Type effect, $F<1$.

Group Differences in Reading Strategy (Raw RTs). Outliers were screened in the manner used in with Experiments 1 and 3 with reading times (RT) less than 150 msec removed from the data and upper-
limit outliers five standard deviations above the median for that word within each age group were replaced with this maximum value. Two elderly and one young subject were omitted from further analyses due to excessive replacements (greater than 134 data points, resulting in an average of 2% of data points replaced and dropped for all remaining subjects). Medians for each subject were then calculated separately for intrasentence-boundary, sentence-boundary, and nonsentence-boundary words. The final sample used in all analyses included 49 young and 48 older readers.

An analysis of group differences in reading strategy as indexed by raw reading times at boundary and nonboundary locations was not possible in a fully-crossed design because of a confound between age and expertise; older adults were predominantly experts and younger adults were predominantly novices. Thus, younger adults were left out of this analysis because the "expert" group had relatively little knowledge about cooking. However, the effects of cooking expertise on reading strategy could be assessed within older adults. To, at least in part, parallel Experiment 1, a 2(Expertise) x 2(Recall Group) x 2(Passage Type: cooking, control) x 3(Location: intrasentence, sentence, nonboundary) ANOVA on reading times, with Passage Type and Location as the repeated-measures variable was performed for the older subjects only. Surprisingly, Expertise had no effect on reading strategy in terms of overall reading rate and wrap-up processes as indicated by nonsignificant effects of Expertise, and Expertise x Location, F<1, for all. Thus, the effects of knowledge were not evident in time allocation to wrap-up processes as was the case in Experiment 1. However, consistent with Experiment 1, there were effects of Recall on reading times. First, overall reading rates of high recallers indicated that they read more slowly than did low recallers, F(1,42)=4.24, p<.05, and this difference was mostly attributable to increases at sentence boundaries, as evident in a significant Recall x Location effect, F(2,84)=3.48, p<.05, as depicted in Figure 10. This tendency for high recallers to read more slowly overall and at boundaries, however, was independent of Expertise and Location; the Expertise x Recall and Expertise x Recall x Location interactions failed to reach significance, F<1, for both. Thus, although the effects of knowledge failed to appear among older readers in the present study, differences in reading strategy were evident between more and less successful older readers.
Figure 10. Reading time allocation to sentence, intrasentence, and nonboundary locations as a function of recall group, and expertise among older readers.
Predicting Recall from Reading Strategy and Individual Differences. To explore the possibility that the ANOVA approach was insensitive to the relation between expertise and reading strategy, regressions were conducted to predict recall from both reading strategy and individual differences including expertise as a continuous variable (cooking test scores). Two sets of regressions were performed for each age group, one predicting recall from the cooking passages and the other predicting recall from the control passages. The predictors consisted of three categories of variables: reading strategy (sentence-boundary effect and intrasentence-boundary effect), individual differences (average sentence span, vocabulary, and age), and expertise (cooking test). Among the young readers, none of these variables predicted recall for the cooking passages, however for the control passages, the sentence-boundary effect alone accounted for 9.4% of the variance in recall. Although it was not surprising that expertise failed to predict recall among younger adults given the low-level of performance on the cooking test, it was surprising that reading strategy did not. Apparently, the reading strategy of younger readers was not driven by pronounced organizational processing. The data predicting recall of the control passages, on the other hand, did show that younger readers were sensitive to wrap-up demands. It is unclear from the present data, why this difference should exist between the two sets of passages.

Among older adults, both the sentence-boundary effect and the cooking test significantly (at p<0.05) predicted recall for the cooking passages, Adj. R$^2$=.22. Thus, as predicted, real-world expertise facilitated recall for older readers. Interestingly, reading strategy also contributed to high recall among older readers when expertise was considered. This departs from the finding in Experiment 1 that reading strategy failed to predict recall for older HK readers. When expertise was not considered (i.e., reading nondomain specific passages), vocabulary predicted recall among older adults (accounting for 10.0% of the variance). Thus, consistent with the notion that expertise facilitates discourse processing among older adults, reading successfully within one's domain of expertise relied on domain knowledge and further that high recall is related to increased resources allocation to boundary locations (wrap-up). They also suggest that expertise is domain-specific (cooking knowledge) rather than domain-general (vocabulary knowledge), consistent with research showing that expert performance cannot be accounted for by high general intellectual abilities (Schneider, Korkel, & Weinert, 1989; Yekovich, Walker, Ogle, & Thompson, 1990).
These findings are not completely consistent with Experiment 1 (granted they are not parallel sets of regressions in that knowledge was a between-subjects variable in Experiment 1). Considering only older readers, high recall in Experiment 1 was dependent on reading strategy when schematic knowledge was lacking, but on vocabulary when knowledge was present. These findings are reversed in the present study: reading strategy was important for recall when expertise was factored in and vocabulary was crucial when expertise was not. Thus, these data suggest that schematic knowledge and real-world domain-specific knowledge may rely on slightly different mechanisms of discourse processing. This question awaits future research on the effects of expertise on on-line reading.

Individual Difference in Reading Strategies. Although an attempt was made to predict reading times for each subject by text characteristics as was done in Experiments 1 and 3, the model (Ltrs, Word f, NewL, CCxInt, CCxSnt, SP) failed to significantly predict for the majority of subjects. It appears that the naturalistic expository texts used in this experiment were not controlled by the same text features as those used in the earlier experiments.

Conclusions. Although the effects of real-world expertise within the domain of cooking failed to parallel the effects of knowledge found in Experiment 1, some interesting findings arose. Because older adults have a more extensive knowledge base of cooking knowledge than do younger adults, only their data are considered here. Among older readers, reading strategy differences were obtained for cooking passages in that high recall was related to increased resource allocation to sentence boundaries. Cooking expertise was also related to recall when reading domain-related materials.
GENERAL DISCUSSION

The above four experiments yield a substantial amount of data surrounding the effects of knowledge, age, and outcome on discourse processing. Consistent with past research demonstrating the benefits of knowledge on discourse processing using off-line (e.g., Voss et al., 1980; Spilich et al., 1979), and on-line methodology (Sharkey & Sharkey, 1987), these studies demonstrate the benefits of knowledge during reading and listening. Knowledge provides a stable set of retrieval cues which enable individuals to use long-term memory to extend processing abilities (Ericsson & Kintsch, 1995). For older adults, this advantage is particularly advantageous given working memory limitations. These data suggest several possible mechanisms through which older adults can use knowledge to circumvent age-related declines in processing resources.

Factors Affecting Age Differences in Discourse Processing.

The data presented here shed light on the conditions under which age differences in discourse processing occur using on-line reading methodology and outcome measures. First, some age differences appear as a function of task demands. As Experiments 1 and 3 demonstrated, reading strategies of older adults depended upon whether participants read for recall or comprehension. In Experiment 1, older readers allocated the same amount of time to conceptual integration as did the young when demanded to do so with recall instructions. Past research found that older adults allocated less time to conceptual processing (Stine et al., 1995) and in fact, when task demands instructed readers to read for comprehension in Experiment 3, this was also the case. However, Stine et al. (1995) differed from Experiment 3 in two respects. In that experiment, (1) participants were instructed to read for recall, and (2) older adults produced lower levels of recall than did young adults. Therefore, it could be that older adults allocate less time to conceptual processing relative to the young when reading for comprehension or when reading for recall but are less able than the young to subsequently produce recall. That is, when older adults read for recall and achieve levels of recall comparable to those of the young, no age differences in this aspect of resource allocation appear.
Age differences in reading strategy also appear as a function of background knowledge. Clearly, these data show that the attempt to form retrieval structures, when faced with a lack of knowledge, has a large impact on older adults' reading strategies. Relative to high-knowledge individuals, those with less knowledge spent more time reading overall, more time at boundary locations performing wrap-up, and more time performing conceptual integration when reading for recall. Differences were also apparent for speech processing; high-knowledge listeners showed superior phonological and conceptual memory traces relative to their low-knowledge counterparts. This was evident in high verbatim recall for increasingly larger segments and the use of more syntactically meaningful parsing strategies. The extension of these findings to real-world expertise, however, remains for future research. Thus, on the whole, older adults appear to process discourse relative to task demands in terms of instructions, text coherence, and level of prior knowledge.

One age difference in reading strategy that does not appear to be sensitive to either task demands or prior knowledge is chunking. In both Experiments 1 and 3, older adults allocated more time to words falling at the ends of smaller units of text than did younger readers. This is consistent with past research showing that older adults used more intrasentence boundaries for wrap-up processes than did younger readers (Stine et al., 1995). These findings also appear to generalize to auditory discourse processing. Older listeners used intrasentence boundaries more often relative to the young as places to segment the flow of speech. Although past research suggests that this shift may be advantageous in terms of outcome (Stine et al., 1995), these data do not support this notion. However, because there were age differences in outcome (i.e., recall performance) in Stine et al. (1995), it is possible that those successful older adults were comparable to the older adults in both Experiments 1 and 3 where no age differences in outcome were evident. If this were the case, then it may be that chunking text into smaller portions may be more characteristic of successful older readers.

The Effects of Expertise on Discourse Processing

Does knowledge affect the way we process discourse? The data from Experiments 1 and 2 overwhelmingly suggest that it does. Overall reading rates were slower among low-knowledge individuals, and this was particularly true for words falling at boundary locations, where wrap-up processes occur (Just
& Carpenter, 1980). Thus, it seems that reading in general, and wrap-up in particular, is more difficult for LK readers. Sharkey and Sharkey (1987) also demonstrated that the effects of script knowledge were primarily at sentence boundaries among young adult readers. Similarly, when considering the influence of conceptual load, LK readers spent longer than their HK counterparts to perform conceptual integration. HK readers also had lower word-frequency parameters suggesting that they had an easier time accessing word meanings, and had lower serial position coefficients, indicating they needed to spend less time early on in a passage relative to LK readers setting up a situation model of the text.

In the domain of listening, knowledge also had beneficial effects on discourse processing. Data from Experiment 2 showed that HK listeners had superior verbatim recall as evident in their higher slope parameters relating verbatim recall and segment size than did LK listeners. Furthermore, knowledge appears to facilitate a conceptual memory trace which enables listeners to parse the flow of text into more meaningful segments. High-knowledge listeners in Experiment 2 showed a trend toward using more syntactically meaningful locations to parse the flow of speech than did low-knowledge listeners.

These benefits of knowledge, however, appear to be limited by task requirements. Participants in Experiment 3 expended less effort on wrap-up processes than did those in Experiment 1, suggesting that the requirements of reading for comprehension are different from those required for recall (Aaronson & Ferres, 1984). Consequently, even though the effects of knowledge were present in the higher comprehension scores of HK readers, their reading strategies showed no effects of this knowledge. While it could be that the overall faster reading times found in Experiment 3 are responsible for the lack of knowledge effects, the presence of wrap-up peaks across all readers and the differentially larger intrasentence peaks among older readers suggests that this manipulation was sensitive to reading strategies. Thus, it appears that LK readers in Experiment 3, who were not faced with the additional task of encoding linguistic structure, did not need to allocate more time than HK readers to wrap-up processing and to conceptual integration. LK readers also no longer needed to allocate more time to decode words or to establish a situation model. It appears, then, that the benefits associated with knowledge are specific to tasks that demand a certain level of difficult processing and this was true for both younger and older readers. (However, it is unclear from the present data whether reading under these two task conditions is quantitatively or qualitatively different, for
example, whether the demands of certain processes change or rather all processes are made easier or more difficult.)

Comprehension can be decomposed into levels of difficulty, from superficial aspects of comprehending the textbase to a deeper understanding of the situation and knowledge differentially affects these different levels of comprehension (Kintsch, 1994). This notion was supported in Experiment 3 in that LK readers scored higher on comprehension questions that tapped a textbase representation than those that tapped a situation model level representation. The converse was also supported; HK readers scored higher on situation model questions than on textbase questions. Thus, the benefits of knowledge appear to be most evident on situation model construction and this is true for both young and older readers alike.

How these findings surrounding the effects of knowledge on discourse processing generalize to real-world expertise is an open question. Although, among older readers, expertise predicted recall along with one index of reading strategy (sentence wrap-up), the data from Experiment 4 failed to demonstrate benefits of cooking knowledge on on-line discourse processing in the same manner found in Experiment 1. Possibly the range of expertise in the sample was not expert enough to demonstrate advantages for experts relative to novices. That is, it may be necessary to have more extreme cases of expertise, perhaps by having master chefs read texts within and outside of their domain. Additionally, it may be that the domain of cooking is comprised of several different types of expertise, for example, baking, preparing meat dishes with sauces, or handling and preparing mass quantities of food. As is the case with medicine, experts in one area may not know a great deal about other areas.

Age Differences in the Effects of Knowledge on Discourse Processing.

Ericsson and Kintsch (1995) suggested that knowledge affects discourse processing by facilitating the construction of retrieval structures which serve to both guide encoding and facilitate recall. Given that older adults typically show age-related declines in processing resources (e.g., Salthouse, 1991), knowledge could differentially benefit older adults by providing a mechanism by which older adults can circumvent these declines. The data from Experiments 1 and 2 provide some support for this position. In Experiment 1, older LK readers allocated disproportionately more time to organize and integrate text than did HK older adults and this was true when considering the cumulative effects of conceptual integration as well as raw
reading times at boundary locations. The absence of knowledge among younger readers, however, failed to have this impact. Apparently, younger LK readers had ample processing resources with which to create adequate retrieval structures under these challenging circumstances. These findings suggest that knowledge allowed older readers to circumvent age-related working-memory declines by providing retrieval structures thereby reducing the time required to organize and integrate text.

Similarly, in Experiment 2 older HK listeners were able to achieve a level of performance comparable to younger HK listeners. There were no age differences among HK listeners in the accuracy of verbatim recall for increasingly larger segments of text. Older LK adults, on the other hand, showed performance declines relative to LK younger adults. These data suggest that when outcome is considered, knowledge mitigates age differences in performance.

Consistent with this notion, successful older readers in Experiment 1 showed exaggerated benefits of knowledge. That is, when readers were separated into those who were more or less able to recall the text, resource allocation to organizational processes were more pronounced. In particular, older readers who lacked knowledge to facilitate processing, and who were nevertheless able to achieve high levels of recall, showed even larger increases in reading times at boundary locations.

In the domain of speech processing, older adults once again showed differential benefits associated with knowledge. Particularly, when faced with the demanding conditions of trying to comprehend fast speech, parsing strategies suffered unless they had knowledge to guide their processing. Thus, knowledge appears to facilitate the short-term conceptual memory trace of older listeners to a greater extent than it does among the young (Potter, 1993). Additionally, older HK listeners showed benefits of knowledge at the level of verbatim memory. Thus, not only does knowledge enable older adults to circumvent WM limitations during on-line reading, it also helps them during speech processing.

As mentioned above, the effects of knowledge on on-line reading were limited to tasks in which adults were asked to read for recall. The data in Experiment 3 indicate that these limitations of knowledge were constant across age. There were no differential effects of knowledge on reading strategy or outcome for older adults in Experiment 3.
In summary, knowledge appears to lend support to discourse processing among older adults by enabling them to circumvent age-related declines in processing resources. Consistent with Ericsson and Kintsch (1995), knowledge facilitates the construction of retrieval structures which guide encoding and retrieval and this facilitation appears to be of greater benefit to older adults than it does to younger. In reading, this facilitation occurs primarily through a reduction in the processing load associated with organization and integrating text. Younger adults show very little facilitation of knowledge presumably because of their ample supply of processing resources which allows them to process text without a corresponding increase in resource allocation. Through an assessment of outcome, it also appears that, for older adults, reading successfully involves increased resource allocation to these same processes (even with knowledge available). In speech processing, knowledge appears to differentially enhance conceptual and phonological memory traces which in turn support retrieval. Thus, knowledge does indeed appear to enable older adults to utilize crystallized intelligence so as to avoid reliance on diminished fluid abilities and, in this way, to age successfully. Future research on the effects of age and knowledge on discourse processing may benefit from consideration of task demands, outcome, and real-world instances of expertise to further elaborate on mechanisms responsible for high levels of performance into late adulthood.
REFERENCES


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APPENDICES

Appendix A Passages used in Experiments 1-3.

Washing Clothes (Bransford & Johnson, 1972)

The procedure is actually quite simple. First you arrange things into different groups depending on their makeup. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step, otherwise you are pretty well set. It is important not to overdo any particular endeavor. That is, it is better to do too few things at once than too many. In the short run this may not seem important, but complications from doing too many can easily arise. A mistake can be expensive as well. The manipulation of the appropriate mechanisms should be self-explanatory, and we need not dwell on it here. At first the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then one never can tell.

Christopher Columbus (Dooling & Lachman, 1971)

Hocked with gems financing him, our hero bravely defied all scornful laughter that tried to prevent his scheme. "Your eyes deceive," he had said. An egg, not a table, correctly typifies this unexplored planet. Now three sturdy sisters sought proof, forging along sometimes through calm vastness, yet more often over turbulent peaks and valleys. Days became weeks as many doubters spread fearful rumors about the edge. At last, from nowhere, welcome winged creatures appeared signifying momentous success.

The First Space Trip to the Moon (Dooling & Lachman, 1971)

Joe looked outside from cramped quarters. Numerous unknown objects moved swiftly by in vague blackness around his field. Two fearless companions worked along manipulating buttons while reading complex patterns. Flat familiar homeland now actually resembled a tiny rubber ball. Everyone here and at home knew that only lifeless things would be found among huge cold mountains surrounding deep barren valleys. But all important papers anxiously awaited their arrival for no man had ever made such big news.

Driving A Car

The strength and flexibility of this equipment is remarkable. Not everyone is capable of using it even though most try at one point or another. The soothing sounds and comfort can be deceiving. Keep in mind that all the components must be carefully controlled to prevent injury or even death. You must find a comfortable position and be ready with your hands, while at the same time, prepare one or both feet (depending upon the model). Complications can occur if you allow the equipment to become noisy or interfere with someone else. But the possibilities are limitless. In addition to being practical, it allows you to see new perspectives and opens up new territory. The initial investment may be high, but when you realize all its capabilities, there really is no other way to go.
Appendix B Comprehension Test used in Experiment 2.

Washing Clothes
1. Going to another facility refers to a place in another:
   a) state
   b) building
   c) room
   d) desk

2. The grouped items probably refer to:
   a) files
   b) paper
   c) cloth
   d) chemicals

3. The first step involves:
   a) checking the mechanisms
   b) dividing things into batches
   c) paying for the materials
   d) reading materials to avoid expensive mistakes

4. The advice is to tackle:
   a) only small amounts to minimize errors
   b) a large pile for economy
   c) larger sizes to avoid prolonging the task
   d) smaller units to maximize concentration

5. It is important to be aware that:
   a) the task is easy from the beginning
   b) people need years of education for this task
   c) errors may cost thousands of dollars
   d) the process is only complicated at the start

6. Learning how to run the equipment:
   a) may involve a good deal of errors
   b) can be determined as you proceed
   c) requires a manual
   d) should be done only with a trained expert

7. Complications can arise if:
   a) your partner is not prepared
   b) the room temperature is not regulated
   c) the wrong fuel is used
   d) the job is rushed

8. The future demands for this:
   a) could decrease depending on the market place
   b) will likely never end
   c) will remain constant due to population growth
   d) will increase as the news carries

9. You're all set if you:
   a) can do the job at home
   b) have all the necessary groups
   c) can make up what you're missing
   d) have someone to help

10. There is a slight possibility that:
    a) someday the task may be unnecessary
    b) the government will provide assistance
    c) the demand for this task will increase
    d) the demand for this task will decrease
Christopher Columbus
1. The main character had to be strong while:
   a) people doubted they would survive
   b) his eyes failed him
   c) those around him fought about his ideas
   d) his loved one was scornfully laughed at

2. The reference to "sisters" probably had something to do with:
   a) family struggles
   b) the transportation used to attain his goal
   c) friends that were very dear to him
   d) the strangers who helped him on his journey

3. The planet was:
   a) unexplored
   b) in danger
   c) protected
   d) destroyed

4. The comparison of an egg was used to illustrate:
   a) roundness
   b) a fragile nature
   c) size
   d) hardness

5. In this story, the laughter was:
   a) a sign of relief
   b) intended to deceive
   c) contagious
   d) full of scorn

6. Gems were mentioned because:
   a) the area was rich with treasures
   b) they paid for the project
   c) they were the reason for the conflict
   d) the of the main character's greed

7. Turbulence referred to:
   a) a stormy sea
   b) tensions among the people
   c) difficulty with flight navigation
   d) a destructive conflict

8. The rumors were:
   a) laughable
   b) entertaining
   c) slanderous
   d) scary

9. The creatures were a good sign because:
   a) they were worth a great deal
   b) they symbolized hope and renewal
   c) it meant they had arrived
   d) it meant the war was over

10. The sisters were searching for:
    a) peace
    b) evidence
    c) fame
    d) revenge
First Space Voyage

1. The companions were described as:
   a) brave
   b) unaware
   c) evil
   d) anxious

2. Their arrival was anxiously anticipated because:
   a) the objects they had from the blackness
   b) the solution to the complex puzzle was found
   c) they had come from an unusual place
   d) they had been missing for years

3. They knew that:
   a) all the people had died
   b) the area never supported life
   c) the experiment failed to support life
   d) the objects they left would be ruined

4. The main characters were located in:
   a) a town within a tiny valley
   b) a computer laboratory
   c) a small and cramped space
   d) in an underwater cavern

5. From their location, homeland appeared:
   a) smaller
   b) crowded
   c) lively
   d) arid

6. The "all important papers" were located:
   a) with Joe's belongings
   b) out in the blackness
   c) in the mountains and valleys
   d) on the homeland

7. On their journey, they knew they would find:
   a) papers and other remains
   b) nonhumans
   c) some living beings
   d) nonliving things

8. Upon their return, they had to:
   a) re-establish life as they knew it
   b) fill out reports
   c) talk to the media
   d) interpret their data

9. Their field was:
   a) vast
   b) green
   c) fertile
   d) tiny

10. Joe was with:
    a) one other
    b) two others
    c) a full crew
    d) his dog
Driving a Car
1. Both feet may be required if you:
   a) attempt a difficult task
   b) don't have the proper set up
   c) have a standard model
   d) are just learning how to use it

2. An important caution is that:
   a) the seat is comfortable
   b) the equipment is very strong
   c) one could misplace the equipment
   d) disassembly is very important for proper care

3. The strength of the equipment is:
   a) overpowering
   b) debatable
   c) discouraging
   d) remarkable

4. A remarkable attribute of this equipment is that:
   a) it can be used in most households
   b) capable of entertaining children for hours
   c) it can perform countless calculations
   d) it can be used in a wide variety of situations

5. To prevent injury, you have to:
   a) read the manual carefully
   b) wear the proper gear
   c) keep it headed in the right direction
   d) make sure you have the parts

6. Most people:
   a) attempt to use it
   b) never even try to use
   c) avoid using it
   d) are adept at using it

7. Signs that there are complications include:
   a) a gradual change in color
   b) a sudden change in color
   c) an increase in the sound level
   d) a decrease in the sound level

8. There is the possibility that:
   a) it could interfere with others
   b) it could be quickly worn out
   c) the wrong button could destroy everything
   d) it could be easily stolen

9. A common complaint could be that:
   a) it decreases your ability to see new territory
   b) the initial investment can be high
   c) it only allows you to see certain perspectives
   d) the capabilities are limited at the present time

10. The equipment may become noisy if it's:
    a) broken
    b) operating slowly
    c) operating quickly
    d) overburdened
Appendix C Cooking Test

1. Alcohol cannot be used to:
   a) leaven cakes
   b) preserve fruits
   c) flame an entree
   d) gel frozen desserts

2. "Halibut steaks en papillote" refers to a dish:
   a) cooked with vegetables
   b) with dill sauce
   c) sautéed in garlic butter
   d) cooked with parchment paper

3. The difference between baking powder and baking soda is:
   a) nothing
   b) baking soda is an acid and baking powder is an alkali
   c) baking powder is comprised of several ingredients including baking soda
   d) baking soda includes a powdered acid

4. Blanching is a technique used to do all of the following except:
   a) soften proteins in meats
   b) remove excess salt from bacon and ham
   c) whiten variety meats
   d) remove skins from fruit and vegetables

5. Braising is a technique used to:
   a) produce a concentrated blend of flavors
   b) enhance the appearance of food
   c) deep fry
   d) steam cooking

6. Lecithin:
   a) is frequently used as an emulsifier
   b) is usually served after dinner
   c) is used in the preparation of preserves
   d) is a sweetener used in pastries

7. Which of the following is NOT used to bind fruit and juice:
   a) baking powder
   b) flour
   c) cornstarch
   d) tapioca

8. Cooking a pie at a higher temperature for the first portion of baking and then a more moderate oven thereafter is done to:
   a) set the crust before the pie contents cook too much
   b) ensure the pie contents cook properly without burning the crust
   c) save time on baking
   d) ensure the leavening agents are activated
9. The best way to avoid "weeping" in baked custards is to:
   a) whip the eggs until fine bubbles appear
   b) cook the custard very slowly
   c) use high temperatures to bake the custard
   d) be sure the custard is fully cooked

10. Next to a nut grinder, the best way to prepare ground nuts for a flour-like consistency is to use a:
    a) meat grinder
    b) mortar and pestle
    c) meat tenderizer
    d) coffee grinder

11. Which of the following combinations represents two types of classic soup:
    a) croutons and bouillon
    b) creme and quenelles
    c) consommés and veloutés
    d) puree and aspic

12. Sour milk:
    a) can be made with by adding an extract to milk
    b) is the same as spoiled milk
    c) is sometimes called for in cake recipes
    d) can be made from buttermilk

13. Clarified stock is LEAST likely to be used in:
    a) jellied consommé
    b) chaud-froid
    c) bisque
    d) aspic

14. An extender:
    a) is a tool used to handle hot items
    b) can be added to meat loaves
    c) is an ingredient added to egg whites
    d) can be used to cool breads fresh out of the oven

15. The high content of __________ makes veal well suited to cold preparations.
    a) preservatives
    b) vitamins
    c) salt
    d) gelatin

16. When a recipe calls for zest, it is important to remember to:
    a) use a wooden spoon
    b) clean the outer layer
    c) refrigerate the product before hand
    d) be enthusiastic

17. Which of the following is NOT a basic type of sauce:
    a) suspensions
    b) starch-thickened
    c) reductions
    d) transformational
18. The term reduction refers to:
   a) a technique used to liquefy substances
   b) a method of concentrating flavors
   c) the process of clearing out food items that are no longer fresh
   d) a method of heating during cooking

19. Creme fraiche is most closely similar to:
   a) frozen yogurt
   b) sweet whole milk
   c) heavy cream
   d) ice cream

20. If frying ingredients at high temperatures, it is best to use:
   a) sweetened butter
   b) chilled butter
   c) clarified butter
   d) unsalted butter
Appendix D Passages used in Experiment 4.

The Process of Baking
Unlike other cookery processes, baking involves relatively pure substances in precise chemical relations with each other. Each of the ingredients, their proportions, their handling, and their treatment when combined, will be reflected in the product. One of the most important ingredients is flour. Flour acts as a binder for the other ingredients in the mixture and gives form to the final product. Several types of flour are available: bread, cake, all-purpose, each in many brands. The baking properties of any flour depend on the grain from which it is milled, the fineness to which it is ground, its aging, and the chemicals added to it by the miller. As far as the home cook is concerned, the ratio between the protein, called gluten, and the starch is the most important factor. A high-gluten flour will make a tough elastic dough, good for bread, bad for pastry and cakes. In fact, it is the gluten with which the cook is constantly concerned. For example, if the water and flour are not well mixed in a pastry, too much water will come into contact with the gluten. Or if the pastry is stirred the gluten will be developed. Pie crusts are crumbly, dry, stringy, mealy all because of gluten development. 208

Spring Lamb
Lamb should be cooked only until slightly pink, or medium. It should never be as rare as beef is requested at times, and it will look gray and unappetizing if cooked well done. Rosemary, sage, and basil are three herbs well suited to season lamb. I especially like rosemary, and we sprinkle a few of the pine needle-shaped leaves on the lamb before roasting, and then use some in the lamb sauce. Caution is necessary because the herbs are strong, and too much will take the delicate lamb flavor away. Garlic is also very compatible with lamb, and when used with care, is a very fine seasoning. In French cuisine, finely minced garlic is smothered in butter, some white bread crumbs are added and toasted until lightly browned, and finally some chopped parsley is added to the mixture. This is called "persillade" and is applied or sprinkled over the roast a few minutes before it is taken out of the oven. Roast lamb is always served with a little lamb sauce which can be quickly made with bones and pan juice. The sauce should not be very thick, yet it should have a little body and not run off like roast beef juice. If you want to use wine in the sauce, it should be white wine rather than red wine. If you have chosen to flavor the lamb with a particular herb, it should also be represented in the sauce. 241

What Makes Sauces Separate?
This condition can be caused by a number of things. In some cases, the egg yolks may not have been cooked enough to permit the yolks to absorb the large amount of butter. In other cases, the egg yolks may have been cooked too much, with too little water, and you have scrambled egg yolks and they cannot absorb any butter, either. In still other cases, the butter may have been too hot, and, finally, the sauce may have been left on a spot that was too hot and that caused it to separate. In all of these cases, the sauce should be left to separate completely, and be permitted to cool down to about 100 degrees F. Then a few tablespoons of hot water are put into a bowl, and drop by drop, a little of the broken hollandaise is added, stirred well into the water, gradually an emulsion is worked up so that the sauce becomes smooth again. If there is no time to cool the sauce down, the same method can be tried using a little ice water or crushed ice instead of the hot water. Again, the sauce is added gradually to the ice-cold bowl and worked back to a smooth sauce. If the egg yolks were overcooked, it is better to start from scratch with a few fresh eggs yolks and try to work the broken sauce in along with a little fresh, melted butter. In this case, the sauce will no be smooth, but you can try to salvage the sauce by straining it though a very fine strainer. 263
The Mexican Jumping Bean
Among the most fascinating of the wild plants in the vast southwest desert region of North America is the Mexican jumping bean. The beans are produced by a small native shrub that grows wild in the deserts of Mexico and in the rugged Cape region of Baja California. The remarkable "beans" jump and roll about with seemingly perpetual motion that is accelerated when the beans are in bright sunlight. However, the actual jumping "bean" is not a bean at all, nor is it a seed. The jumping bean is actually a small, thin-shelled seed pod or capsule which contains the larva of a small gray moth called the jumping bean moth. The robust, yellowish-white larva throws itself forcibly back and forth against its walls after the jumping bean moth larva consumes most of the seed within the pod. This causes the jumping movements of the capsule. Larvae become more active when warm, and that is why the movements of the jumping beans intensify in the sun. Jumping beans can continue their movements and vibrations for weeks or months only if they are placed in a container where they can get air. Their life cycle will be terminated when they finally die as the adult moths emerge from the beans up to six months later.

Swordmaking
Swordmaking plays a unique role in the culture of the Japanese, who have always been credited for manufacturing quality swords. As some of the most respected craftsmen in history, Japanese swordmasters were the creators of these formidable weapons. The swords are forged by a process called lamination in which steel is heated to very high temperatures and then pounded into thin sheets. As the blades were given from father to son through generations of the same family, the swordmaster's craft was also passed down. If on occasion there were no family member to carry on the tradition, a swordmaster would then take an apprentice. This would ensure that the secrets of the lamination process would not be lost. The signatures of these craftsmen is one thing that collectors look for when appraising the value of a sword. Made by placing pressure-sensitive paper over the blade of the sword and gently scraping with a plastic spoon, these rubbings expose their signatures. Even though signature markings help an expert to estimate a sword's value, the true assessment of the sword depends upon the detail of its manufacturing. Facilitating the appraisal of a sword's value when a signature is not present, the shape of the blade and file markings along its edge both contribute to documenting the manufacture and history of the sword. Thus, there are many features of a sword's history and quality of construction which contribute to its value.

Whales
There are two different kinds of whales, baleen whales and toothed whales. The main difference between the two is the way in which they catch their food. Baleen whales feed by sifting plankton directly out of the ocean through a structure called a baleen. The baleen looks like a huge mustache which hangs just inside the mouth where it can trap tiny creatures as water flows in and out of the whale's mouth. Some of these whales are called "skimmers," swimming close to the surface with their mouths open. Other baleen whales are called "gulpers" because they start feeding by gulping huge amounts of water and plankton into their mouths. The plankton are caught in its fringed edges and swallowed as the tongue forces the water out through the baleen. Whales that do not have baleen have teeth. Toothed whales catch only one animal at a time, by grabbing prey with their large teeth and swallowing it whole. These whales have different sizes and shapes of teeth which are related to the size and type of their prey. Toothed whales with many small, sharp teeth feed upon smaller fish. Those with only a few large, teeth are able to catch larger fish and squid.