INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI®

Bell & Howell Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

A

TWO GENERATION TASKS: AGE-RELATED DIFFERENCES IN ITEM AND SOURCE MEMORY

by

Inbahl Heth

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2000

UMI Number: 9986337

Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

7-19-00

Date

Chair of Examining Committee

7-25-00

Date

Executive Officer

Wilma A. Winnick, Ph.D.

Doreen Berman, Ph.D.

David Friedman, Ph.D.

Rhea Dornbush, Ph.D.

Alan Kluger, Ph.D.

Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

ABSTRACT

Two Generation Tasks: Age-Related Differences in Item and Source Memory

by

Inbahl Heth

Adviser: Wilma A. Winnick, Ph.D.

Young and old adults studied words under three encoding conditions: A baseline Read condition requiring the target word to be read along with its definition; a Generate Word condition which presented a definition as cue to word generation; and a Generate Definition condition where the target word was the cue for the generation of its definition. Elaborative definitions were presented in the Read and Generate Word conditions of Experiment 1, while shorter definitions were used in Experiment 2.

Memory for the taget words was tested after a short delay. Following recognition of a word (item memory), participants indicated the study condition in which it was encountered (source memory). Results of both experiments showed that for both age groups, item and source memory scores were directly related to the amount of generative processing, i.e., lowest scores following the Read condition, and highest following the Generate Definition condition. Older adults benefited from generative processing at least to the same extent as younger adults. Age differences in recognition scores were greatest for items from the Generate Word condition and smallest for items from the Generate Definition condition.

Results of Experiment 2 showed that shortening the definitions reduced item and source memory scores in the older group but had no effect on the younger group. These results reflect the ability of young adults to process material in an elaborative manner spontaneously, making up for the missing details, while older adults depend on receiving elaborately processed material in the form of more detailed definitions. The Generate Definition condition was unaltered between the two experiments, and indeed yielded very similar recognition and source memory scores in both age groups, confirming reliability of procedures. Both experiments showed better source memory in the young compared with the old group, even when recognition memory was no different from that of young adults (Experiment 1), demonstrating that source memory is weaker than item memory and more susceptible to age-related decline.

ACKNOWLEDGMENT

This dissertation could not have been accomplished without the contributions of several individuals who dedicated of their time, energy, and support. Foremost among them is my adviser and mentor Dr. Wilma Winnick with whom I am privileged to have worked. Her experience, knowledge, kind nature and positive attitude were invaluable to me as we molded this project from inception to completion. Dr. Winnick dedicated many hours to reviewing and revising the drafts of this dissertation. Her belief in the value of this work was inspiring and encouraging to me. For all these I am most grateful.

My sincere gratitude and appreciation is extended to Dr. Doreen Berman and Dr. David Friedman for graciously agreeing to serve on my committee, for accompanying this study from its early stages, and for contributing their knowledge and experience to guide me along the way. Thanks are also extended to the outside readers, Dr. Rhea Dornbush and Dr. Alan Kluger, for dedicating their time and providing thoughtful comments. I am also grateful to Dr. Philip Ramsey for his valuable assistance with the statistical analyses, and to John Zhu for computer programming.

Honorary mention is also due my dear friends who were a surrogate family to me in this foreign land: Frida Kleiman, Naomi Amir, Pooa Bloomberg, Yael Cycowitcz, and Roni Geva. My years of study would have been dull and dreary without their support, companionship, good humor and encouragement.

Last but not least, I wish to acknowledge my beloved family—my brother Carmel for his kind words and cheerful personality, and my parents Erella and Dan, whose love, support and devotion sustained me throughout this arduous endeavor. I could not have made it without you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This study compared young and old adults on item and source memory performance for words presented in three processing conditions. Two of the processing tasks were generative in nature: in one, the target word was generated from its definition, and in the other, a definition was generated from the target word. The third task was a nongenerative control condition, requiring the passive reading of both target word and its definition.

Predictions for both young and old memory scores for target words were based on the assumptions, first, that generative processing enhances item memory by adding an enriching network of associations to the item and, second, that this associative network is more effective when it is initiated by the target word rather than when it serves as the generating cue. Both young and old were predicted to show this hierarchy of recognition scores: lowest scores for words read with their definitions, intermediate scores for words generated from definitions, and highest scores when definitions were generated from the target words. However, young and old were expected to differ in item memory, showing the greatest divergence in scores for the control condition and the least for the definition-generating condition.

As for the source scores, they were predicted to produce effects paralleling the hierarchy described for the target words. This prediction stems from the nature of the source task which required identifying the cognitive operations performed on the target word during encoding. Such an effect differs from the typical source paradigm, requiring identification of extrinsic, episodic details such as auditory or visual modality of input or gender of voice delivering each item. It was predicted that elaborative processing would reduce and possibly eliminate age-differences in source memory.

Much of the framework for this study, in particular the view on age differences, was provided by the theoretical formulation of Craik (Craik, 1983; 1984; 1986; Craik & Jennings, 1992). According to Craik, age-related decline in memory performance is due to a reduced tendency to encode information in an elaborative manner. Thus, as people age, they tend to encode information with fewer contextual details, arousing fewer associations. Elaborative encoding is taken to be a process stimulating the activation of a rich associative network and requiring the expenditure of cognitive resources. These resources are assumed to be in increasingly limited supply as we age. Therefore, while elaborative processing is spontaneously performed by young adults, it is not easily utilized by older persons, resulting in stereotyped, impoverished processing.

Another facet of Craik's (1984) theory is that the ability for more efficient processing is not entirely lost with age but can be induced by appropriate experimental manipulations. Moreover, Craik asserted that, at least for some tasks, older adults possess a potential for memory performance equaling that of young adults. This potential can be expressed if the older participant receives environmental support, in which "...the operations are induced and guided by the task, by specific instructions, or by other supportive aspects of the current environment" (p. 10). The present study attempted to apply the environmental support hypothesis using the manipulation of generation, which involves an active form of processing at encoding. Generating a response (usually a single target word) has been shown to result in better memory for the word compared to passively reading the same target word. Furthermore, young and old adults were shown to benefit from the generation effect, sometimes to the same extent.

Within the field of memory research, various approaches to the study of age-related changes in memory have been used, each conceptualizing memory from its own perspective. The following literature survey begins with a description of some of these theories followed by a review of studies of the generation effect and of source memory.

Theories of Age-Related Memory Decline

The Cognitive Psychology View. In the last two decades, the leading theoretical perspectives of cognitive psychologists regarding age differences in human memory fall under the general heading of cognitive, information-processing points of view. In their chapter on human memory, Craik and Jennings (1992) describe three broad theoretical perspectives, namely memory stores, processing models, and memory systems, which are outlined below.

The dominant viewpoint in the 1960s and 1970s was that human memory is composed of different stores, containing information at successive levels of processing. Murdock (1967), proposed a "modal model", which held that perceived information is first held briefly in modality-specific sensory registers. Attentional processes then select pertinent information and pass it on to limited capacity short-term memory. The short-term memory store integrates the incoming material with previously learned information and makes it available to conscious awareness. The final stage is the transfer of the material to a more permanent long-term memory store. This "transfer" is presumed to depend on rehearsal and learning operations. According to the memory stores approach, age-related memory decline can stem from biological changes in structural components such as reduced capacity, faster decay, or greater vulnerability to interference.

Alternatively, aging could affect the processing aspects, in particular the "transfer" of information from short-term to long-term storage. However, Craik and Lockhart (1972), noted that once transfer becomes the central issue, the structural assumptions of storage become less useful, and memory can be studied in terms of the encoding and retrieval operations themselves—forms of active processing.

Baddeley's (1986) model of working memory originated from the theoretical framework of memory stores. In this model, structural components (e.g., the phonological store) are combined with processing activities (e.g., the articulatory loop). A third component termed the "central executive" was assumed to coordinate the flow of information among the structural and processing units. The coordination of attentional resources gives working memory a key role not only in memory, but also in learning, reasoning, forward planning, and other cognitive processes. Executive type processes show clear deterioration in Alzheimer's disease (Baddeley, 1992; Becker, 1988), which many researchers believe to be an extreme case of the cognitive decline seen in normal aging (e.g., Drachman, 1983; Nebes, 1992). Thus, in this view, working memory plays a part in age-related cognitive decline.

Several researchers adopted Craik and Lockhart's (1972) line of thought, conceiving of human memory in terms of processes (mental activities) rather than stores (mental structures). Craik and Lockhart suggested the very influential idea of levels (or types) of processing, according to which the type of processing performed at study determines memorability during later testing. Kolers (1973), proposed that the process of retrieval be regarded as the repetition of operations performed during acquisition. Tulving & Thompson (1973) added that retrieval cues are effective to the extent that they help reinstate the original encoding process. Whereas in the stores model short-term memory was presumed to store the information for a given time, in the processing model short-term memory are those processing operations that are presently at work. In this model, the effect of aging may be seen in the nature of the operations performed on the material, the number of processes that can be carried out simultaneously, the influence of context on encoding, and the ability to repeat encoding operations at the time of retrieval. The main criticism of processing models is that they are poorly specified, outlining general principles rather than precise procedures. As a consequence they do not easily lend themselves to validation or refutation.

A third theoretical approach to the study of human memory, with Tulving (1972, 1983) as its major proponent, is that of memory systems. This approach is similar in kind to memory stores and does not emphasize processing. Neuropsychologists and neuroscientists find this approach appealing because different systems can be identified with specific brain structures. Here age differences can be sought in comparing the effect of aging on the various systems.

Tulving (1972) conceived of two interacting memory systems: *episodic memory* for personal events and their circumstances, and *semantic memory* for general knowledge and facts that do not vary from one time and place to another. Warrington and Weiskrantz (1974) reported a third type of memory which was found to exist in amnesic patients, later termed *procedural* or *implicit memory*. This type of memory was evidenced by improved performance on certain motor and cognitive tasks without the patients having any conscious recollection of prior experience with the task. That is, the procedural system appeared intact in amnesic patients who had severely impaired episodic memory.

The procedural memory system was later demonstrated in healthy normal individuals (e.g., Graf, Mandler & Haden, 1982; Jacoby & Witherspoon, 1982; Tulving, Schacter & Stark, 1982). Tulving (1983, 1985) proposed that the three memory systems develop in sequence, with the procedural system developing first, followed by the semantic and finally the episodic system. Such an interpretation would be consistent with the finding that only procedural memory remains available to patients who are deeply amnesic for autobiographical events. With relation to aging, the question was whether the systems that mature later in life would be those that are lost first when memory declines.

The core argument in support of the systems approach has been the experimental findings of dissociations between tasks assumed to depend on the integrity of different systems. However, as experimental evidence accumulated, in particular with regard to implicit memory data, dissociations were found between tasks that were presumed to depend on the same memory system. For example, a dissociation was found between perceptual and conceptual implicit memory tasks (Blaxton, 1989), but also between priming on two perceptual implicit tasks (Witherspoon & Moscovitch, 1989). Under the initial premise, such findings would argue for further division and subdivision of systems, making the theory less useful. An alternative interpretation of the dissociations would be that performance on any memory task depends on the particular study and test requirements (e.g., Jacoby, 1983; Roediger, Weldon, & Challis, 1989). Such an approach represents a swing of the pendulum back toward processing views. As noted by Roediger and McDermott (1993) "If one defines a memory system as whatever neural structures underlie performance on a particular test, then there is no distinction to be made between processing and systems theories" (p. 120).

Global Neuroanatomical Correlates of Cognitive Aging (Raz, 1999). Aging is associated with numerous alterations of brain structure and function. Age-related changes that affect the total volume of the brain and the integrity of the white matter predict global decline of cognitive functions. Post-mortem studies of the aging brain consistently show a progressive decline in brain weight and volume of about 2% per decade (Kemper, 1994). CT studies show the gyri shrinking in size while the sulci and ventricles widen (Stafford, Albert, Naeser, Sandor & Garvey, 1988). This finding was confirmed by MRI studies showing age-related reduction in brain volume with the estimated correlation varying between r = -.60 and r = -.20 (Blatter et al., 1995; Raz, 1996). Most of the atrophy is in the cerebral cortex with the frontal lobes (especially prefrontal cortex) most heavily affected, followed by temporal lobe (hippocampus) which is moderately affected, the occipital cortex is mildly affected, while the pons seems to be unaffected by age (Raz, 1999). Thus, those parts of the brain which are the latest to develop (phylogenetically and ontogenetically) are also the most vulnerable to the effects of aging. The marked reduction in the volume of the prefrontal cortex is comparable in magnitude to other profound and well-established features of aging such as decreased lung capacity, reduced skin elasticity, drop in maximum oxygen uptake, and hearing loss (Balin, 1994). Interestingly, the change in volume of the hippocampal formation is only mild in normal aging. Early attempts to correlate brain structure, as observed on CT, and cognitive aging revealed an association between general atrophy and performance on a battery of neuropsychological tests in healthy older adults (e.g., Albert, Duffy, & Naeser, 1987). More recent MRI studies correlating reduced volume of the cerebral hemispheres with measures of cognitive performance and found r = -.22 (Gunning-Dixon & Raz, 1999, in Raz, 1999).

Cognitive aging parallels the pattern of preserved and impaired brain regions. For example, episodic memory and executive functions show a greater age-related decline than semantic memory and verbal reasoning. Moreover, tests of episodic memory requiring generative effort such as free and cued recall are more sensitive to aging than recognition memory, while least impaired is repetition priming (LaVoie & Light, 1994; Verhaeghen, Macron, & Gooses, 1993). Age-related declines in various aspects of prefrontal cortex appear specifically related to well-established deficits in executive functions (Raz, 1999).

Many studies suggest that a large proportion of the variance in cognitive performance with aging can be attributed to two factors: generalized age-related slowing and reduced capacity of working memory (Meyerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1996; Verhaeghen & Salthouse, 1997). Reduced information processing speed can be attributed to structural changes in cerebral white matter as seen in diseases of demyelination (Kail, 1998), and has been related to increased white matter abnormalities (Gunning-Dixon & Raz, 1999). Cognitive performance of older adults has been shown to drop dramatically when white matter lesions increase beyond a critical level (Boone et al., 1992). This finding led to the suggestion that the association between cognitive aging and cerebral white matter was a threshold phenomenon. Functional neuroimaging studies raised the possibility that reduced information processing speed reflects the need of older brains "to recruit additional resources to manage the executive overhead of otherwise simple and largely automatic tasks" (Raz, 1999, p. 65). In such a case a circumscribed deficit in executive functions could result in generalized cognitive impairment. Several other cognitive neuroimaging studies found that older brains usually do not demonstrate a well defined pattern of activation compared with young adult brains, and exhibit a more wide-spread activation, occasionally of lesser magnitude (Grady et al., 1995; Kohler, Moscovitch, Winocur, Houle & McIntosh, 1998). Such findings suggest that the older information processing systems cope with decline in task-specific resources by broadening their recruitment base.

The Neuropsychological View. A primary assumption of the neuropsychological view is that normal memory depends on the integrity of a wide network of prefrontal and limbic structures that are sensitive to normal aging to various degrees. Studies in neurological patients reveal that the most prominent of these brain areas is the hippocampus and surrounding medial temporal lobe (Milner, 1966; Zola-Morgan, Squire, & Amaral, 1986; Hyman, Van Hoesen, & Damasio, 1990). Squire (1992) attributes the formation and maintenance of memories to the hippocampal formation and associated structures. It is generally believed that explicit (declarative) memory depends on two subdivisions of the CNS: the limbic-diencephalic system and the prefrontal cortex (for a review, see Nyberg, Cabeza, & Tulving, 1996; Squire, 1992). However, there is little agreement on the exact role played by specific limbic and anterior association structures in various memory functions. A study of healthy older adults (Golomb et al., 1994) found that delayed recall was significantly correlated (r = .49) with the volume of the hippocampal formation. The correlation did not change much after controlling for age, sex, and vocabulary scores. Several of the original participants were retested four years later (Golomb et al., 1996). It was found that a reduced size of the hippocampal formation predicted a decline in performance on memory tests. However, other studies yielded contradictory results (Raz, Gunning-Dixon, Head, Dupuis & Acker, 1998).

Tulving and his colleagues (Nyberg, Cabeza, & Tulving, 1996; Tulving & Markowitsch, 1997) developed a model they termed hemispheric encoding-retrieval asymmetry (HERA) which describes multiple cortical structures as participating in the mnemonic act. According to the HERA model, *encoding* of episodic memories is primarily mediated via the *left prefrontal cortex,* while *retrieval* depends more heavily on the *right prefrontal cortex.* Functional neuroimaging studies show that in young adults, retrieval of episodic information also activates the anterior cingulate, the cuneus-precuneus, the thalamus, and the brain stem. Encoding does not involve as much activation as retrieval in prefrontal areas and is associated with increased rCBF in bilateral temporal and entorhinal cortices, left fusiform gyrus, and the right parahippocampal gyrus (Tulving & Markowitsch, 1997).

Long before neuroimaging techniques were developed, localization of psychological functions to brain structures was inferred from patients with focal brain lesions and from dissociation paradigms. Pros and cons of dissociation paradigms in the study of cognitive aging (see Moscovitch & Winocur, 1992, for a review), are mentioned here due to their relevance to studies of experimental psychology in general and the present study in particular. Experimental psychologists use these paradigms to infer stochastic independence of two experimental measures and usually do not focus on the underlying neural substrates mediating the performance. Neuropsychologists traditionally used dissociation paradigms to reveal which brain areas mediate a specific function and make it possible to predict structural damage from behavioral decline, as well as the reciprocal prediction of functional impairment from the location of a lesion. Localization of functions was possible by examining patients with different focal brain lesions who demonstrate loss in different functions. The ideal finding is that of double dissociation (Teuber & Milner, 1968) in which a lesion to structure A results in impairment in function A while sparing function B, whereas a lesion to structure B results in impairment to function B while sparing function A.

There are difficulties in applying double dissociation experiments to the study of aging. One difficulty is that healthy elderly people do not usually have focal brain lesions but, rather, a generalized deterioration involving many structures (see above). Moreover, the same structures are affected in most old adults. A way of bypassing this impediment is the establishment of normative samples for brain anatomy and psychological functioning. Such baselines allow the comparison of structural with functional changes in healthy older adults. Once it is established that certain tests are a valid measures of localized brain atrophy, they can be used as evidence for structural damage which would otherwise require neuroimaging or histological techniques for verification. This approach has the advantage of being relatively inexpensive and simple to administer compared with the more direct measures of neuroimaging which require complex apparati and a large financial investment. A modified double dissociation experiment can then be conducted that would correlate performance on two psychological tests (evaluating different functions) with the degree of deterioration of two brain structures (Jernigan, 1986). If a test or a group of tests evaluating a common function is correlated with deterioration of one brain structure and not another, and the reverse is true for another test, a double dissociation has been established. Functional dissociations, inferred from stochastic independence between neuropsychological tests, demonstrate divergence in cognitive abilities, and are often tested in healthy rather than patient populations. In the present study, the groups by tasks design has been utilized to search for age-based task dissociations.

When double dissociation studies are not feasible, single dissociation experiments are the best alternative. Such experiments evaluate the effects of damage to only one area of the brain by showing impaired performance on tests associated with a particular function and not on other tests. The disadvantage of single dissociation experiments stems from their inconclusiveness since the possible contribution of other brain areas to performance on this particular test is not evaluated. They also have limited precision and may be influenced by factors other than the integrity of brain structure, e.g., education, emotional state, and cultural background. When applied to aging research, single dissociation experiments are those in which atrophy to a certain brain structure is correlated with performance on tests mediating a specific function but not on tests mediating other functions. Performance of young and old subjects on these tests is compared, and results are related to postmortem studies of brains of matched individuals (Huppert, 1991). However, as mentioned earlier, age-related deterioration is found in many brain structures and in many cognitive functions with concomitant decline in performance on a variety of tests. It, therefore, becomes difficult to draw conclusions regarding causal relationships between performance on certain tests and damage to a particular structure.

When the focus of interest is structural impairment, neuroimaging techniques are preferred. Structural neuroimaging, e.g., MRI, provides images of high spatial resolution, while functional neuroimaging, e.g., fMRI and PET, provide images reflecting changes in brain activity while participants perform cognitive tasks. Structural neuroimaging studies are, therefore, useful for comparing long-term changes in the brain but do not reflect age-related changes in brain activity while the brain engages in cognitive functions. Functional neuroimaging (fMRI) is better suited for observing age-related changes in cognitive functioning as they occur.

In ten functional neuroimaging studies of *encoding* (7 PET, 4 fMRI), the most consistent finding is that older participants either show reduced activation in the left inferior prefrontal cortex (i.e., area 47; Cabeza, Grady et al., 1997; Cabeza, McIntosh, Tulving, Nyberg & Grady, 1997; Grady, McIntosh, Rajah, Beig, & Craik, 1998) or fail to activate that area at all (Grady et al., 1995). Age-related reduction of the activation of the anterior cingulate gyrus was also observed (Cabeza, Grady et al., 1997; Grady et al., 1995; Madden et al., 1996). Neuroimaging of age differences during *retrieval* reveal that young participants show increased activation in the right prefrontal regions (Cabeza, Grady, et al., 1997; Grady et al., 1995; Schacter, Savage, Alpert, Rauch, & Albert, 1996), while older participants show increased rCBF of either the opposite hemisphere (Madden et al., 1999) or of both prefrontal regions at once (Cabeza, Grady, et al., 1997; Grady et al, 1995). The added activation of the left prefrontal cortex in older adults could be due to increased difficulty of the task. In young adults more difficult tasks induce increased activation of the left prefrontal area (Nolde, Johnson, & Raye, 1998). Older brains show reduced activation in the areas activated by young adults. In addition, activation is less focused and more widespread, involving areas not activated by young adults. It appears as though older brains need "to recruit additional resources to manage the executive overhead of the task," (Raz, 1999), i.e., activate additional brain areas to those activated by young adults.

The effect of task difficulty on age differences in regional activation were examined during explicit retrieval of study material (Schacter et al., 1996). Participants performed a word-stem completion task on two sets of words, one studied under semantic encoding conditions and repeated four times, the other under perceptual encoding conditions and repeated once. Word-stem completion of the latter list was expected to be more difficult and to result in many failures. It was thus possible to compare retrieval attempt with retrieval success. Actual recollection of study words was accompanied by increased rCBF to the hippocampus in both young and old. However the two age groups differed during the more effortful retrieval attempt, the young showing increased bilateral anterior prefrontal activation, while the old showed more posterior frontal lobe activation. The authors concluded hippocampal activation during successful retrieval is age invariant whereas effortful retrieval attempt involves different frontal lobe regions in young and old and may reflect age-related changes in retrieval strategies.

An example of a functional single dissociation is most relevant to the present work. It comes from studies of source memory in patients with frontal lobe lesions and elderly adults (described more fully in the following sections). Stated briefly, Schacter, Harbluk, and McLachlan (1984) mentioned a correlation between source memory deficits in amnesic patients and their performance on a test of frontal lobe functioning (the Wisconsin Card Sorting Test – WCST). The source memory deficit was not correlated, however, with the degree of amnesia. The question then became whether source memory was dependent on frontal lobe integrity. Janowsky, Shimamura, and Squire (1989) showed a dissociation such that patients with frontal lesions who were not amnesic were impaired on source memory tasks whereas amnesic patients with intact frontal lobes had no differential impairment in source compared with item memory. Craik and his colleagues (McIntyre and Craik, 1987; Craik, Morris, Morris, & Loewen, 1990) showed this functional dissociation in an elderly group. They found that source memory deficit was related to performance on the WCST, implying frontal lobe involvement.

Several other studies found double dissociation between item and source memory using standardized neuropsychological tests (e.g., Glisky, Polster, and Routhieaux, 1995), event-related potentials (e.g., Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999), and functional neuroimaging (Cabeza, Anderson, Mangels, Nyberg, & Houle, 1999), and are described in some detail below, under neuropsychological studies of source memory in the elderly.

The Attention and Information-Processing-Speed View (Hartley, 1992). Salthouse (1985a, 1988a, and 1988b) proposed that reduced attentional functioning in aging is due to a reduction in energy resources supporting cognitive processing. Hartley (1992) argued that attention itself is often considered a resource in which case Salthouse's explanation is circular and not a true explanation. However, if attention were viewed as a filter for selecting tasks or dealing simultaneously with more than one task, then a decrease in this resource would explain age-related decline in many areas. Hartley added that "Agreement on techniques for measuring attentional capacity independent of the performance to be explained would come only after there was agreement on the nature of the capacity or capacities" (Hartley, 1992, p. 6). Therefore, until a more specific definition of the hypothesis of reduced attentional energy is proposed, it does not provide clear predictions, which lend themselves to research scrutiny.

Hasher and Zacks (1988) suggested a more narrowly defined resource hypothesis.

They proposed that aging impairs inhibitory functioning and that "older adults have attentional deficiencies in the mechanisms that control access to activation" (p. 168). Reduced inhibition is observed for example in more frequent intrusions of personal stories into text recall by older adults (Hasher & Zacks, 1988) and in losing train of thought or difficulty remaining focused on a topic due to intrusions from associations triggered by the details or context of the speech (Gold, Andres, Arbuckle, & Schwartzman, 1988). Viewed in this way inhibition can be considered a resource because it is essential for higher level cognitive functioning. It is different from 'energy resources' in that there is no assumption as to a final amount of inhibition capacity, and it is more similar to the ideas of processing speed advanced by Salthouse (1985a, 1988b). Hartley (1992) notes that reduced inhibition has the advantage of explaining diverse cognitive functions, which involve focusing on target stimuli while ignoring distractors. By the same token it could explain age-related difficulties in divided attention tasks. The prefrontal (primarily orbitofrontal) cortex is generally accepted as the region associated with inhibitory control. Other studies disagree with the hypothesis of generalized "reduced inhibition" in aging. For example, a study comparing several measures of inhibitory processing in aging found older adults to have reduced inhibition in only two of six inhibitory measures. They concluded that "age related inhibitory failures are specific rather than general in nature" (Kramer, Humphrey, Larish, Logan, & Strayer, 1994; p. 509).

One theoretical model of cognitive aging, which is relevant for attention as well as memory and reasoning, is that of general cognitive slowing (Cerella, 1985; Hale, Myerson, & Wagstaff, 1987; Salthouse, 1985a). Many examples of cognitive slowing exist in the literature (e.g., Cerella, 1985; Salthouse, 1985a). A physiological mechanism for slowing can readily be conceived of, such as slowing or reduced efficiency of synaptic transmission (Myerson, Hale, Wagstaff, Poon, & Smith, 1990). This theory would predict the growing gap in reaction times on various tasks with increasing age. Since age-related slowing is almost taken for granted, the question often becomes: Is there an age-difference in cognitive functions beyond that which could be explained by slowing alone? Thus, to be considered a significant age-related effect, a disproportionate slowing, beyond the predicted rate, should be observed in the older group. Such findings were indeed demonstrated in various studies (e.g., Madden, 1986, 1987).

Salthouse's (1988a) Activation Model. Although many cognitive functions deteriorate with age, others do not. A distinction is often made in the literature between two forms of cognition – one corresponding to basic capacity involving reasoning, synthesis and invention, and termed *fluid intelligence* because it can 'flow into' a wide variety of intellectual activities (Horn, 1967). The other form of cognition involves changes in behavior and perceptual organization induced by the first factor, and termed *crystallized intelligence* (Horn, 1967). Salthouse (1988a) called the first form "process" because it reflects the operations that enable knowledge acquisition and the latter "product" because it reflects the acquired knowledge. Fluid intelligence or 'process type' of cognitive functioning deteriorates with age. Crystallized intelligence or 'product type' of cognitive functioning continues to accumulate with age, or at least is not as susceptible to age-related cognitive decline. Salthouse argues that most theories of cognitive aging attempt to explain the decline in various abilities and ignore the stability or even improvement in other cognitive functions. As such, they offer at best a partial explanation for age-related cognitive changes, since a good theory has to be able to explain both aspects of age-related cognitive change.

Salthouse (1985b) reported a meta-analysis of age comparisons in cross-sectional studies of three major areas of cognitive functioning: memory, reasoning, and spatial abilities. In this meta-analysis 67 contrasts of memory performance revealed that the average scores of older adults were 1.26 standard deviations lower than scores of young adults (expressed in young adults standard deviations). For 22 spatial ability contrasts the value was –1.27, and for 22 reasoning contrasts it was –1.60. Such findings make clear why different normative standards exist for different age groups. An average score by a healthy older person would be considered below the norm if obtained by a younger adult. Thus, there is little doubt as to the deterioration of cognitive abilities with age. In the same meta-analysis correlations were computed between test scores and age. The mean correlation of 22 memory measures with age was -.33, for 18 spatial measures it was -.38, and for 14 reasoning measures it was -.35. Therefore age can account for 10%-14% (correlation squared) of the variance in performance of young and old, which is considered a large effect size and therefore merits investigation. Nonetheless, it is interesting to note that most of the variance on these tests was unrelated to chronological age.

A few years later, Salthouse (1988a) proposed a model for a theory of cognitive aging based on a metaphor of a spreading-activation through an associative network. (This is only one of several network models proposed in recent years.) The network is composed of nodes, representing concepts, with many interconnections, representing associations. The organization of the network is hierarchical and resembles the structure of the central nervous system, with the lower levels analogous to sensory input and higher levels analogous to more abstract forms of processing. A key factor in this model is the capacity for parallel processing within and between levels, and bi-directionality of information flow between the lower and upper levels. Some models also allow for inhibition of competing nodes. Because such models were successfully used to simulate phenomena in learning and memory (McClelland & Rumelhart, 1985), word and speech perception (McClelland & Rumelhart, 1981; 1986), and language acquisition (Dell, 1985; Sabbah, 1985), an attempt was made to apply it to age-related cognitive changes.

Salthouse (1988a) suggested several ways by which processing efficiency could be affected. A network could enhance its activity by increasing the number of viable nodes while keeping the number of connections intact, by increasing the number of interconnections between existing nodes, or by varying the strength of different interconnections without changing the number of nodes or the number of connections. Increasing the number of nodes is analogous to acquisition of new facts (not necessarily adding new neurons but attaching meaning to previously undifferentiated ones). Increasing the number of connections is analogous to increasing associations between the same group of facts, and varying the strength of different interconnections relates to organizing acquired knowledge by giving different weights to various concepts and associations.

A reduction in network efficiency, which is analogous to cognitive decline, could also be conceived of in several ways. One example of inefficiency is a reduction in the number of nodes that can be simultaneously active. Such a limitation is analogous to decreased working-memory capacity, and similarly implies that certain types of operations would be delayed or even not be carried out at all. Another example of network inefficiency is a limitation on the amount of activation available to the system. This limitation is analogous to reduced attention or lower energy resources necessary for cognitive processing. A third way by which the network functioning may be limited is through a reduction in the speed of spreading activation or information exchange between nodes. Under such conditions processes requiring simultaneous activation will be impaired. The psychological analogy is reduced information processing speed and its effects on many types of cognitive operations.

The proposed model seems promising in being able to predict both enhancement and decline of cognitive function, but there are complications. More than one of the alternatives for accumulation of information may be functioning at a given time, and so far there is no easy way of distinguishing among them. A similar argument is applicable for processing decline. The inability to distinguish among the various alternatives would make it difficult to attribute performance to a particular mechanism. Nevertheless, the associative network model has the advantage of having specific testable predictions. Therefore, at least in a formal model (computer simulation) it is possible to test each type of processing limitation.

The Environmental Support Hypothesis. The present study was designed with the viewpoint that some of the cognitive decline seen with aging is not due to loss of ability as much as reduced efficiency in processing information. Such a viewpoint is congruent with opinions of several scholars of cognitive psychology, most prominent of whom is Craik (Craik, 1984; Craik & Jennings, 1992; McFarland, Warren, & Crockard, 1985). According to this viewpoint young people encode information in a rich, meaningful, and elaborate fashion, i.e., more details of a stimulus and its context are encoded, and a wide variety of associations (semantic, perceptual, emotional, etc.) are automatically evoked in a way sometimes referred to as "spreading activation". Older individuals do not tend to spontaneously encode in a rich and elaborate manner, presumably because it requires greater cognitive resources. The tendency to limit cognitive effort with depleted cognitive resources has been extensively used as a basis for age related cognitive decline (Craik, 1983; 1984; 1986; 1991; Hasher & Zacks, 1988; Salthouse, 1988b). According to Craik (1984), under optimal conditions, when older adults do encode information in an elaborate manner, or when the task does not demand extensive cognitive resources, the true potential of the older individuals is more likely to be realized, reducing or even eliminating age differences. Craik (1983, 1984, Craik & Jennings, 1992) formulated the "environmental support" hypothesis which states that the more support provided by test materials and/or test instructions (the environment) at encoding and retrieval, the smaller the age differences would be. [It has long been assumed (Craik & Jacoby, 1979; Kolers, 1973) that retrieval processes essentially recapitulate encoding operations and thus any factor influencing the one will affect the other as well.] Craik argued that "...cognitive processing reflects an interaction between processes that are driven by external stimulation and those that are initiated from within the organism. These latter "self-initiated" processes are heavily dependent on available processing resources, and so may decline in effectiveness as the person ages. However, performance decrements may be reduced by minimizing the demands on diminished resources and maximizing the contributions of external stimulation or environmental support." (Craik & Jennings, 1992, p. 67)

This theory was used to explain the consistently smaller age differences observed in recognition compared with cued or free recall. Whereas in a recognition test the original stimulus is re-presented, recall requires the participant to initiate retrieval, which is arguably a more effortful process. Self-initiation of mental operations such as that required for free recall or generation of a response, is considered a function demanding much cognitive resources, and therefore taxing on the limited resources available to older people. However, if the environment is made more supportive, providing elaboration and enrichment, age differences will be reduced.

The manipulations chosen in the present study in order to induce elaborative processing in older participants is that of word and sentence generation. Since older adults do not spontaneously process information in an elaborative manner, we gave encoding instructions directing them to generate a word in response to its definition, and a definition in response to a word. Both generation tasks can only be completed with attention to word meanings and both provide opportunity for arousal of a host of associations by the definition components and details. As such, both tasks are assumed to be exemplars of elaborative processing. Thus, study instructions directed participants toward elaborate encoding regardless of their ability to do so spontaneously. It should be noted that environmental support was given by experimenter-provided materials in the Read and Generate Word conditions, and by task instructions in Generate Word and Generate Definition conditions. Participants were left with the responsibility of actually carrying out the instructions they were given, a process which likely required an investment of cognitive resources.

Generation as a Vehicle to Study Age Effects

Slamecka & Graf (1978), coined the term 'generation effect' to denote the memorial benefit for self-generated materials over items supplied by the experimenter and simply read by the participants. They reported five experiments that compared memory for words that were generated by the subjects with the same words that were simply read. The words were generated given a cue word and a generation rule. Several study-rules employing generation were used. Participants were to generate an associate (lamp-*light*), another member of the same category (ruby-*diamond*), an antonym (long-*short*), a synonym (sea-*ocean*), or a rhyme (save-*cave*). In order to ensure that the words presented in the Read study condition would be identical to those that participants would create in the 'generate' condition, the first letter of the required word was given for each item to be generated. Thus, with the rule *synonym*, the stimulus *rapid*, and the letter *f*, participants were to generate the word *fast*. This procedure was successful in reliably evoking the desired responses, with very few errors of omission or commission. In all cases, memory test performance following the 'generate' condition was superior to that in the Read condition, whether memory was tested by free recall, cued recall, or recognition. The generation effect withstood variations in encoding rules, timed or self-paced presentation, between- or within-subjects designs, and whether or not participants were informed of the impending memory test.

An additional important finding was reported when the generation rule was rhyme (save-*cave*), and the memory test was recognition. Two recognition lists were used, one for stimuli and the other for responses. Each item on the stimulus recognition list included the original generation cue, two-alternative options, and the generated response, all rhyming. For example, a stimulus recognition item appeared as wave/save/rave - cave, and the corresponding response recognition item was save – wave/cave/rave. It was found that, compared with the read condition, the memory benefit was specific to the generated item and not to the cue stimulus that evoked the word. This result was not obtained using the same stimuli in a multi-trial learning task, with cued recall following each study trial. Cued recall of a generation cue was tested by presenting the generated response alone as the recall cue. Over the five learning trials, gains in recall were obtained for both stimuli and responses, but there was no significant interaction favoring recall of the response member as opposed to the stimulus member of the generation pairs. Nonetheless, the data seemed to be pointing in that direction: across trials, the difference between Read and 'generate' conditions was three times greater for response terms than for the generation cues.

Slamecka and Graf considered several theoretical approaches to explain the generation effect. The first was the "levels of processing" approach (Craik and Lockhart, 1972). This theory asserts that information is better remembered to the extent that it involves semantic processing. The greater the semantic involvement ("deeper" level of processing) the better remembered the material would be. This theory would predict that tasks that require attention to the meaning of a word (e.g., generating an antonym) will yield better memorability for the target word than tasks which direct attention to surface or perceptual features (e.g., letter font or vowel-to-consonant ratio). Slamecka and Graf point out some difficulties in applying the levels-of-processing approach to their findings. First, since the stimulus elicits the response it has to be encoded at least to the same depth as the response and therefore be remembered to the same extent. Thus, differential memorability of cue and response could not be explained. Second, the rhyme rule is considered a relatively shallow level of processing compared with the more semantic rules, but it did not show a significantly weaker generation effect, and there was no interaction between rules and the generation effect. Nonetheless, the authors do not abandon the levels-of-processing theory altogether, but suggest a novel approach to it, speculating that "the act of generation itself, regardless of what encoding rule applies, intrinsically entails a more profound processing level than does the virtually automatic act of reading" (p. 602). They note, however, that an independent measure of processing depths of generation versus reading is required to give credence to this explanation.

Slamecka and Graf also considered a theoretical approach that emphasized the paired-associates nature of the materials. They reasoned that a generation task requires encoding of stimulus-response relations, while the reading task does not. If this difference in encoding requirements determines memorability, it could provide an explanation for the generation effect. Other possible explanations were that generation requires more cognitive effort than reading, and effort increases memorability; that generation strengthens nodes and interconnections in the associative network; or that generation is a production of a response without copy prompts, which is the most efficient type of learning. At the time of publication of their work (1978) there were no studies available favoring one explanation over the others.

While these theoretical approaches were raised as possible explanations for the generation effect, none were offered to explain the differential memorability of cue and response. The lack of a generation effect for cues posed a problem for theories that explained the generation effect by a strengthened association between cue and response.

As stated by Hirshman and Bjork (1988, p. 484): "All [effort or depth of processing] explanations... appear to be discredited by Slamecka and Graf's (1978) finding that there is no generation advantage... for the stimulus term". Since all processing theories rely on this association, this finding posed a theoretical dilemma.

Greenwald and Johnson (1989) attempted to resolve the dilemma by demonstrating memory enhancement for generation cues. They accepted Slamecka and Graf's assertion that the definitive proof of memory for cues must use cued recall as a memory test, with the originally generated responses as cues. Cued recall was preferred because in recognition and free-recall tests enhanced memory for cues could be secondary to a generation effect for responses, which are semantically associated with the cues. This artifactual advantage was assumed to no longer exist if the generated responses were presented as test cues for the original generation cues. Performance would then be compared with cued recall following Read condition.

In the first experiment, subjects generated antonyms (in writing) by completing two missing letters in the middle of the word, or simply copied the second word of the pair. Memory was tested by free-recall, cued-recall, and recognition, in this order, which assumes no contamination from prior tests. The generation effect for cues was highly significant only on the free-recall test, marginally significant on cued-recall, and nonsignificant on the recognition test. In a second experiment, antonym generation (this time orally) was compared with reading of word pairs. Using study responses as test cues a generation effect for cues was demonstrated on a cued-recall and a recognition test. However, the authors note that the effect was consistently smaller than that observed for responses.

In a third experiment the authors attempted to eliminate the associative connection between cue and response. The strategy was to use nonsense responses for which it was implausible that a generation effect for cues could be an artifact of a generation effect for responses. The subjects saw two words, either semantically related or non-related (in different lists) and were to form a third word using the first letter from the first word and all-but-the-first letter from the second word. For example, day-night would produce *dight*, and doctor-night would also produce *dight*. Participants responded in writing. Free recall showed a generation effect for both cues and responses when using related word-pairs but not when using unrelated word-pairs. Cued recall (using the first word of the two-word cue and asking the subjects to produce the second) also showed a generation effect for cues only in related word pairs. On a recognition task no generation effect was observed for responses (the made-up nonsense word), but a generation effect was observed for the first-word cue, for both related and unrelated word-pairs.

Greenwald and Johnson concluded that memory benefits are obtained for generation cues, although the effect is weak, and propose that Slamecka and Graf did not detect the effect because of insufficient power. They believe that their findings "deflate the major empirical argument against associative interpretations of the generation effect" (p. 680).

It is unclear why Slamecka and Graf believed that cued recall using the generated responses would eliminate the artifact of recalling cues due to recall of responses. It seems to this writer that as long as the generation rule is semantic, there will necessarily be pre-existing associations regardless of the experimental manipulation. Pre-existing associations between cues and responses continue to exist when the generated response is presented as a test cue to the generation cue. Pre-existing associations will influence cued-recall, free recall, or recognition memory, since they are an integral part of the lexicon. The attempt to avoid these associations is artificial and bound to fail, as was seen in Experiment 3, where generation effects were observed for cues and responses only for words with pre-existing associations. Furthermore, it is likely that the only times that a generation effect for cues is observed is precisely when there is a strong association between cue and response. The premise that the cue must be processed to the same extent as a response is therefore inaccurate. The cue should be remembered at a level between that of read items and generated items, according to the amount of cognitive processing invested in relation to the word.

A study by Hertel (1989) investigated whether advantage of generated over read material is a consequence of greater cognitive effort in generating than reading. Under incidental learning conditions, the tasks used were: to generate words from anagrams or incomplete sentences, to verify that the words solved the anagrams or fit in the sentences, or to evaluate which rule had been used to construct the word from the anagram or sentence. A secondary task required subjects to respond to tones during the study period. Latencies in responding to the tone during these study tasks were used as a measure of cognitive effort. The most memorable words were found to be those that had been generated, with evaluation and verification study conditions producing significantly lower free recall scores. However, the evaluation study condition produced significantly longer latencies than the other two conditions. Thus, generated words were better recalled even though the task was not the most effortful. Hertel concludes that memory is not directly proportional, and may be unrelated, to the amount of effort invested during study.

This conclusion was qualified by raising the possibility that in order to observe a direct relationship between effort and recall, the effort has to be focused at the target items and not at the process of producing them. In this study the conditions which resulted in less recall were those which did not direct attention and effort to the target items themselves. Thus, a direct relationship between effort and recall may still be possible if the effort would be dedicated to the type of processing that improves recall. Other studies (Jacoby, Craik, & Begg 1979; Mitchell & Hunt, 1989) have commented that recall depends on the specific operations performed at study rather than on the amount of effort invested in producing the material.

Begg, Vinski, Frankovich, and Holgate (1991) investigated the essential difference between reading and generating. The generation task was word-fragment completion and the memory test was recognition or cued recall. The authors were able to demonstrate that if (1) subjects are informed of an impending memory test (2) subjects are asked to imagine the word that they read or generated, and (3) reading and generating are given to different subject groups (between subject design), the generation effect can be reduced or even eliminated. Thus, under such conditions, there is no significant memorial advantage for generating over reading. In fact, reading coupled with imaging instructions sometimes resulted in a higher recognition rate than generating and imaging. A generation effect was reliably and consistently seen only when imaging was not required and both readers and generators were merely asked to pronounce the cue and target words. The authors believe that when the read and generated words are given to the same subjects, generated words stand out and become more distinct in comparison to read words. In their opinion, the distinctiveness bestowed on generated words suppresses memorability for the words that were read. As Begg and Snider (1987) phrased it: "There is nothing special about generating, but the demand to generate is special; it hurts reading" (p. 553). However, their findings could also be interpreted differently. It appears that instructions to form an image of the named object give it a similar memorial advantage to that gained by generating. Even though these are different cognitive processes, both require some manipulation of the concept of the word, which involves its meaning. Therefore, by instructing subjects to image the read words, they are essentially performing a type of generation task on these words. The instruction to also image the generated words thus becomes a 'double generation' task, which does not increase memorability, and in some cases interferes with recognition.

The generation effect studies mentioned so far used synonyms, antonyms, rhyming rules or word fragment completion. It is noteworthy that many other generation rules have been employed. Examples include crossword problems (Jacoby, 1978), familiar bigrams (Gardiner & Hampton, 1985) and solutions to multiplication questions (Gardiner & Rowley, 1984), all of which showed the generation advantage. A different variation (Graf, 1982) required generating a sentence from a group of given words. The possibilities appear to be limited only by the researchers' imagination.

Studies Employing Definitions as Generation Cue

We turn now to a form of generation adopted in our study, which used definitions as the generation cue. This manipulation enabled us to use a novel approach to investigate the issue of reversibility of cue and response: A definition can be given as a cue to evoke the target word; alternatively, the target word can be given as a cue to evoke a definition.

While several studies (described below) used a definition as a generation cue, none had used the corresponding task of a word cue with instructions to generate a definition.

Most generation studies typically present a single word as cue and a generation rule, and instruct participants to produce a single word as a response. The word definition task is different in that the cue contains more information, i.e., a definition, as a basis for evoking the target word. An early use of the paradigm by Winnick and Daniel (1970), demonstrated that words generated from definitions or by naming pictures were better recalled than words that were read. A follow-up study by Winnick, Kooper, and Sprafkin (1974), added the finding of greater recall of words generated from their definitions than words generated from pictures. Winnick et al. attributed the superior recall to conditions that require 'problem solving'.

Although not designed to investigate the generation effect, but rather age-differences in word retrieval, Bowles and Poon (1985, Exp. 2), used definitions as cues and asked young and old adults to generate the defined word. Six priming categories were used, each with a different set of twenty words. The prime appeared on the screen shortly before and during the display of the definition. Priming categories were (1) the word itself, (2) the first two letters of the word, (3) an orthographically related word, (4) a neutral signal (XXXXX), (5) an unrelated word, or (6) a semantically related word. No age differences were observed when priming with the word itself or the first two letters of the word, but significant age differences were obtained in all other categories. Young adults were able to accurately name more words than older adults and had a shorter reaction time. Bowles and Poon concluded that age differences in word retrieval are found when subjects are primed with conceptual rather than orthographic stimulus material. This conclusion is based on the significant age difference found when priming with a semantically related word.

Craik and Jennings (1992) commented on this study saying that it is an exception to the systematic findings of small or no age-differences in semantic memory. This study supports their belief that it is not the memory system that declines with age but rather the type of processing operation (i.e., retrieval, in this case) required to complete the task.

Schwartz (1989) compared the implicit memory tests of word identification (tachistoscopic) and word completion (e.g., CHIM_: CHIMP, CHIME). During the study phase subjects generated words from their definitions, aided by the first letter (e.g., "a small ape – C"), or read the intact word (CHIMP). Generation had different effects on performance in the two tests: generated words were more poorly remembered on the word identification test, but were remembered as well as read words on word completion. Thus, a generation effect was not observed in this study. Schwartz concluded that performance on different implicit memory tests depends on different types of processing. She speculated that priming might differ between the tests because tests of identification and completion involve different demands and require subjects to engage in different types of processes to produce the word. Thus, it is the operations performed during study and the degree to which they are repeated at test, which determines test performance. Priming in word identification seems to rely more on data-driven processes than on conceptually driven processes, whereas priming in word completion seems to rely on both data-driven and conceptually driven processes.

Generation Effect in the Elderly

The earliest work addressing age-related changes in the generation effect is that of McFarland et al. (1985). The study phase consisted of reading or generating synonyms or rhymes to stimulus words. Memory was tested by an immediate multiple-trial free recall, and a 48-hour delayed recognition. A significant generation effect was observed for both young and old in both retention intervals. However, the older adults showed a generation effect only in the second or third free-recall trial. The young group recalled and recognized a greater number of words, but there was no interaction between age and study condition (read vs. generate). Thus, across the three free-recall trials and in the recognition test both age groups appeared to benefit from the generation effect to a similar degree.

In the first study to combine aging, generation effect and source memory, Mitchell, Hunt, and Schmitt (1986) asked their subjects to read or generate the object word in subject-verb-object sentences. For example, 'The horse jumped the *fence*', and 'The gentleman opened the _____' (for read and generate conditions, respectively). Age differences appeared in subjects' ability to identify whether the object words were originally read or generated. However, when removing results of the three elderly participants with the lowest scores (and analyzing on the remaining 9) age differences were eliminated. Nonetheless, the authors note that ceiling effects in the young group may have prevented the expression of age differences.

Crockard-Brown, Niinikoski, and Warren-Duke (1993) investigated age differences in generation effect and frequency judgments. The generation task asked to provide an instance in response to a category cue and a beginning letter (e.g., flower:

r____). In one experiment, subjects generated and read *the same words* either 2, 5, or 8 times, with read and generate conditions alternated during the study phase. Subjects then attempted to judge the number of times they generated or read these words. Neither age groups could discriminate read from generate frequency. In another experiment, the two age groups generated and read *different words* either 1, 2, or 3 times and judged the frequency of both the generated and read words. Following a 24-hour retention interval, there was reduced accuracy of frequency judgments, but this result did not interact with either age or generation efforts. In both experiments, generation improved accuracy of frequency judgments comparably for both age groups.

Isingrini, Vazou, and Leroy (1995) compared the effects of age and divided attention on the implicit conceptual test of category exemplar generation with their effects on an explicit test of cued recall. During study, participants rated the pleasantness of words on a 5-point scale. In both memory tasks, category names served as cues and priming was measured by counting the number of targets mentioned and comparing primed and unprimed categories. Four age groups were compared. Performance on cued recall showed a steady decline with increasing age and was significantly affected by a secondary letter-detection task (divided attention condition). By contrast, category exemplar generation was unaffected by age or divided attention. Thus, cued recall, which poses the constraint of identifying the words that were studied and relies on episodic memory, declines with aging. On the other hand, the ability to generate words from semantic memory is well preserved across the life span.

Several studies addressed the hypothesis of age-related decline in spontaneous semantic elaboration, using both experimenter-provided elaborations and self-generated ones. Rankin and Collins (1985), appear to agree with Craik's (1984) production deficiency hypothesis, that age-related memory decline is due to reduced tendency to encode material in an elaborate manner. However, contrary to Craik's hypothesis, the authors argued that "...pervasive age differences in memory... are observed when encoding is directed by instructions or orienting tasks." (p. 451).

Rankin and Collins (1985) employed an intentional learning paradigm in which target words were embedded in a base sentence to which precise and imprecise elaborations were added. For example, the base sentence of "The angry man threatened the *judge*" was completed with a precise elaboration of "who had sent him to prison", or an imprecise elaboration of "who lived down the street." Thus, a precise elaboration clarified the significance of the target word, while an imprecise elaboration added information that was not pertinent to the target word. A cued recall test used the entire sentence with a blank substituting the target word. Results showed improved performance following precise elaborations compared with the base sentence alone. However, both age groups improved to the same extent, and age differences were not diminished. This finding supports the assumption of improved memory with increase in elaborative processing, but implies that young as well as old adults do not spontaneously elaborate on given material. The latter conclusion is discordant with Craik (1984). A second experiment compared experimenter provided- and self-generated elaborations in a between-subjects design. Generation of precise elaborations (in writing) was induced by leading with the word 'because', e.g., The *rich* man showed us the car because _______, whereas imprecise elaborations were induced by the word 'and', e.g., The *young* boy walked past the sign and ________. Older adults were less likely than young adults to generate precise elaborations, however, as in the previous experiment, precise elaborations resulted in higher cued recall scores for both age groups. Surprisingly, generation failed to improve recall in either age groups, and age differences remained significant in all conditions. This is rare example in the literature of the generation effect where no benefit was found to generated over read material.

In a follow-up study, Rankin and Collin (1986) used the same paradigm under incidental learning conditions, which they believed more likely simulated everyday functioning. Incidental learning took place under the disguise of rating the comprehensibility of the sentences. Contrary to their previous findings (and to Craik's environmental support hypothesis), neither age groups showed improved recall when provided with precise elaborations compared with base sentence alone. Older adults were again found to generate fewer precise elaborations than young adults. However, when they did generate precise elaborations, older (but not younger) adults had *lower* memory scores than when such elaborations were experimenter provided. Thus, not only was there no generation effect in the old group but generation *increased* age differences compared with the experimenter provided condition. Both age groups did show a generation effect following the imprecise elaboration condition.

The findings of both studies of Rankin and Collins (1985, 1986) could not be reconciled with Craik's environmental support hypothesis, and are at odds with most other studies of the generation effect. Not surprisingly they were soon challenged by Hashtroudi, Parker, Luis, and Reisen (1989b), who used the same paradigm to compare experimenter provided and self-generated elaborations. Precise elaborations were defined as those explaining the relevance of the target adjective in the base sentence. For example, a base sentence was "The *lucky* man left the town", and its precise elaboration "before the earthquake struck", whereas its imprecise elaboration was "to exchange the raincoat". Participants rated the comprehensibility of the experimenter provided sentences, or generated endings (in writing) for base sentences. Generated endings were later rated as being precise or imprecise elaborations. A cued recall test of the base sentence alone (with a blank for the target word) revealed that older adults, benefited from generation but not from precision. Thus, contrary to Rankin and Collins (1986), target words from self generated sentences were significantly better recalled than those from base sentence alone, from experimenter-provided precise elaboration, and from experimenter-provided imprecise elaboration, which did not differ. Younger adults benefited equally from precision and generation compared with the base-only condition, and showed reduced recall for experimenter-provided imprecise elaborations. Unlike Rankin and Collins (1985), the proportion of precise and imprecise elaborators generated by young and old was almost identical illustrating no decline in use of semantic knowledge with aging. When comparing experimenter-provided versus self-generated precise elaborators, older adults showed a large generation effect whereas the younger adults did not. A generation effect was seen in both age groups in the imprecise elaboration conditions, where overall levels of recall were significantly lower. Older adults had highest levels of recall when they generated precise elaborators.

Improved performance with self-generation is expected according to Craik's environmental support hypothesis (1984). The hypothesis predicts that experimental guidance of elaborative processing, such as that induced by self-generation or experimenter provided precise elaborators, would reduce age differences. Older adults showed improved recall from self-generation but not from experimenter provided elaboration. Nonetheless, age-differences in cued recall were reduced and nearly erased when older adults generated precise elaborators.

Age differences in generative processing were recently investigated using structural neuroimaging techniques (Dorfman & Raz, 1998, in Raz 1999). The authors studied the predictive validity of volumetric measures of various brain regions on performance in repetition priming and cued recall. A rather large sample group (83 healthy adults, range 18-81 years) performed the new-associations priming paradigm developed by Graf and Schacter (1985). Word pairs were studied under two elaborative encoding conditions: sentence generation and sentence rating. Tests of word-stem completion or stem-cued recall were performed with the study words paired with their study associates or with new words. Surprisingly, age-related decline was seen only in cued recall of words studied under the generation condition. This was unexpected since sentence generation is assumed to involves more elaborative encoding than sentence rating and therefore reduce age differences. However, the results could be attributed to recall being a more difficult task than word-stem completion. Recall index was correlated with hippocampal volume ($r = .36$, $p<.001$) and volume of the dorso-lateral-prefrontal-cortex (DLPFC), ($r = .41$, $p<.001$), both of which remained significant after controlling for age ($\beta = .26$ for the hippocampus and $\beta = .33$ for the DLPFC, both $ps<.05$). Interestingly, for 17 participants who were older than 65, no significant correlation between hippocampal volume and cued recall was found ($r = .19$, ns). Performance on the priming tasks in this study and in Raz et al. (1998) was not related to age or to regional brain volume.

As can be seen, studies involving the generation effect in older adults have employed a variety of paradigms, procedures and techniques. With noted exceptions, in a range of memory tests the generation task produced an improvement over the read condition, often with the finding that both age groups benefited to a similar degree.

Source Memory in Young and Old

In recent years there has been a surge in studies involving source memory, presumably due to the relevance of source memory to fundamental questions regarding the organization of human memory. Studies comparing fact versus source memory echo Tulving's semantic versus episodic distinction (see: Shimamura & Squire, 1987; Craik, Morris, Morris & Lowen, 1990; Spencer & Raz, 1995). The ability to demonstrate dissociations, both behaviorally and anatomically, is therefore of significant theoretical value. With regard to aging, since episodic memory shows a more rapid decline with age compared with semantic memory, it would be expected that age-differences on source memory tasks will be greater than on tasks relying on semantic memory alone.

Over the past two decades, the study of source memory has been conducted in two parallel, though often interacting, traditions. The neuropsychology tradition attempts to investigate the organization of human memory via its aberrant manifestations in pathological populations such as patients with amnesia, frontal-lobe lesions, or dementia of the Alzheimer type (e.g., Schacter et al., 1984; Janowsky et al., 1989; Craik et al., 1990). The experimental psychology tradition typically employs theoretical models of memory organization and investigates their validity in healthy populations (e.g. Johnson & Raye, 1981; Rabinowitz, Craik, & Ackerman, 1982; Rabinowitz, 1989). The neuropsychological tradition could be described as "bottom-up" reasoning, starting from examination of individual cases and drawing conclusions when several similar cases converge. The experimental psychology tradition, on the other hand, may be described as "top-down" reasoning, developing theoretical models and constructing experiments which test their validity. These two scientific approaches use different terminology and employ different experimental paradigms, but they have converged in their interest in the study of age-related memory changes, and source memory in particular.

Source memory has been defined as "Recollection of the episodic source from which a specific item or fact was acquired, e.g., from a person, a book, or television" (Schacter, Kaszniak, Kihlstrom & Valdiserri, 1991, p. 559). Johnson, Hashtroudi, and Lindsay (1993), however, gave a more inclusive definition, which closely relates source memory to memory for context. They wrote "The term *source* refers to a variety of characteristics that, collectively, specify the conditions under which a memory is acquired (e.g., the spatial, temporal, and social context of the event; the media and modalities through which it was perceived)" (p. 3).

Johnson et al. (1993), view source memory (in their terminology 'source monitoring' or 'judgment of origin') as based on memory characteristics combined with decision making. They describe the most prominent memory characteristics as "records of perceptual information (e.g., sound and color), contextual information (spatial and temporal), semantic detail, affective information (e.g., emotional reactions) and cognitive operations (e.g., records of organizing, elaborating, retrieving, and identifying) that were established when the memory was formed." (p. 4). The decision as to the origin of specific information relies on the relative weight of these characteristics in different sources. In our study, the memory characteristics that serve as cues to the source are the cognitive operations performed on the material. Memory of a word that was generated would include more details of a completed cognitive process and weaker perceptual characteristics, while memory for a word that was read would include more perceptual characteristics and less information on completed cognitive operations. Weighing these characteristics against each other for a given word provides clues to its source. Studies of source memory conducted in the neuropsychology tradition will be reviewed first followed by those conducted in the experimental tradition.

The Neuropsychological Approach

Schacter et al. (1984) defined the term *source amnesia* as "retrieval of experimentally presented information without any recollection of the episode in which it was acquired" (p. 593). Source amnesia has been found in patients with various brain pathologies such as dementia, infectious diseases, and head injury. Schacter et al. developed an experimental paradigm which has since been used, with occasional modifications, for studying source amnesia in the "neuropsychological tradition". The paradigm involves one of two experimenters telling subjects made-up "facts" about well-known and unknown people (e.g., "Bob Hope's father was a fireman", "Elizabeth Taylor grows peaches in her orchard", "Alice Reznak loves to travel by train".). Creating fictitious "facts" was necessary in order to assure that subjects could not have acquired the information from a source outside the experimental setting. Memory for facts (e.g., What job did Bob Hope's father have?) and their sources (which speaker imparted the information) was tested a few minutes after acquisition. Schacter et al. distinguished between 'source forgetting' i.e., being unable to identify which one of the two experimenters told them the fact, and ‘source amnesia’ i.e., attributing the fact to a source outside the experimental setting (this distinction was dropped later on, since there was no qualitative difference between the two). Amnesic patients displayed source amnesia, attributing knowledge of the facts they recalled to extra-experimental sources. They also recalled fewer facts than normal controls. Schacter et al. attempted to control for the difference in fact recall by testing normal subjects a week after study. Even then, source amnesia was significantly greater in the patient group. This finding implied that source memory could be dissociated from fact memory and that it shows greater vulnerability than fact memory to the pathology of memory disorders. It was also found that the degree of source memory errors correlated with the number of errors on tests of frontal lobe functioning, suggesting a possible link between source memory and integrity of the frontal lobes. Thus, Schacter at al. suggested that not all amnesic patients, but only those with frontal lobe lesions, demonstrated disproportionately greater loss in source memory than in fact memory. This finding led to the conclusion that the ability to link a fact with the episode or context in which it was acquired, or the ability to encode simultaneously both fact and source, may be lost with deterioration of frontal lobe functioning.

Shimamura and Squire (1987) used a design very similar to that of Schacter et al. (1984) in studying fact and source memory in amnesic patients. True but obscure facts (e.g., Angel Falls is located in Venezuela) were studied before electroconvulsive therapy and tested following the treatment. The patients displayed both impaired memory for facts and source amnesia. Most interestingly, the extent of source errors was unrelated to the severity of memory impairment, i.e., patients who exhibited source amnesia recalled as many facts as patients who did not. This finding supported the dissociation between recall or recognition of facts and memory for the context or episode in which the facts were acquired.

Source Memory in the Elderly

The study of source amnesia evolved from investigation of the phenomenon in amnesic patients (some of whom also displayed signs of frontal lobe dysfunction), to studies in patients with frontal lobe lesions, who also displayed source memory deficits (Janowski et al., 1989). Since an age-matched control group for patients with frontal lobe lesions included elderly people, it was found that a similar pattern of source errors occurred in normal aging. These studies provide important background to the present work, which focuses on age-differences in source memory.

McIntyre and Craik (1987) reported two experiments that investigated age differences in memory for facts and sources. In the first experiment, subjects were presented, either visually or auditorily, with answers to real (but obscure) facts about Canada. They were later tested for fact memory by free recall and for source memory, i.e., modality of presentation, by recognition. Older subjects showed poorer fact and source memory than young subjects; however, source memory was not disproportionately impaired relative to fact memory. In the second experiment the authors borrowed Schacter et al. (1984) materials and experimental procedure and tested them on the young and old groups. Again, both fact and source-memory deficits were displayed by the elderly, confirming the finding of the first experiment using made-up facts. However, the older group had many more source errors than the young group, at least in one of the delay conditions. This error pattern resembled Schacter et al.'s (1984) amnesic patients, although it appeared at much greater delays.

The dependence of source memory on the integrity of the frontal lobes was investigated by Janowski et al. (1989). They studied patients with frontal lobe lesions, and included both young and old control groups. The paradigm of Schacter et al. (1984) was used with obscure true statements rather than fictitious ones. Testing was conducted a week after acquisition. In the first experiment fact recall in the patient group and the two control groups did not differ, however, both control groups had better source memory than the patient group. In the second experiment, older adults had a similar number of source errors to those of the frontal lobe patients. This finding revealed disproportionate deterioration in source compared with fact memory in normal aging, and raised the possibility that source memory deterioration in older persons may also be attributed to a deterioration of frontal lobe functioning. The results also lend support to the idea that the frontal lobes serve to associate memory for facts with various aspects of their context.

Craik et al. (1990) explored the relations between source amnesia and frontal lobe functioning in normal aging. Source amnesia was again measured using the paradigm and materials developed by Schacter et al. (1984). Frontal lobe functioning was measured by several parameters of the Wisconsin Card Sorting Test (WCST), verbal fluency, and addition psychometric measures. The degree of source amnesia (attributing information learned in the experiment to sources outside the experiment) showed a positive correlation with age (.49), and perseverative errors on the WCST (.42), and a negative correlation with years of education (-.52), verbal fluency (-.38), and the number of categories completed on the WCST (-.55). Source amnesia was not reliably correlated with fact recall (-.29), or with two performance subtests of the WAIS-R (-.20). The correlations remained statistically significant even after partialing out the effects of vocabulary, years of education, and performance IQ. This led Craik et al. to suggest that the relationship between mild degrees of frontal dysfunction and source amnesia in an elderly group is not secondary to general age related cognitive decline. However, when the influence of age was eliminated, the correlation between perseverative errors and source amnesia was no longer significant. Thus, normal aging is associated with reduced efficiency of frontal lobe functioning, which was expressed in this study as an increase in source errors. The authors took this finding to mean that an age-related deterioration in frontal lobe functioning is basic to impairment in source memory.

Schacter et al. (1991) investigated the effect of organization of study material on item and source memory in young and old. Presentation of the Schacter et al. (1984) material was either blocked, such that each experimenter presented several items in a row before alternating, or random, with frequent alternations between the two experimenters. Young and old participants were exposed to the study material twice. Regarding fact recall, older adults remembered more facts following the blocked compared with the random study condition, while young adults were not affected by the blocked versus random manipulation. Young adults recalled more facts than did old following the random condition, but interestingly there were no age-differences in fact recall following the blocked condition. Regarding source recall, i.e., which of the two experimenters provided the information, older adults did more poorly than young in both blocked and random conditions, with no difference between the two study conditions. Thus, despite equal levels of fact recall for old and young in the blocked condition, old adults displayed poorer source memory than young, supporting the dissociation between the two types of memory.

In order to show dissociation between item and source memory in the old, Schacter et al. (1991) believed that age differences in source memory must be demonstrated when levels of item memory are equal in young and old. This finding was spontaneously obtained following the blocked but not the random condition. Subsequently, Schacter et al. induced equal levels of item memory in the random condition by exposing an addition group of older adults to the study material four times (rather than two). However, together with eliminating age differences in fact recall, the uneven number of exposures (two for the young and four for the old) resulted in equal levels of source memory. Thus, under these conditions it was not possible to demonstrate a dissociation of fact and source. The authors concluded that the relation between fact and source recall varied across experimental conditions.

Bayen and Murnane (1996) criticized the procedure used by Schacter et al. (1991) on two grounds. The first was insufficient temporal distinctiveness of the blocked condition. Bayen and Murnane point out that the blocks used by Schacter et al. (1991) were of 12 items each, read alternately by sources A and B in an ABABAB pattern, which made them of low temporal distinctiveness. Thus, what Schacter et al. considered a more organized, i.e., blocked, condition, is in effect too similar to a random condition. In their opinion (and in their study, described later as part of the Experimental Psychology tradition) a blocked condition should be in an AB pattern to achieve a higher level of temporal distinctiveness. Their second criticism relates to the random condition of Schacter et al. (1991), where no age differences were found. Bayen and Murnane believe that the multiple presentations of study items to older adults confounded age with frequency of presentation, and eliminated age differences in source memory because both fact and source were strengthened.

Nonetheless, Schacter and his colleagues did not desert their ‘matching’ approach, and eventually were able to demonstrate disproportionate source memory impairment in older adults despite equated fact memory. Schacter, Osowiecki, Kaszniak, Kihlstrom, and Valdiserri (1994) considered the influence of two variables on age-related differences in source memory: the number of items attributed to each source, and the differential allocation of attention to facts versus sources. In the previous studies many facts were presented by few sources (usually two). It was reasoned that the elderly may be especially sensitive to interference effects that arise from many-to-one mapping of any type of information and not particularly of source (cue-overload hypothesis). This was tested by examining fact and source memory under conditions in which each fact was presented by a different source. Regarding the differential allocation of attention to facts and sources by old and young adults (differential attention hypothesis), it was speculated that the elderly may be allocating less attention to the source than young adults due to limited cognitive resources. These resources were interpreted by some to take the form of working memory capacity (Craik, 1991; Zacks & Hasher, 1988). Thus, older adults may focus their limited attentional resources primarily on the fact, resulting in disproportionately poor source recall. This hypothesis was tested by systematically directing subjects’ attention to the fact or to the source at the time of study (evaluating the believability of the fact, versus evaluating the likability of the source). The results did not support either of these hypotheses. Age-related deficits in source memory were seen in the one-to-one mapping of fact with source and were observed even when study conditions directed the subjects' attention to the sources. Moreover, source memory impairment in older adults was found under conditions that equated level of fact recall by multiple presentations of the study list to the older adults. Thus, a dissociation of the two types of memory was demonstrated but the mechanisms underlying poor source memory of older adults remained obscure. Schacter et al. suggested that the difficulty lies in associating perceptual information with item or fact information. Thus, source memory impairments are due to difficulties in reconstructing perceptual information on the one hand and in associating perceptual and fact information on the other.

Spencer and Raz (1994) measured age-related differences in memory for facts, source, and contextual details. Source was defined as the general circumstances under which information was acquired (intra- vs. extra-experimental), whereas context was defined as the fine-grain details (spatial, temporal, and perceptual attributes). They used the source memory paradigm of Schacter et al. (1984), and measures of frontal lobe functioning. Old age was associated with source memory errors that increased with an increase in retention interval. However, contrary to previous studies, measures of frontal lobe functions did not predict source memory, i.e., the ability to distinguish the source as intra- vs. extra-experimental did not correlate with frontal lobe measures, but some of these measures were related to memory for contextual details. The number of perseverative errors on the WCST was associated with errors in both fact and context memory but the correlation with contextual details was stronger. It is noteworthy that under the more inclusive definition of source by Johnson et al. (1993), both variables of intra/extra-experimental and contextual details would be considered source memory measures. The finding of greater decline in memory for contextual detail than for the more general "source" demonstrates the tendency of older people to encode in a more limited, possibly resource conserving, manner.

A particularly creative approach was adopted by Glisky et al. (1995) regarding double dissociation of item and source memory. They pointed out that source memory is always a more difficult task than item memory and people with weaker memory such as amnesic patients or older adults are likely to have more trouble with source tests due to their greater difficulty rather than the particular brain structures involved. Additionally, source memory is usually tested only for items recognized or recalled and as such is not independent of item memory. The authors approach was to divide healthy elderly participants a-priori according to their ability on frontal lobe tests (high-ability group versus low-ability group) and compare the two groups on tests of item and source memory. There was no difference between the groups on a sentence memory test (item memory) but participants with high-ability on frontal lobe tests showed better source memory for the sex of the voice in which sentences were presented (source memory). Opposite findings were obtained when the same participants were divided according to their performance on tests of temporal lobe functioning. No difference between high and low temporal lobe test performers was seen in ability to identify the sex of the presenter, but high performers had better memory for the presented sentences. This elegant study provides strong support for the dissociation of item and source memory and their dependence on the integrity of temporal and frontal lobe structures, respectively.

Converging evidence for double dissociation of item and source memory comes from studies of event-relation potentials (ERPs). In these studies electrophysiological changes generated by neuronal structures in response to presented stimuli are measured by external electrodes attached to several scalp locations. ERPs have the advantage of great temporal precision (milliseconds) as their measurement is time locked with stimuli presentation. Summation of the electrophysiological response over many similar stimuli cause random variations to cancel each other, and result in a waveform presumed to reflect the event-related neural activity. Overt performance on memory tests (termed in this literature "behavioral data") is then compared with the obtained ERPs.

Two ERP studies share the interest of the present work in age differences as well as source memory (Trott, Friedman, Ritter, & Fabiani, 1997; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999). For each item identified as old on a recognition test participants stated which of two temporally distinct lists the word had come from during the study phase. There was a greater age difference in source attribution (which list the word was from) compared with item memory. In both age groups, ERPs of previously seen words differed in magnitude from new words on posterior sites. In the young group, ERPs during the recognition test to words which at a later point in time got correct source attribution were different from ERPs to words which got incorrect source attributions. The source-related ERP appeared over prefrontal sites in the young but was not present in the waveforms of the older adults. The findings of temporal and topographical differences in ERPs were interpreted as reflecting a functional dissociation in underlying neuronal structures which process item and source memory. Recognition memory was associated with medial-temporal areas while source selection and/or retrieval was associated with frontal areas. The weakness of source memory in the old group was related to reduced efficiency of frontal lobe functions with aging.

Very recently, age differences in item and source memory began to be explored via functional neuroimaging techniques. Cabeza et al. (1999, in Raz, 1999) used positron emission tomography (PET) to investigate age differences in neural activity as reflected in regional cerebral blood flow (rCBF) while participants performed tasks of item and source memory. A list of words presented during study was tested for recognition (item memory) and for recency discrimination (source memory task). When comparing item and source memory in young adults, temporal discrimination was associated with increased rCBF to the right prefrontal cortex, the parieto-occipital cortex, the precuneus, and the cerebellum. Older adults did not show greater activation in these regions during the source task as compared with the item memory task. However, older participants showed higher increases in rCBF to the left prefrontal cortex and the right cerebellum during the recognition task than during the source task. Thus, older adults do not show increased activation in regions associated with memory for temporal order and show diffused (bilateral prefrontal) activation during item recognition. These findings are consistent with differential age deficits in prefrontal regions assumed to be involved in temporal discrimination in particular and source memory in general (Spencer & Raz, 1995).

The Experimental Psychology Approach – Reality Monitoring

The study of source memory in the experimental psychology tradition has been conducted under the theoretical model of *reality monitoring* proposed by Johnson and Raye (1981). The term reality monitoring refers to the cognitive processes used to distinguish between information derived from external sources (i.e., perceived by the senses) and information generated internally (i.e., thoughts and images). According to the model, reality monitoring relies on differences in the characteristics of memories from external and internal sources. Memories from external sources would typically include sensory information, and spatial/temporal information, to a much greater degree and with greater detail than internally generated memories. Internally generated memories, on the other hand, would typically include information about the cognitive processes performed as they were generated. A reality monitoring decision would be based on comparing relative values of these characteristics. Additionally, reality monitoring would involve judgments based on prior knowledge and meta-memory, i.e., understanding of one's own memory processes (Hashtroudi, Johnson, & Chrosniak, 1989a).

Rabinowitz (1989) suggested that the forgetfulness of older adults might partly be attributed to failures in reality monitoring. Studies have reported age-related deficits in identifying spatial location (Perlmutter, Metzger, Nezworski, & Miller, 1981; Park, Puglisi, & Sovacool, 1983), temporal order of words in a list (Kausler, Salthouse, & Saults, 1988), and sensory information such as voice for orally presented words and case type for visually presented words (Kausler & Puckett, 1980, 1981). Thus, older adults demonstrated some impairment in all three types of cues that are more characteristic of externally derived memories. There have been few studies of the fourth factor, of age-related differences in meta-memory, or ability to retrace one's own cognitive processes. As discussed above, knowledge of completed cognitive operations was assumed to be the primary cue to internally generated memories (Johnson & Raye, 1981). This factor is of critical importance in our work, as the ability to recall mental operations is the primary cue to source in our study. Overall, results of studies examining age-differences in reality monitoring have been mixed and seem to vary with the type of source monitoring task.

Reality Monitoring in the Elderly

The study of Mitchell et al. (1986; mentioned earlier under the section Generation Effect in the Elderly), are also relevant here because their results showed age related decline in reality monitoring: Older adults were not as accurate as younger adults in remembering whether studied information was originally read or generated. However, the authors suspected that the three lowest scoring adults may have exhibited symptoms of early Alzheimer's' disease. They, therefore, performed a second analysis without these three participants and found no age differences in reality monitoring. However, they note that the young group showed ceiling effects which may have masked an age-related deficit. Taken together, the results are inconclusive regarding age related decline in reality monitoring.

Another reality monitoring study with far reaching implications for older adults' eyewitness testimony was conducted by Cohen and Faulkner (1989). Participants performed, imagined, or watched a series of simple actions involving moving objects on a grid. While no age-differences were seen in recognition rates, the elderly adults were less accurate in source monitoring of recognized actions (i.e., recalling whether they performed, imagined, or watched these actions). Older adults also made more false-alarm responses than the young, claiming to have watched actions that never occurred or that were merely imagined. These finding alerted Cohen and Faulkner to the issue of age-differences in credibility of eyewitness testimony. They investigated age differences in noticing discrepancies between a story presented in a movie and a subsequent misleading printed description of it. There were no age differences in proportion of recalled control events (that remained unchanged), but older adults did more poorly in identifying the two events on which they were mislead. Thus, they were asked to report what they saw in the movie but reported what they read. Moreover, 37% of the source monitoring errors were made with a confidence rating of "very sure". Both experiments of Cohen and Faulkner support the dissociation of item and source memory, with item memory appearing intact in old adults, but source memory showing deficits compared with the young.

Hashtroudi et al. (1989a), found that older adults had more difficulty that young in distinguishing between two types of externally derived memories and between two types of internally generated memories, but not in the ability to discriminate between externally derived and internally generated memories (reality monitoring). Thus, there was no indication of an age deficit in remembering cognitive operations. For both age groups, self-initiated (i.e., generated) information was more memorable than externally derived information. The disadvantage of older adults in distinguishing between two sources of the same class was attributed to the need to rely on a similar set of cues. Such decisions are more difficulty because the two sources are more similar and discrimination cannot rely on different characteristics of the memories but on the differences in detailed contents. Distinguishing between two external sources is assumed to depend on sensory/perceptual, spatial/temporal, and semantic details of the material, all of which have shown age-related decline (Kausler & Puckett, 1980, 1981; Perlmutter et al., 1981; Rabinowitz et al., 1982). Since older adults are less inclined to spontaneously engage in elaboration and organization of target material (see Craik, 1984), the researchers speculated that to the extent that spontaneous elaborate processing helps in making source judgments, age deficits would emerge.

Reliance on perceptual and spatial cues for source discrimination was further investigated by Ferguson, Hashtroudi, and Johnson (1992), in a study reminiscent of Schacter's source memory paradigm. Young and old participants heard words from one of two speakers and later decided which of the two speakers had said the words. Perceptual cues (visual and auditory) were varied by having two women speakers (low perceptual distinctiveness) versus a man and a woman (high perceptual distinctiveness). Spatial cues were varied by changing the locations of the speakers: Sitting next to each other (low spatial distinctiveness) versus in different corners of the room, one next to a large plant, the other next to a colorful print (high spatial distinctiveness). When the only cue to source was perceptual, and perceptual distinctiveness was high, no age-differences were observed on either source identification or recognition. When the only cue to source was spatial, greater distinctiveness improved source memory similarly for both age groups, although young adults performed better on both spatial conditions. Thus, both age groups benefited from increased distinctiveness of source, with perceptual cues bringing older adults to a source and item memory level indistinguishable from that of younger adults. When perceptual and spatial cues were used simultaneously no age differences in item recognition were observed. However source memory of young adults improved over the level obtained with a single cue, while that of older adults did not. Ferguson et al. concluded that young adults are able to use multiple cues in source memory judgments whereas older adults have difficulty in using multiple cues effectively. They speculated that this difference might be behind age-related decline in source memory. It is noteworthy that under certain experimental conditions (single cue) there was no disproportionate impairment in source memory compared with item memory, while other conditions (multiple cues) revealed a discrepancy between the two. Thus, the relationship of item and source memory seems to vary with changes in experimental conditions.

Bayen and Murnane (1996) attempted to test the generality of the multiple cue hypothesis proposed by Ferguson et al. (1992). Participants heard a taped narrative while viewing an image on a computer screen. Each participant saw two images describing the same event from different perspectives, and later decided whether target details had been presented by Source A, by Source B, or were new. Perceptual distinctiveness of the sources was manipulated by varying the physical similarity of the portraits displayed on the computer screen as the two sources. Temporal distinctiveness was manipulated by presenting information either blocked by source in an AB pattern or having sources alternate in their presentation of information in an ABABAB pattern. When temporal distinctiveness was high (AB pattern), young adults were able to identify sources at a high level of accuracy regardless of the level of perceptual distinctiveness. However, when temporal distinctiveness was low (ABABAB pattern), source accuracy improved as a direct function of perceptual distinctiveness. Significant differences in source accuracy in response to temporal manipulation were only observed at the low perceptual distinctiveness level. By contrast, the old adults group displayed increasing levels of source accuracy as a direct function of both temporal and perceptual distinctiveness. Thus, old adults' source attributions showed significant differences between high and low temporal distinctiveness at each level of perceptual distinctiveness. It was therefore demonstrated that older adults are able to use multiple source characteristics in their judgment of origin and tend to benefit from them to an even greater extent than young adults, contrary to the multiple cue hypothesis of Ferguson et al. (1992).

A study by Rabinowitz (1989) is most pertinent to this work since it used the cognitive process of generation as a source, a manipulation adopted in the present study.

Rabinowitz combined the generation effect and 'judgment of origin' (source memory). During the study phase, participants read target words or generate them from word fragments (e.g., AL_OHO_). During the memory test, for each word recognized as old participants had to indicate whether it was originally read or generated. Rabinowitz argues that sensory and contextual (spatial/temporal) characteristics are similar in read and generated words. Therefore, participants would have to rely primarily on knowledge of the cognitive operation they performed to make judgments of origin. His assumption regarding the generation effect was that generated words leave a stronger memory trace or more information on the performed cognitive operations than read words. (Relevant to our study are the findings for of words that were read or generated once, and only these are described here.) Regarding recognition, both age groups demonstrated a clear generation effect, similar in size, but generation did not eliminate age differences. Although a trend was observed for reduced age differences in recognition following the word generation condition, the interaction of Age X Read/Generate was only marginally significant. In addition, older adults were less accurate in their judgment of origin than younger adults, but surprisingly, no improvement of source judgments was seen following the generation condition in either age group. This finding was unexpected because generative processing involves greater elaboration than reading, is assumed to produce a stronger memory trace, and to result in reduced age differences. However, it should be kept in mind that Rabinowitz used a word completion task that may have been very simple to perform. Thus, elaborative processing may not have occurred because minimal effort was involved in this task.

Rabinowitz (1989) proposed that "... records of cognitive operations are stored as an integral part of the memory trace for a given experience and ... access to the memory trace for the event automatically gives access to the record or operations stored as part of the event" (p. 226). Whereas this proposal has considerable intuitive appeal, it cannot be reconciled with the many studies showing dissociation of item and source memory levels. A more inclusive statement was made by Johnson et al. (1993), who mention in their review that "Many source monitoring decisions are made rapidly and relatively nondeliberatively on the basis of qualitative characteristics of activated memories (e.g., amount or type of perceptual detail).... Sometimes, however, source monitoring involves more strategic processes. Such decisions tend to be slower and more deliberate and involve retrieval of supporting memories.... and initiation of reasoning (e.g., 'Does this seem plausible, given other things that I know?')." (p. 3) Johnson et al. called the first type of judgment "automatic" or "heuristic", and the second "controlled" or "systematic". They claim that most source judgments belong to the heuristic type, and that the systematic process "tends to be slower and more subject to disruption." (p. 5).

Rabinowitz (1989) suggested two possible reasons for age-related deficits in origin discrimination. The first involved the decision process. His assumption was that judgment of origin relies primarily on knowledge of completed cognitive operations. Other target characteristics such as semantic, sensory, or contextual cues are considered less effective in making the discrimination decision. A greater reliance of old compared with young adults on this less effective information in making source decisions would result in poorer source memory scores. The second explanation takes a different perspective: To the extent that contextual, semantic, and sensory information does play a role in judgment of origin, older adults would be at a disadvantage compared with younger adults since sensitivity to these characteristics was shown to deteriorate with age.

Overview of the Current Study

The present study attempted to apply the environmental support hypothesis using the manipulation of generation, which involves an active form of processing at encoding. Generating a response (usually a single target word) has been shown to result in better memory for the word compared to passively reading the same target word. Furthermore, young and old adults have been shown to benefit from the generation effect, sometimes to the same extent. The study phase included two levels of generative processing as well as a non-generative, baseline condition. Participants performed a recognition test for the target words accompanied by source identification where the encoding condition of the target word had to be specified. The expectation was that the advantage that generation confers on item memory might also apply to source memory in both old and young persons. Additionally, it was expected that, with increased amounts of generative processing, older adults would demonstrate increased memorial benefits and age-differences would be reduced.

In this study, participants performed the traditional Read task and two generative tasks. In the Read task, participants read a word and its definition. The two generative tasks required participants to read a definition and name the defined word, or to read a word and provide a definition for it. Since participants were asked to say out loud both word and definition in each of the study tasks, total verbal output during study was more-or-less equated in the three study conditions; however, different components were generated in each tasks. As a result, three degrees of processing were obtained, differing in elaboration.

These tasks represent a novel approach in studies of the generation effect, which traditionally require generating a single word (e.g. antonym, synonym, etc.) to a single word cue. In this study, a full sentence (the definition) containing several semantic associates was presented as a cue or required as a response. The differences among study conditions related to the amount of generative processing required to produce the reply and the extensiveness of the cognitive search and selection. For experienced readers, reading is fairly automatic, requiring a minimum of cognitive resources. In fact, reading could be a purely mechanical process carried out with no attention to word meanings or even no knowledge of their meaning, as in reading a newly learned foreign language, unfamiliar words in one's native language, or a set of nonsense syllables. When this is the case, of course, the amount of semantic involvement is quite limited. This condition can, therefore, be used as baseline to which generative processing can be compared. In contrast to the Read condition, the type of cognitive operations performed in the two generative conditions cannot occur without semantic involvement and investment of cognitive resources. When provided with a definition, participants need to comprehend it and search in their semantic lexicon for the defined word. Greater elaboration is required when participants are provided with a word and asked to supply a definition for it. In this condition they are required not only to search in their semantic lexicon for the meaning of the word but also to provide a syntactically correct and semantically coherent description for it. Thus, the study conditions can be thought of as three levels of elaboration.

It should be noted that a distinction is made here between the support provided by the environment in the form of elaborate definitions presented at encoding (i.e., the Read condition, see details below), and guidance by specific instructions directing participants to perform tasks which would benefit their recognition memory (i.e., the two generation tasks, see details below). While both environmental support and the generation effect improve participants memory performance, in the former the support is provided by an external source (experimental material), while in the latter the support comes from within the participants. Thus, encouraging our older participants to perform elaborative encoding still required them to invest extra cognitive resources compared with a nongenerative condition, which is the only task with full external environmental support. In the two experiments described here, guidance provided by task instructions cannot be considered entirely synonymous with environmental support. This is because the "environment," i.e., test materials, provides the most "support" in the Read condition where participants merely have to read the presented material. Slightly less support is provided in the Generate Word condition, and the least in the Generate Definition condition. As generative requirements increase, the environment is in fact less supportive, and the participant has to expand increasingly greater cognitive resources to generate the response. Thus, even though task instructions are guiding the participant to perform elaborative/generative, processing they are essentially providing less support as generative requirement increases. It is the case, however, that should the participant be up to the task, he/she is expected to enjoy a stronger memory trace for the material and the cognitive process they performed. But if increased generation will require too high a price in terms of cognitive resources, participants will not be able to enjoy its benefits.

Memory for the studied words was measured by a recognition test. It was predicted that, for both age groups, the two generative tasks would yield better recognition memory than that following the Read task. Moreover, the Generate Definition task was expected to result in better recognition than the Generate Word task because it requires a greater amount of elaborative cognitive processing. During the recognition test, for each recognized word participants had to indicate what task relating to the word they performed during the study phase. Following Rabinowitz (1989) and Mitchell et al. (1986), the study conditions became the sources among which participants had to choose. Thus, a participant's own generative effort, or, in Rabinowitz' words, "the trace of completed cognitive operations," served as the clue to the source. Unlike identifying a person or a book as a source of information, source memory in this paradigm was intrinsically related to item memory, as it was the cognitive operations performed during reading or generating the target word or its definition. Therefore, in this study, source memory scores were expected to parallel those of item memory, improving with increased generative processing during study. Source memory was expected to be weaker than item memory because it poses additional requirements of more specific identification of the learning circumstance.

The paradigm used in this study also enabled us to investigate the reversibility of cue and response by measuring memorability of the same words presented as cues (when generating a definition) or generated as responses (when generating a word). Previous studies failed to demonstrate a generation effect for cues, posing a problem for theories that explained the generation effect by a strengthened association between cue and response. We expected to demonstrate that the factor determining later memorability is not the position of a word as cue or response, but rather the type of processing performed with it.

The crucial aspect of this investigation involved the effect of generation on age differences in both item and source memory. When considering the benefits of generation alone, it was expected that age differences would be inversely related to the amount of generative processing during study. As generative requirements increased, those older adults who could comply were expected to perform more closely to the level of young adults. As a result, for both item and source memory, greatest age difference was predicted to occur following the non-generative Read task, while the least divergence was expected following the Generate Definition task. However, as mentioned above, there are two sides to the environmental support hypothesis. Since the most external support is provided and least internal resources needed in the Read task, while the opposite is true for the Generate Definition task, the environmental support theory would predict the direct opposite of the generation effect prediction. In other words, the two groups would be closest following the Read study condition and furthest apart following the Generate Definition study condition. It is, of course, expected that both influences would be simultaneously active during encoding and retrieval. Since the two effects yield opposing predictions it would be possible to evaluate which of them tilted the balance.

EXPERIMENT 1

Two generative conditions were compared to a baseline Read condition. Memory scores and age differences were expected to be influenced by the generation effect and by environmental support. Regarding the generation effect, item recognition and source memory scores were expected to be directly related to the amount of generation, i.e., gradually improve from a study condition of no generation (Read) through a study condition requiring generation of a single word (Generate Word), to a study condition requiring generation of a full sentence describing the meaning of a word (Generate Definition). Although source memory is predicted to lag behind item memory, for both item and source memory largest age differences were expected to be found in the baseline condition, and to be reduced with increased levels of generative processing.

As to environmental support, the most support is provided by experimental material in the Read study condition where participants need not contribute anything and are mere recipients. Less support is provided in the Generate Word condition, and the least is given in the Generate Definition study condition. Accordingly, age differences were expected to be minimal following the Read study condition, increase in the Generate Word condition and be largest in Generate Definition study condition.

It should be noted that although the three study conditions are assumed to be on a continuum for each one of the opposing influences of generation and environmental support, there is no *apriori* assumption that they are equidistant from each other. Additionally, both effects are working simultaneously but there is no clear prediction as to their relative strength.

Method

Participants. Twenty-eight young (18-35 years of age) and 27 old adults (68-86 years of age) participated in the experiment. Young adults were undergraduate psychology students at Queens College who participated for course credit. Old adults were community dwelling volunteers recruited from Senior Centers in Manhattan. All participants reported themselves to be native English speakers, free of a history of neurological disease, emotional disorder, head trauma, or substance abuse.

Data of four of the young adults were not included in the analysis because they were judged to have given inaccurate reports regarding their native language. Data of three of the old adults were not included in the analysis for failure to consider one of the source response categories (usually Generate Word).

Demographic information is summarized in Table 1. As can be seen, the two groups were very similar in gender composition and in handedness. However, old adults had more years of education and better vocabulary, whereas young adults reported themselves to be in better health.

Materials. 125 concrete nouns, 4-12 letters long, were chosen from the compilation by Kucera and Francis (1967). Of those chosen, alphabetically successive words were alternately assigned to two lists of 60 words each. Words from one list were used in the study phase, while words from the other list served as distractors in the test phase. The remaining five words served as practice at the beginning of the recognition test in order to familiarize participants with the response procedure. The two lists were similar in word length (mean number of letters: List 1=5.85, List 2= 5.90) and word

Table 1: Demographic characteristics of young and old participants in Experiment 1.

	YOUNG		OLD		
Gender M/F	6/18		6/18		
Handedness R/L	24/0		22/2		
	M (SD)	**Range**	**M (SD)**	**Range**	**Age Difference**
Age	22.1 (5.0)	18-35	75.9 (6.1)	68-86	
Years of Education	13.1 (1.2)	12-16	15.3 (2.1)	10-18	p<.001
WAIS-R Vocabulary*	22.5 (7.6)	6-35	33.3 (5.3)	21-40	p<.001
Perceived Health State**	3.6 (0.5)	3-4	3.1 (0.6)	2-4	p<.004

* Raw score of last 20 items, maximum 40 points (after Multhaup, 1995).
** On a scale of 1-4: 1=poor, 2=fair, 3=good, and 4=very good

frequency (mean occurrences per million: List 1= 37.57, List 2=37.30). Definitions for each word were shortened and slightly modified versions of the Random House Webster's College Dictionary (1992) definitions. For example: "Crown - Headgear worn by a monarch, often made of precious metal and set with gems."; "Suitcase - A usually rectangular piece of luggage, especially for carrying clothes while traveling." (See Appendix A for Experiment 1 material.) Test stimuli and instructions were programmed into a Sager 486-DX laptop computer, and displayed in Arial 14-point boldface font (black and white display on a 19.4x14.1cm screen; 7"5/8 x 5"3/4).

Counterbalancing. The study phase had three processing conditions, each with directions applied to 20 words: (1) to read a word and its definition; (2) to read a definition and generate the defined word; and (3) to read a word and generate its definition. Order of presentation of the three instructional conditions was counterbalanced among participants, with every three participants completing a fully balanced set (1-2-3, 2-3-1, 3-1-2). Thus, the first participant saw instruction (1) first, the second participant saw instruction (2) first, etc. Each of the three instructions was paired with each of three blocks of 20 words. Thus, across participants, all the words were paired with all study conditions. Order of the 20 words within each block was computer randomized for each participant. Altogether, there were nine configurations of instructions and word-blocks: three possible presentation orders of instructional condition, and three possible pairings of instructional condition with 20-word blocks. An identical arrangement was used for List 2. Thus, a completely counterbalanced design required at least 18 participants in each age group.

In order to determine that counterbalancing had the desired effect, a preliminary

ANOVA was carried out on word-lists, order of instruction presentation, pairing of word-blocks with instructions, and age group, with percent correct recognition as the dependent variable. None of the main effects or interactions approached significance. Thus, counterbalancing was deemed to be effective in both age groups, and the main ANOVAs were carried out collapsed across the variables of word-list, order of instructions, and pairing of word-blocks with study instructions.

Design. A 2 X 3 mixed-design ANOVA was performed for each set of data, with group as between-subjects variable, and study conditions as within-subjects (repeated measures) variables. A number of dependent variables were examined, each in a separate analysis: overall item recognition, correct source attribution (see Appendix B for accuracy calculations and considerations), incorrect source attribution, false alarm responses, study time, and inter-stimulus-interval in the recognition test. Several between-subjects ANCOVA's were performed to examine group differences in item recognition and source accuracy, covarying out the effects of years of education, vocabulary score (estimated intelligence), and study time.

Following a significant interaction, contrasts were run to determine group differences in responding to the three study conditions. Contrasts are preferable to pairwise testing because they do not compare all means but only those of interest. Thus, fewer tests are run, minimizing the risk of a Type I error. Although contrasts are also available for the main effect of study condition, pairwise testing was chosen there because of the prevalence of this procedure in the literature. However, contrasts are presented for the interactions. Orthogonal polynomial contrasts were used to test for linear and quadratic trends (Ramsey, 1992). The prediction of decreased age differences with increased elaborative processing would be expressed in an interaction between age group and study condition, with a significant linear trend. In testing for a linear trend among three means, the contrast coefficients are such that only the two end points are compared (Read and Generate Definition), with a significant F indicating linearity. An interaction with a linear trend would, therefore, reflect different rates of improvement in the young compared with the old between the Read and Generate Definition conditions. In other words, group differences in the Read condition would be different from those in the Generate Definition condition.

A quadratic trend tests for departure from linearity. The coefficients are such that the three means are considered (including the middle point). A nonsignificant quadratic trend would prove that the three study conditions are in fact equally spaced. A significant quadratic trend would reflect unequal increments in recognition scores between study conditions. An interaction with a quadratic trend, therefore, reflects different increments between study conditions in the two groups. In testing for a quadratic trend the average of the Read and Generate Definition scores is compared with the Generate Word score. A significant F indicates that the Generate Word score is significantly different from the midpoint of Read and Generate Word.

Procedure. Participants were interviewed and tested individually. Young adults were tested in the memory laboratory at Queens College, while old adults were tested at senior centers. All participants first signed an informed consent form (Appendix C and D) and then filled out a demographics questionnaire (Appendix E), after which the experiment began. Participants sat approximately two feet from the screen of the laptop computer. The study phase started with reading of instructions displayed on the computer screen. Verbal responses were tape-recorded as a ploy meant to ensure that study instructions were followed. The instructions in the three study conditions asked participants to (1) read aloud both the word and its definition, e.g., "Crown - Headgear worn by a monarch, often made of precious metal and set with gems."; (2) read aloud a definition and say what word it defines, e.g., "Headgear worn by a monarch, often made of precious metal and set with gems." (C); or (3) to read aloud a word (e.g., "Crown") and provide a definition for it. An example of a stimulus and a reply was given for each condition (see Appendix F for instructions for the three study condition and for the memory test). In the second condition (Generate Word), the first letter of the required answer was given in parenthesis at the end of the definition to direct the participants to the right answer. Pilot testing demonstrated that this hint was very effective in keeping errors to a minimum. Participants were instructed to press the space bar in order to proceed to the next item on the list. Presentation of stimuli was self-paced, with a new item appearing as soon as the participant responded to the previous item. Participants were not specifically instructed to try to remember the study stimuli.

After the study phase, participants were given a vocabulary test, which included the last 20 items from the WAIS-R Vocabulary subtest (Wechsler, 1981). This subtest is a measure of verbal ability and is considered an estimate of intelligence. It was inserted between study and test because pilot testing showed ceiling effects on the recognition test in the young adult group when no delay was introduced. Following the vocabulary test, the recognition test was administered. Instructions displayed on the computer screen informed participants that for each word presented they must decide whether or not they had encountered the word earlier in the experiment in any form, i.e., as having been read along with its definition, as being provided in response to a definition, or as having been defined. Recognition responses were indicated by pressing one of two keyboard keys. The letter "Y" corresponding with a "Yes" response was marked on a yellow sticker covering the "I" key on the keyboard. The letter "N" corresponding with a "No" response was marked on a yellow sticker covering the "R" key on the keyboard. For each word recognized as being encountered earlier in the experiment, a forced-choice source memory test appeared in which participants indicated the task performed relating to that word. Response was selected by pressing one of three keyboard keys marked with a red sticker. The stickers covered the keys "C", "B", and "M" on the keyboard, and had the letters "B", "D", and "W" marked on them, respectively. The marked letters refer to what the participants read from the screen during the study phase. "B" indicated that the participant read Both the word and its definition, "D" indicated that the participant read the Definition and had to provide the word, and "W" indicated that the participant read the Word and had to provide the definition. Response instructions were continuously displayed on the screen, changing from recognition to source instructions as the participant made the selection.

The first five words on the recognition list served as practice trials. Two of these words were not previously encountered and the other three were encountered during study, one in each study condition. Responses to these trials were not included in the analysis, but served to familiarize participants with the response procedure. Participants were closely monitored at this stage to verify that they understood the procedure. They were encouraged to ask questions if anything was unclear to them. Thereafter, order of target and distractor words on the recognition list was computer randomized, with the limitation that there should not be more than four successive targets or distractors. At the end of the test, participants were given the opportunity to view a summary of their responses and were debriefed. The procedure lasted approximately one hour.

Results

Table 2 summarizes the mean recognition and source scores obtained in all study and response combinations. The table is arranged with the three (repeated measures) study conditions across the top and the corresponding three possible source responses listed vertically for the young and the old groups. Within the body of the table, the bottom line (Mean Total Recognition) displays mean recognition scores following each study condition, collapsed across age groups and source selections. The subtotals of young and old list their total recognition scores following each study condition, including recognition with incorrect as well as correct source attributions. Mean percentages of correct source attributions are emphasized in boldface letters. Subtotals of young and old are also depicted in Figure 1.

Total Recognition Scores – All Attributions. The main effect of study condition on total recognition scores (Mean Total Recognition, Table 2—bottom line) was significant, F (2, 92) = 85.37, MSE = 136.08, p<.001. As expected, lowest overall recognition rates were obtained following the Read study condition and highest recognition rates appeared following the Generate Definition study condition. Pairwise comparisons (Least Significant Difference (LSD) adjustment was applied in all multiple comparisons) revealed that each study condition was significantly different from the other two. Thus, Read—Generate Word (Mean Difference = -21.56%), p<.001, Read—

Table 2: **Percent correct recognition of young and old following the three study conditions, and the distribution of source attributions – Experiment 1.**

	STUDY CONDITION			
SOURCE RESPONSES	**Read**	**Generate Word**	**Generate Definition**	**Grand Mean**
Young (N=24)				
Read	**61.04 (19.45)**	12.24 (11.06)	2.92 (4.87)	
Generate Word	5.83 (7.17)	**81.14 (13.28)**	2.74 (4.27)	
Generate Definition	2.29 (3.29)	2.47 (4.60)	**93.93 (7.11)**	
Subtotal Young	69.17 (16.98)	95.85 (5.22)	99.58 (1.41)	88.20 (6.92)
Old (N=24)				
Read	**52.71 (26.21)**	19.64 (16.96)	4.17 (6.02)	
Generate Word	12.29 (12.42)	**57.76 (25.65)**	9.17 (11.95)	
Generate Definition	3.13 (8.32)	7.17 (10.22)	**84.79 (14.26)**	
Subtotal Old	68.13 (20.58)	84.57 (16.30)	98.13 (3.23)	83.61 (10.48)
Mean Total Recognition	68.65 (18.67)	90.21 (13.26)	98.85 (2.58)	85.90 (9.09)

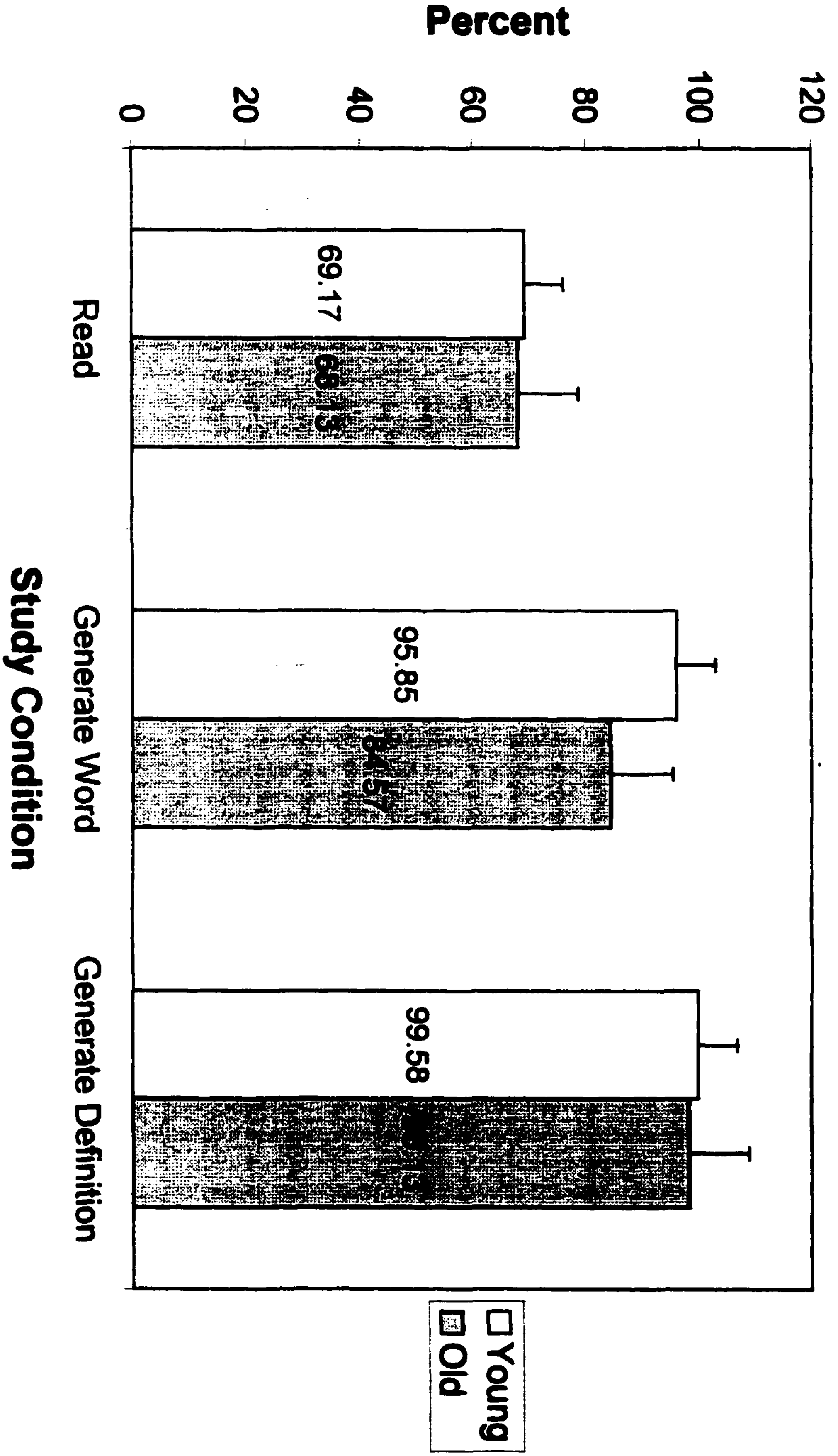


Figure 1: Item Memory (Overall Recognition) - Experiment 1

Generate Definition (Mean Difference = -30.21%), $p<.001$, Generate Word—Generate Definition (Mean Difference = -8.65%), $p<.001$. The main effect of group (comparing grand means of young and old) fell short of significance, F (1, 46) = 3.21, MSE = 236.50, $p>.079$, as did the interaction of group with study condition F (2, 92) = 2.96, MSE = 136.08, $p>.057$, implying that both age groups reacted similarly to the study condition manipulation. Since the interaction approached significance, trends in age differences were evaluated to determine group differences in responding to the three study conditions. The linear trend was nonsignificant, F (1, 46) = .006, MSE = 168.98, $p>.937$, but there was a significant quadratic trend, F (1, 46) = 7.801, MSE = 103.18, $p<.009$, reflecting a more pronounced quadratic trend of study conditions in the young than in the old, most likely due to ceiling effects. Thus, the extent to which Generate Word study condition exceeded the average of Read and Generate Definition conditions, was greater in the young than in the old.

Since older adults had more years of education and better vocabulary scores, which may have aided their memory performance, two ANCOVA's were performed comparing groups on overall recognition while covarying out the contributions of these variables. Number of years of education was not significantly related to overall recognition rate F (1, 45) = .09, MSE = 80.43, $p>.767$. However, vocabulary scores were found to be marginally related to recognition scores F (1, 45) = 3.62, MSE = 74.59, $p<.065$, and covarying out the contribution of vocabulary ability caused group differences in overall recognition to become significant F (1, 45) = 6.94, MSE = 74.59, $p<.012$. Thus, age differences in mean overall recognition scores increased following the covariance analysis. Before covariance group means were: Young = 88.20%, and Old = 83.61% (a nonsignificant difference, see above), while following covariance the corrected means became: Young = 90.20%, and Old = 81.61%. This finding suggests that the better vocabulary of individuals in the older group attenuated age differences in recognition.

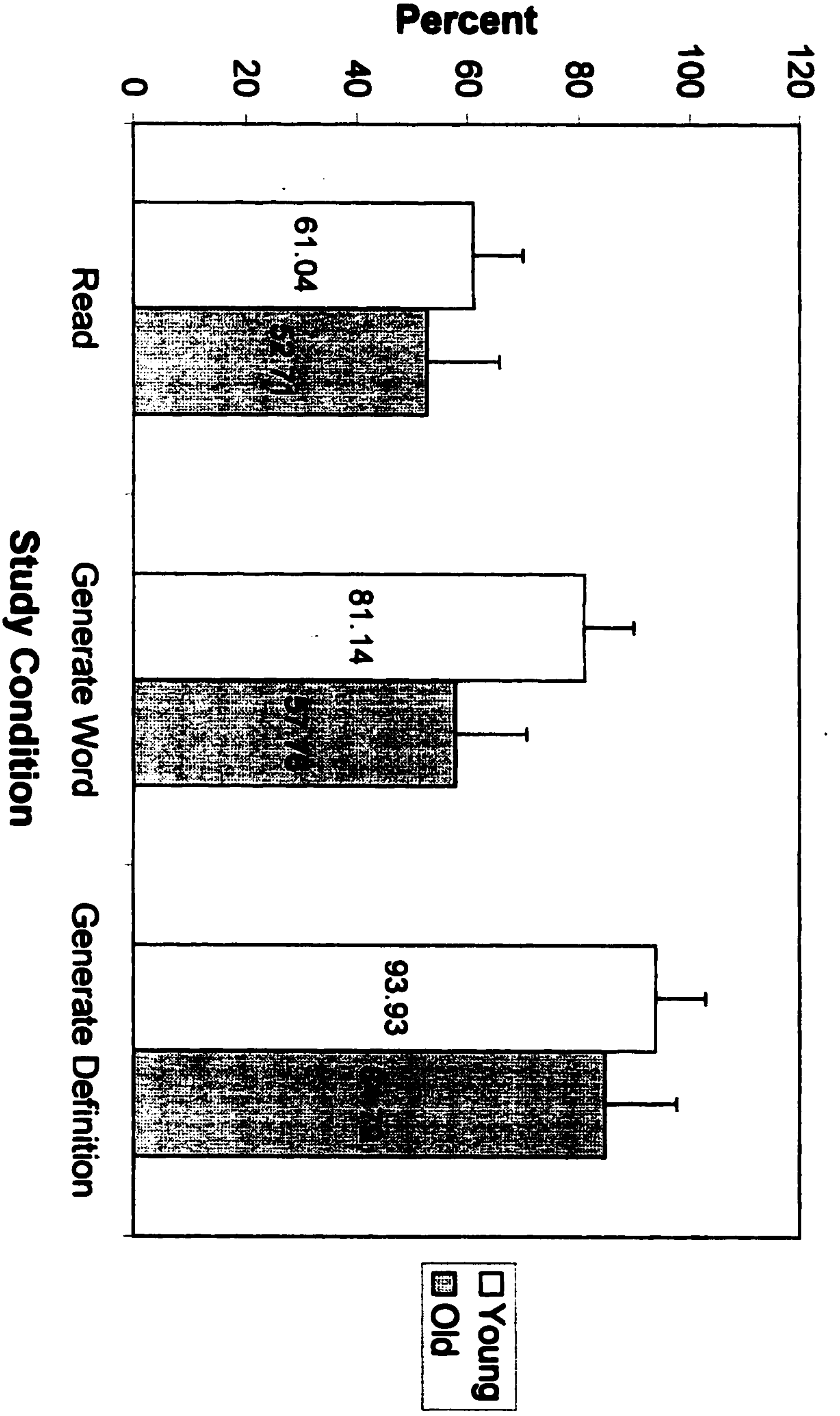
Correct Recognition – Correct Source Attribution. For easy reference, correct source attributions are repeated in Table 3 together with overall means, and displayed in Figure 2. When analyzing recognition scores that also received correct source attributions, the main effect of study condition, collapsed across age groups, was significant F (2, 92) = 37.71, MSE = 341.53, p<.001. Means of the three correct source attributions collapsed across age groups were: Read = 56.88%, Generate Word = 69.45%, Generate Definition = 89.36%. Pairwise comparisons revealed that the three means were significantly different from each other: Read—Generate Word (Mean Difference = -12.57%), p<.016, Read—Generate Definition (Mean Difference = -32.48%), p<.001, Generate Word—Generate Definition (Mean Difference = -19.91%), p<.001. The main effect of group was also significant F (1, 46) = 16.96, MSE = 393.54, p<.001, reflecting greater accuracy of the young group. The interaction of age group and study condition did not reach significance F (2, 92) = 2.52, MSE = 341.53, p>.085, implying that the two groups had a parallel trend of improved source accuracy with increased generation. Since the interaction approached significance trends in age differences were evaluated. The linear trend was nonsignificant F (1, 46) = .012, MSE = 332.46, p>.914, but there was a significant quadratic trend F (1, 46) = 4.899, MSE = 350.60, p<.033. Thus, the extent to which Generate Word study condition differed from the average of Read and Generate Definition conditions, was greater in the old than in the young.

Two ANCOVA's were performed comparing groups on correct source attribution

Table 3: **Percent correct source attributions of young and old for items from the three study conditions – Experiment 1.**

	Read	Generate Word	Generate Definition	Grand Mean (SD)
Young	61.04 (19.45)	81.14 (13.28)	93.93 (7.11)	78.70 (9.45)
Old	52.71 (26.21)	57.76 (25.65)	84.79 (14.26)	65.08 (13.16)
Mean	56.88 (23.22)	69.45 (23.41)	89.36 (12.06)	71.89 (13.26)

Figure 2: Correct Recognition and Correct Source Attribution - Experiment 1



while covarying out the contributions of years of education and vocabulary scores. Number of years of education was not significantly related to overall source accuracy rate F (1, 45) = 1.83, MSE = 128.87, p>.182, while vocabulary scores did covary with source accuracy F (1, 45) = 5.35, MSE = 119.85, p<.026. Age differences in overall source accuracy increased following vocabulary covariance. Before covariance group means were: Young = 78.70%, and Old = 65.08%, while following covariance the corrected means became: Young = 81.78%, and Old = 62.01%. However, covarying vocabulary did not change group differences in source accuracy as these were significant before (see above) and after covariance analysis F (1, 45) = 22.90, MSE = 119.85, p<.001.

Incorrect Source Attribution. Table 4 shows incorrect source attribution in each study condition. The main effect of study condition on wrong source attribution was significant F(2, 92) = 11.33, MSE = 150.24, p<.001. Thus, across age groups, significantly more errors of source attribution were committed following the Generate Word (M=20.76%) study condition than in the Read (M=11.77%) or Generate Definition (M=9.50%) conditions which did not differ. Pairwise comparisons showed Read—Generate Word (Mean Difference -8.99%), p<.006, Read—Generate Definition (Mean Difference 2.28%), p>.999, Generate Word—Generate Definition (Mean Difference 11.26%), p<.001. The main effect of group was also significant F (1, 46) = 19.82, MSE = 147.90, p<.001, indicating a greater number of errors in the old group across study conditions. The interaction of wrong source attribution with group was not significant F (2, 92) = .57, MSE = 150.24, p>.566, indicating that the two groups had a parallel pattern of error scores in the three study conditions.

Table 4: **Percent wrong source attribution of young and old for items from the three study conditions – Experiment 1.**

	Read	Generate Word	Generate Definition	Grand Mean (SD)
Young	8.13 (8.32)	14.71 (11.42)	5.66 (6.69)	9.49 (5.72)
Old	15.42 (14.36)	26.81 (16.12)	13.33 (13.65)	18.52 (8.12)
Mean	11.77 (12.18)	20.76 (15.11)	9.49 (11.32)	14.01 (8.31)

False Alarm Responses. False alarm rates are shown in Table 5, and it is noteworthy that these were very low (less than 3%) in both groups, demonstrating that most participants had no difficulty correctly rejecting words they had not encountered in the study phase. Eighteen of the 48 participants did not make even a single false alarm response.

The main effect of study condition was significant F (2, 92) = 3.84, MSE = 1.21, p<.026, reflecting a lower tendency to falsely attribute responses to the Generate Definition study condition than to the Read or Generate Word study conditions. Pairwise comparisons showed Read—Generate word (Mean Difference .04%), p>.876, Read—Generate Definition (Mean Difference .52%), p<.018, Generate Word—Generate Definition (Mean Difference .56%), p<.026. The two groups were not significantly different in number of false alarm responses F (1, 46) = 1.65, MSE = 2.31, p>.205, nor was the interaction significant F (1, 46) = .685, MSE = 1.21, p>.506.

Study Time. Study time is presented in Table 6, and compares the mean time dedicated to an item in each of the three study conditions. The main effect of study condition was significant F (2, 92) = 17.52, MSE = 11.12, p<.001. Collapsed across age groups, increased generation required significantly longer study times: Read—Generate Word (Mean Difference –1.34 sec.), p<.002, Read—Generate Definition (Mean Difference –3.96 sec.), p<.001, Generate Word—Generate Definition (Mean Difference -2.62 sec.), p<.003. The young were faster than the old F(1, 46) = 15.06, MSE = 20.39, p<.001. The interaction of group and study condition failed to reach significance F (2, 92) = 2.74, MSE = 11.12, p>.069, reflecting parallel increases in study time with increased generation in the two groups.

Table 5: **Percent false alarm responses of young and old adults and their erroneous source attributions – Experiment 1.**

	ERRONEOUS SOURCE ATTRIBUTIONS			
	Read	Generate Word	Generate Definition	Total False Alarms
Young	.83 (1.47)	.83 (1.39)	.07 (.34)	1.74 (2.53)
Old	.97 (1.09)	1.04 (1.69)	.70 (1.09)	2.71 (2.73)
Mean	.90 (1.28)	.94 (1.53)	.38 (.86)	2.22 (2.65)

Table 6: **Mean item study time (in seconds) in each study condition – Experiment 1.**

	Read	Generate Word	Generate Definition	Grand Mean (SD)
Young	8.09 (.93)	9.80 (2.27)	10.89 (3.91)	9.59 (1.97)
Old	10.48 (3.08)	11.45 (2.95)	15.60 (6.76)	12.51 (3.12)
Mean	9.28 (2.56)	10.62 (2.73)	13.24 (5.96)	11.05 (2.97)

It was important to evaluate whether increased recognition with increased generation could be partly or wholly attributed to the longer study time spent on items requiring greater generative effort, rather than to the generative process itself. A one-way between-subjects ANCOVA was performed to examine the effect of group on total item recognition, covarying total study time. Total study time was not significantly related to total recognition F (1, 45) = .716, p>.401. Three additional between-subjects ANCOVA's compared recognition subtotals following each study condition, covarying their respective study times. In each case, study time was found to be unrelated to recognition: Read F (1, 45) = 1.238, p>.271; Generate Word F (1, 45) = .135, p>.714; Generate Definition F (1, 45) = .371, p>.544.

Lastly, three ANCOVA's examined the effect of study condition on correct source attributions, covarying the study times in each condition. The covariate of study time was not significant in each case: Read F (1, 45) = .099, p>.753, Generate Word F (1, 45) = .001, p>.977, Generate Definition F (1, 45) = .451, p>.504. Thus, correct source attribution was not influenced by study time.

Inter-Stimulus Interval. Inter-stimulus interval (ISI) measured the time between successive items on the recognition test. It includes the sum of the time for yes/no recognition and the time for the source selection. Results are displayed in Table 7. N is mentioned separately for each source attribution, because each cell mean was computed according to the number of participants who made the particular source attribution. Dividing each cell by the total number of participants would have artificially decreased mean interval time.

Table 7: **Inter-Stimulus-Interval (in seconds) during the recognition test in Experiment 1. N = The number of participants who made the particular source selection.**

		STUDY CONDITION				
SOURCE RESPONSES		Read		Generate Word		Generate Definition
Young	N		N		N	
Read	24	**8.09 (2.04)**	19	8.35 (3.54)	7	8.73 (3.74)
Generate Word	14	9.36 (5.18)	24	**7.82 (1.88)**	9	10.42 (5.15)
Generate Definition	9	9.14 (4.47)	7	8.64 (4.06)	24	**6.71 (1.82)**
Mean Young		8.34 (2.50)		7.86 (2.32)		7.39 (2.41)
Old	N		N		N	
Read	23	**18.07 (6.97)**	20	17.12 (9.69)	10	27.83 (29.04)
Generate Word	18	18.64 (6.94)	23	**17.65 (9.47)**	15	14.84 (5.32)
Generate Definition	7	27.94 (10.26)	16	18.71 (12.12)	24	**12.01 (3.53)**
Mean Old		18.73 (6.13)		18.09 (8.94)		15.36 (10.71)
Overall Mean		13.54 (7.00)		12.98 (8.27)		11.38 (8.67)

The main effect of study condition did not reach significance F (2, 92) = 1.77, MSE = 34.19, p>.176, reflecting no significant difference in ISI of items from the three study conditions. Young adults were faster than old adults F (1, 46) = 57.81, MSE = 56.52, p<.001. The interaction of group and study condition did not reach significance F (2, 92) = .64, MSE = 34.19, p>.529, indicating that the advantage of young over old persisted in the three study conditions.

A summary of all statistical analyses of Experiment 1 data is presented in Table 8.

Discussion

The results of Experiment 1 show that the three study conditions were effective in producing three levels of recognition memory. Congruent with the generation effect predictions, both generation tasks produced greater recognition rates than the Read task. Importantly, the task of generating a definition to a word was most effective and resulted in higher recognition scores than generating a single word in response to its definition.

Although age differences in recognition are usually smaller than in recall, it was somewhat unexpected to find no significant difference in total recognition between young and old suggesting that generative processing can eliminate age differences. However, covariance analysis showed that this finding may be partly attributed to the better vocabulary ability of the older group, as covarying the contribution of vocabulary resulted in a significant difference between the two groups in overall recognition.

The two groups reacted similarly to the manipulation of study condition, increasing in recognition rates steadily with added generation. However, while the young group displayed over a seven-fold increase in recognition rate between Read and

Table 8: Summary of statistical analyses in Experiment 1.

Dependent Variable	Main Effects			Pairwise Comparisons In Main Effect of Study			Contrasts on Interaction	
	Study	Group	Interaction	R-GW	R-GD	GW-GD	Linear	Quadratic
Total Recognition	S	NS	NS	S	S	S	NS	S
Correct Source	S	S	NS	S	S	S	NS	S
Source Errors	S	S	NS	S	NS	S		
False Alarms	S	NS	NS	NS	S	S		
Study Time	S	S	NS	S	S	S		
ISI	NS	S	NS	NS	NS	NS		

Legend:
S – Significant
NS – Nonsignificant
ISI – Inter-Stimulus-Interval

Contrasts:
Linear trend: is the age difference in Read significantly different from that in Generate Definition
Quadratic trend (departure from linearity): is the age difference in Generate Word significantly different from the mean of Read + Generate Definition

Generate Word (26.68%) than between the two generation conditions (3.74%), the old group had a similar increase in recognition scores from Read to Generate Word (16.44%) as from Generate Word to Generate Definition (13.56%). The smaller improvement of young adults between Generate Word and Generate Definition is likely due to a ceiling effect, which seems to be behind the quadratic trend of the interaction. Nonetheless, it appears that compared with old adults, young adults are better able to benefit from generation of a single word. Age differences were greater for items of the Generate Word study condition than in the other two conditions.

Older adults were not as accurate as younger adults in recalling the source of a learned word, as reflected both in percent correct source attribution and percent wrong source attributions. This finding demonstrates the relative weakness of source memory compared with item memory in old adults because, as mentioned above, no significant age difference was observed in total recognition rate. As seen in total recognition, young adults had a greater improvement from Read to Generate Word (20.1%) than from Generate Word to Generate Definition (12.8%). The old group showed a very small improvement in source accuracy with word generation (5.05%), and had a much greater improvement between the Generate Word and Generate Definition conditions (27.04%). Thus, similar to overall recognition findings, older participants had to invest a greater amount of generative effort before showing a marked improvement in source accuracy over baseline. Age differences in source memory were also largest for items of the Generate Word study condition. Older adults made more source errors than young adults consistent with weaker source memory with increased age. There was a trend across age groups for higher error rates following the Generate Word study condition than the other two conditions, which did not differ.

No age difference was seen in false alarm responses, which were very rare (less than 3%) in both groups. Even this low level may be inflated, as the computer program did not allow correction of impulsive responses (i.e., it was not possible to go back in the recognition list and change a response). Thus, both groups had no difficulty correctly rejecting words they had not encountered during study. Across groups, fewest false attributions were made to the Generate Definition study condition. Metamemory considerations may have contributed to this finding, i.e., if participants were not quite sure about a word and made a false positive recognition response they were more likely to attribute it to the Read or Generate Word conditions than to the condition they remembered best.

Study time was directly related to the amount of generation and resulted in three study durations significantly different from each other. However, total study time did not covary with total recognition, and mean study time in each of the conditions did not covary with recognition or correct source attribution in the respective conditions. Thus, increased memorability with increased generation was unrelated to the amount of time dedicated to items during study. Not surprisingly, older adults were consistently slower than younger adults in responding to items during study. It is noteworthy that older participants tended to produce longer and more detailed definitions than young adults who occasionally gave very abbreviated definitions. Thus, the time difference is not only due to slow information processing speed but also due to the more elaborate answers of older adults, possibly due to the more talkative and less hurried nature of this group. Although young were faster than old in the recognition test as well, there was no difference in inter-stimulus-interval of items from the three study conditions.

Taken together, the major findings of Experiment 1 show that recognition memory was directly related to the degree of generative processing during study. Additionally, despite equal levels of item recognition in the two groups, the old did more poorly than the young on the source memory task. This result supports previous findings of greater susceptibility of source compared with item memory to age-related decline.

Regarding age differences, a parallel trend was seen for both item recognition and source memory for greater age difference in Generate Word than in the Read and Generate Definition conditions. This was a puzzling finding as it did not reconcile with our predictions and could not be accounted for by the theories we considered.

Somewhat unexpectedly, compared with the baseline Read condition, the old group showed improved source accuracy with generation following the Generate Definition study condition but not following the Generate Word study condition. This result suggested either failure to benefit from word generation, or an inflated level of recognition and source memory following the Read study condition in the old group. The first explanation was rejected because total recognition of the old group improved between the Read and Generate Word study conditions, and both recognition and source memory improved between the Generate Word and Generate Definition study conditions. It was, therefore, decided to investigate the second explanation, reasoning that the definitions used may have been overly detailed and lengthy, providing abundant associations and more elaborate processing than is appropriate for a baseline. As a consequence, the Read condition was not completely passive and likely included elaboration.

In Experiment 2 the lengthy definitions of Experiment 1 were shortened. It was predicted that reducing the amount of details and associations included in the definitions would induce lower recognition and source memory rates in the Read condition. As a consequence, older adults would display a more robust improvement in source memory following the Generate Word study condition. This change was also expected to reduce age differences in the Generate Word condition.

EXPERIMENT 2

Experiment 2 was a modification of Experiment 1 and similar to it in all but two respects. First, definitions were considerably shorter and unnecessary enrichment was removed. For example the Experiment 1 definition for the word "Crown" was "Headgear worn by a monarch, often made of precious metal and set with gems." The shortened, Experiment 2 version, became "Headgear worn by a monarch." (See Appendix G for Experiment 2 material.) Second, variance in delay time between study and test was noticed during Experiment 1, presumably due to variability in vocabulary knowledge. Therefore, delay between study and test was measured in Experiment 2.

Method

Participants. Twenty-four young and 24 old adults participated in the experiment. Young adults were undergraduate psychology students at Queens College who participated for course credit. Old adults were community-dwelling volunteers recruited from Senior Centers in Manhattan.

Demographic information is summarized in Table 9. As was the case in Experiment 1, the male to female ratio and the handedness ratio were very similar between the two age groups. Older adults had more years of education and better vocabulary scores than younger adults, while younger adults reported themselves to be in better health.

Table 9: Demographic characteristics of young and old participants in Experiment 2.

	YOUNG		OLD		
Gender M/F	2/22		3/21		
Handedness R/L	18/6		20/4		
	M (SD)	**Range**	**M (SD)**	**Range**	**Age Difference**
Age	23.9 (5.7)	18-35	78.7 (4.7)	69-85	
Years of Education	13.4 (0.8)	12-15	15.2 (2.9)	12-21	p<.008
WAIS-R Vocabulary*	20.5 (6.4)	9-34	34.9 (3.8)	23-40	p<.001
Perceived Health State**	3.4 (0.5)	3-4	3.0 (0.7)	2-4	p<.013

* Raw score of last 20 items, maximum 40 points (after Malthaup, 1995).

** On a scale of 1-4: 1=poor, 2=fair, 3=good, and 4=very good

Results

Total Recognition Scores – All Attributions. Recognition scores of Experiment 2 are presented in Table 10. Recognition subtotals of young and old including correct and incorrect source attributions are also depicted in Figure 3. The main effect of study condition (Mean Total Recognition, Table 10—bottom line) was significant, F (2, 92) = 109.17, MSE = 128.32, p<.001. Pairwise comparisons revealed that each study condition was significantly different from the other two. Thus, Read—Generate Word (Mean Difference = -21.97%), p<.001, Read—Generate Definition (Mean Difference = -33.65%), p<.001, Generate Word—Generate Definition (Mean Difference = -11.67%), p<.001. As in Experiment 1, increased generation resulted in increased recognition scores with the lowest overall recognition rates following the Read study condition and highest following the Generate Definition study condition. Unlike Experiment 1, young adults recognized significantly more items than old adults (comparing grand means collapsed across study conditions and source responses) F (1, 46) = 8.24, MSE = 306.68, p<.007. The interaction of group with study condition was not significant F (2, 92) = 2.25, MSE = 128.32, p>.110, implying that the two groups reacted similarly to the study condition manipulation.

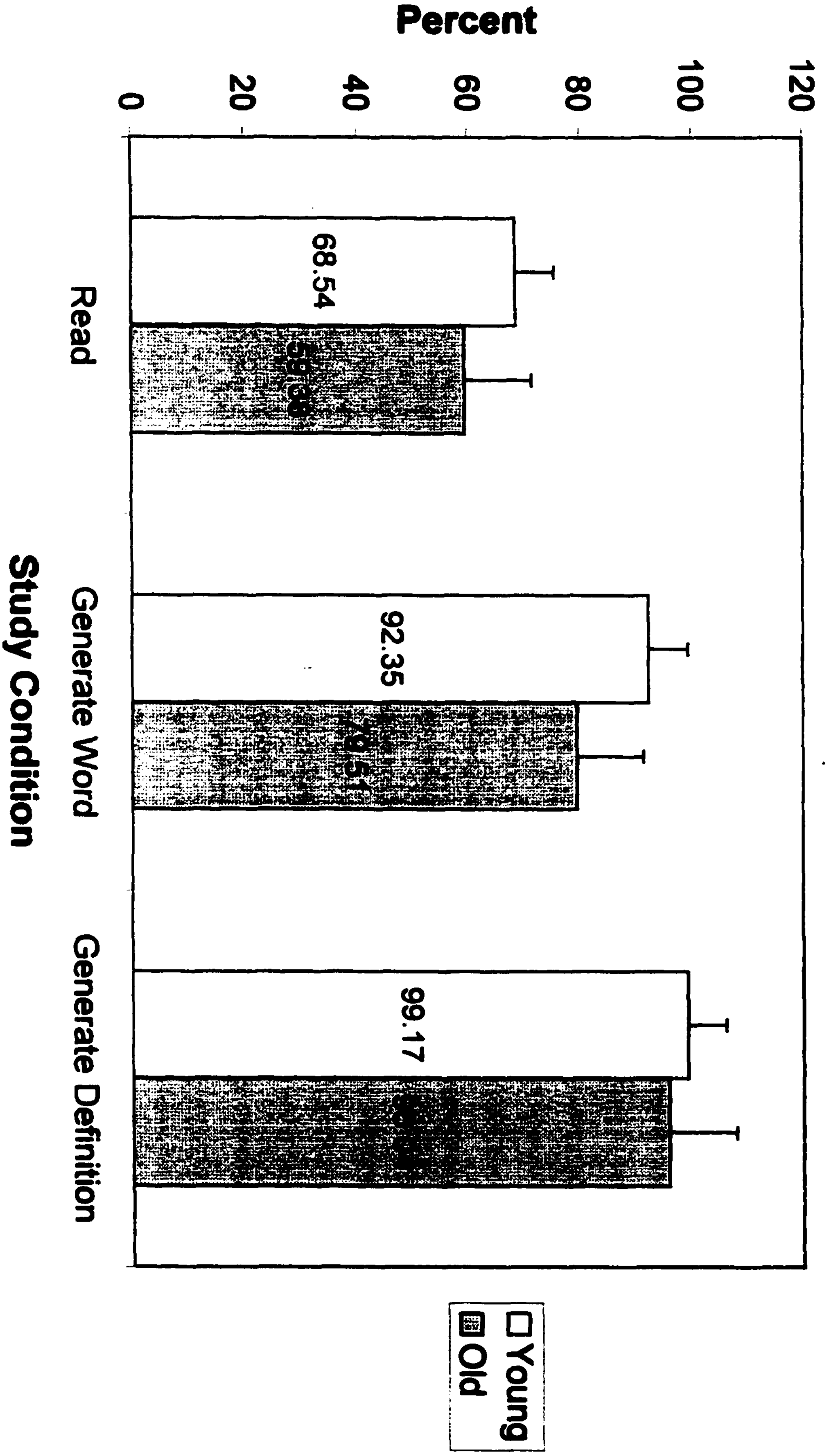
Since older adults had more years of education and better vocabulary scores, which may have aided their memory performance, two ANCOVA's were performed comparing groups on overall recognition while covarying out the contributions of these variables. Number of years of education was not significantly related to overall recognition rate F (1, 45) = 1.10, MSE = 102.00, p>.299, while vocabulary scores were found to be marginally related to recognition scores F (1, 45) = 3.22, MSE = 97.51,

Table 10: Percent correct recognition of young and old following the three study conditions, and distribution of source attributions – Experiment 2.

	STUDY CONDITION			
SOURCE RESPONSES	Read	Generate Word	Generate Definition	Grand Mean
Young (N=24)				
Read	***59.38 (24.82)**	7.70 (6.74)	1.67 (3.81)	
Generate Word	8.96 (17.32)	**80.27 (12.46)**	3.54 (5.99)	
Generate Definition	.21 (1.02)	4.38 (5.43)	**93.96 (8.47)**	
Subtotal Young	68.54 (17.35)	92.35 (8.88)	99.17 (2.41)	86.69 (7.25)
Old (N=24)				
Read	**36.04 (23.96)**	13.61 (13.62)	2.92 (6.41)	
Generate Word	13.54 (15.91)	**48.92 (21.35)**	6.67 (9.63)	
Generate Definition	9.79 (13.39)	16.98 (16.39)	**86.46 (16.65)**	
Subtotal Old	59.38 (20.87)	79.51 (16.52)	96.04 (5.71)	78.31 (12.32)
Mean Total Recognition	63.96 (19.54)	85.93 (14.64)	97.60 (4.61)	82.50 (10.86)

* Correct source attributions are emphasized in boldface letters.

Figure 3: Item Memory (Overall Recognition) - Experiment 2



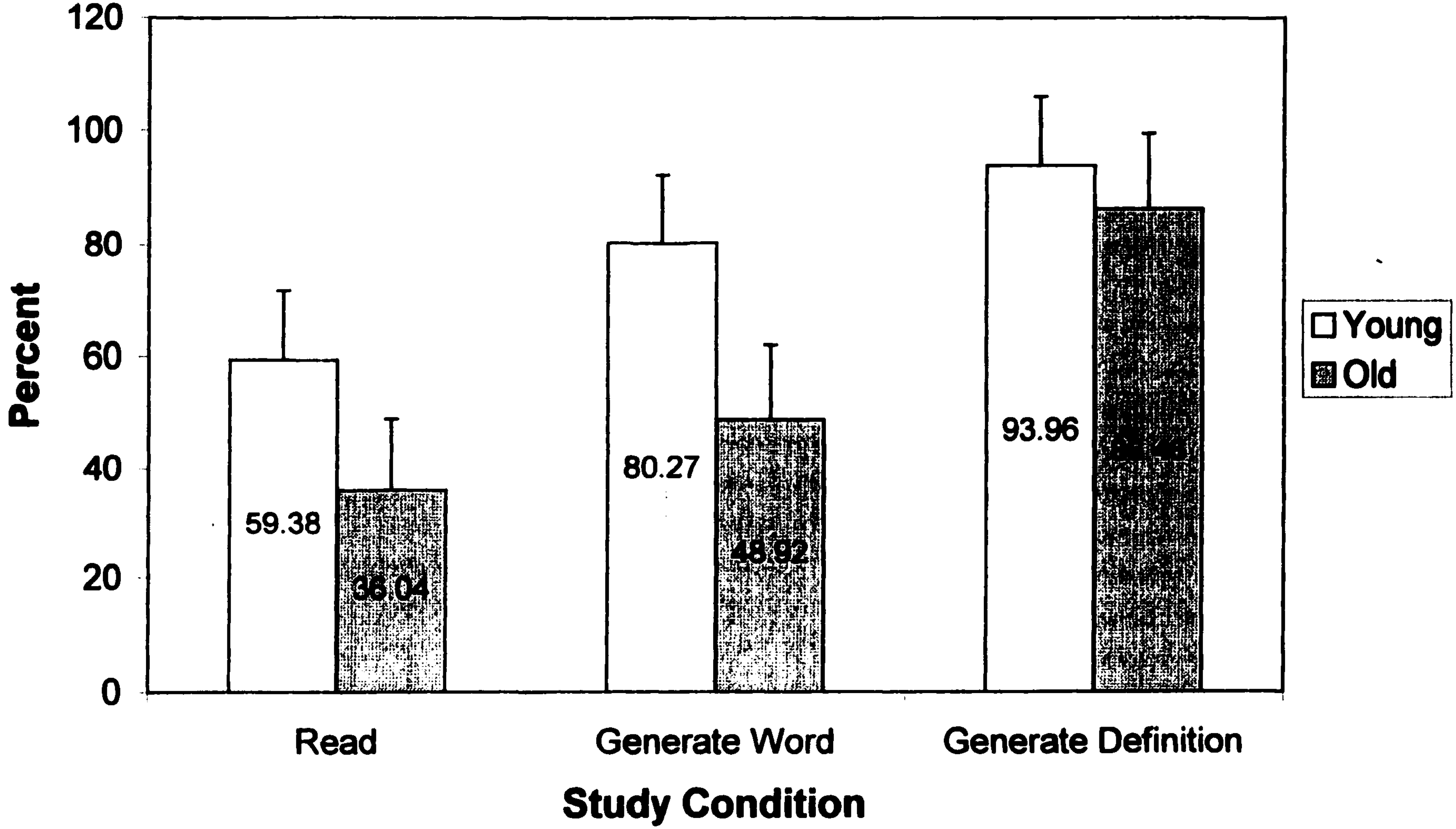
p<.080. Age differences in overall recognition scores increased following the covariance analysis. Before covariance group means were: Young = 86.69%, and Old = 78.31%, while following covariance the corrected means became: Young = 90.26%, and Old = 74.74%. This finding suggests that the better vocabulary of individuals in the older group attenuated age differences in recognition. Nonetheless, age differences in total recognition were significant before (see above) and after covarying out the contribution of vocabulary ability F (1, 45) = 10.05, MSE = 97.51, p<.004.

Correct Recognition – Correct Source Attribution. For easy reference, correct source attributions are repeated in Table 11 together with overall means, and displayed in Figure 4. When analyzing recognition scores that also received correct source attributions, the main effect of study was significant F (2, 92) = 73.22, MSE = 300.19, p<.001. Pairwise comparisons revealed that, collapsed across age groups, source accuracy increased with increased generation: Read—Generate Word (Mean Difference = -16.89%), p<.001, Read—Generate Definition (Mean Difference = -42.50%), p<.001, Generate Word—Generate Definition (Mean Difference = -25.61%), p<.001. Overall, the young were more accurate than the old F (1, 46) = 32.61, MSE = 474.44, p<.001. However, the interaction of correct source attribution with age group was significant F (2, 92) = 5.89, MSE = 300.19, p<.005. Contrasts on the interaction were significant for both linear F (1, 46) = 4.65, MSE = 323.82, p<.037, and quadratic trends F (1, 46) = 7.35, MSE = 276.56, p<.010. Thus, the increase in correct source attribution between the Read and Generate Definition conditions was significantly greater in the old group (approximately 50% difference) than in the young (approximately 34% difference). However, the extent to which Generate Word study condition differed from the average

Table 11: **Percent correct source attribution of young and old for items from the three study conditions – Experiment 2.**

	Read	Generate Word	Generate Definition	Grand Mean (SD)
Young	59.38 (24.82)	80.27 (12.46)	93.96 (8.47)	77.87 (11.91)
Old	36.04 (23.96)	48.92 (21.35)	86.46 (16.65)	57.14 (13.21)
Mean	47.71 (26.86)	64.60 (23.45)	90.21 (13.60)	67.50 (16.26)

Figure 4: Correct Recognition and Correct Source Attribution - Experiment 2



of Read and Generate Definition conditions, was greater in the old (approximately 12%) than in the young (approximately 4%).

Two ANCOVA's were performed comparing groups on correct source attribution while covarying out the contributions of years of education and vocabulary scores. Number of years of education was not significantly related to overall source accuracy rate F (1, 45) = 2.06, MSE = 154.58, p>.157, while vocabulary scores did covary with source accuracy F (1, 45) = 5.49, MSE = 144.08, p<.025. Age differences in overall source accuracy increased following vocabulary covariance. Before covariance group means were: Young = 77.87%, and Old = 57.14%, while following covariance the corrected means became: Young = 83.54%, and Old = 51.47%. However, covarying vocabulary did not change group differences in source accuracy as these were significant before (see above) and after covariance analysis F (1, 45) = 29.03, MSE = 144.08, p<.001.

Incorrect Source Attributions. Table 12 shows incorrect source attribution in each study condition. When evaluating errors in source attributions, the main effect of study condition was significant F(2, 92) = 12.28, MSE = 194.60, p<.001. Across age groups, errors of source attribution increased from the Read (16.25%) to the Generate Word (21.34%) study conditions, but decreased between the Generate Word and Generate Definition (7.40%) study conditions. Pairwise comparisons showed Read—Generate Word (Mean Difference –5.09%), p>.117, Read—Generate Definition (Mean Difference 8.85%), p<.006, Generate Word—Generate Definition (Mean Difference 13.94%), p<.001. Thus, there were significantly fewer errors of source attribution following the Generate Definition study condition than the other two conditions which did not differ. Older adults made more errors of source attribution than young adults F (1, 46) = 19.66,

Table 12: **Percent wrong source attribution of young and old for items from the three study conditions – Experiment 2.**

	Read	Generate Word	Generate Definition	Grand Mean (SD)
Young	9.17 (17.24)	12.08 (8.78)	5.21 (7.59)	8.82 (9.04)
Old	23.33 (20.73)	30.60 (17.13)	9.58 (13.51)	21.17 (10.23)
Mean	16.25 (20.17)	21.34 (16.40)	7.40 (11.06)	14.99 (11.41)

MSE = 279.41, $p<.001$. The interaction of wrong source attribution with group was significant F (2, 92) = 3.24, MSE = 194.60, $p<.045$. However, the linear F (1, 46) = 2.65, MSE = 216.97, $p<.111$ and quadratic trends F (1, 46) = 3.97, MSE = 172.22, $p<.053$ failed to reach significance, although the latter approached significance indicating a departure from linearity. Because pairwise comparisons indicated no overall difference in source errors between Read and Generate Word study conditions, an additional contrast was constructed comparing the age difference in errors of source attribution in the Generate Definition condition to the average age difference in error rate of the Read and Generate Word conditions. This contrast was significant F (1, 90) = 5.87, $p<.05$. Thus, the significant interaction was a consequence of a smaller age difference in errors of source attribution for items from the Generate Definition study condition (4.37%) than the midpoint between age differences of the Read (14.16%) and Generate Word (18.52%) study conditions.

False Alarm Responses. False alarm rates are shown in Table 13, and just as in Experiment 1, the rates in both groups were very low, demonstrating that most participants had no difficulty correctly rejecting words they had not encountered in the study phase. Interestingly, just as in the first experiment, 18 of the 48 participants did not make even a single false alarm response.

The main effect of study condition was not significant F (2, 92) = .761, MSE = 3.76, $p>.469$, indicating that across age groups, there was an equal tendency to falsely attribute responses to each of the three study conditions. This finding was confirmed by pairwise comparisons, none of which reached significance. The two groups made a similar number of false alarm responses F (1, 46) = 1.64, MSE = 3.81, $p>.205$. The

Table 13: **Percent false alarm responses of young and old adults and their erroneous source attributions – Experiment 2.**

	ERRONEOUS	SOURCE	ATTRIBUTIONS	
	Read	Generate Word	Generate Definition	Total False Alarms
Young	1.74 (3.79)	1.04 (1.18)	.28 (.64)	3.06 (4.16)
Old	.35 (.69)	.63 (1.18)	.83 (2.14)	1.81 (2.35)
Overall Mean	1.04 (2.79)	.83 (1.19)	.56 (1.59)	2.43 (3.40)

interaction of group with study condition was not significant F (2, 92) = 3.02, MSE = 3.76, p>.053.

Study Time. Study time is presented in Table 14, and measured the mean amount of time dedicated to an item in each of the three study conditions. The main effect of study condition was significant F (2, 92) = 44.31, MSE = 11.14, p<.001, and reflected increasingly longer study time with increased generation. Collapsed across age groups, study times in the three conditions were significantly different from each other: Read—Generate Word (Mean Difference –1.78 sec.), p<.001, Read—Generate Definition (Mean Difference –6.23 sec.), p<.001, Generate Word—Generate Definition (Mean Difference – 4.44 sec.), p<.001. Overall, young adults were faster than old adults F(1, 46) = 4.62, MSE = 24.59, p<.038. The interaction of study condition and group was not significant F (2, 92) = .070, MSE = 11.14, p>.931, reflecting a similar advantage of the young group in the three study conditions.

A one-way between-subjects ANCOVA was performed to examine the effect of group on total item recognition, covarying total study time. Total study time was not significantly related to total recognition F (1, 45) = .211, p>.647. Three additional between-subjects ANCOVA's examined recognition subtotals following each study condition, covarying their respective study times. The covariate of study time was not significant in each case: Read F (1, 45) = 2.916, p>.094, Generate Word F (1, 45) = .473, p>.494, Generate Definition F (1, 45) = 3.031, p>.087.

Lastly, three ANCOVA's compared age differences in correct source attributions following each study condition, covarying the mean study time in each condition. Study time in the Read condition was significantly related to age differences in correct source

Table 14: **Mean item study time (in seconds) in each study condition – Experiment 2.**

	Read	Generate Word	Generate Definition	Grand Mean (SD)
Young	6.92 (1.32)	8.53 (1.80)	13.22 (4.67)	9.56 (1.95)
Old	8.63 (2.50)	10.59 (4.06)	14.79 (6.65)	11.33 (3.55)
Mean	7.78 (1.16)	9.56 (3.28)	14.00 (5.74)	10.45 (2.97)

attribution following the Read study condition F (1, 45) = 4.199, p<.047. However, covarying study time did not make a difference in group comparison as the age difference in correct source attribution was significant before and after covarying study time. No significant relation was found between study time and correct source attribution in the Generate Word F (1, 45) = 2.605, p>.113, or Generate Definition F (1, 45) = 3.115, p>.083 study conditions.

Delay. No significant age differences were observed in the delay between study and test (Means: Young = 15.93 min.; Old = 15.16 min.), t(46) = .704, p>.484.

Inter Stimulus Interval. Inter stimulus interval (ISI) measured the time between successive items on the recognition test, including the sum of the time for yes/no recognition and the time for the source selection. Results are displayed in Table 15. As in Experiment 1, each cell mean was calculated according to the number of participants who made the particular source attribution.

The main effect of study condition was significant F (2, 92) = 3.69, MSE = 28.36, p<.030. Pairwise comparisons revealed that, across age groups, ISI of items from the Generate Definition study condition (12.73 sec.) was significantly faster than that of items from the Read (15.43 sec.) or Generate Word (15.11 sec.) study conditions. Thus, Read—Generate Word, (Mean Difference .33 sec.), p>.772, Read—Generate Definition (Mean Difference 2.71 sec.), p<.029, Generate Word—Generate Definition (Mean Difference 2.38 sec.), p<.014.

The main effect of group was significant F (1, 46) = 38.44, MSE = 110.21, p<.001, reflecting faster ISI of young adults. The interaction of group and study condition was also significant F (2, 92) = 4.70, MSE = 28.36, p<.012, and had a significant linear trend

Table 15: Inter Stimulus Interval (in seconds) of young and old during the Recognition test of Experiment 2. N = The number of participants who made the particular source selection.

	STUDY CONDITION					
		Read		Generate Word		Generate Definition
SOURCE RESPONSES						
Young	N		N		N	
Read	24	**8.09 (3.23)**	18	11.01 (7.77)	5	21.18 (14.86)
Generate Word	12	9.90 (5.79)	24	**7.82 (2.38)**	8	14.31 (16.30)
Generate Definition	1	39.9 (-----)	11	7.15 (4.48)	24	**6.69 (2.24)**
Mean Young		9.10 (4.58)		8.67 (3.86)		9.23 (6.94)
Old	N		N		N	
Read	22	**23.70 (11.69)**	19	28.24 (16.93)	7	31.89 (26.53)
Generate Word	16	21.16 (10.51)	24	**19.87 (8.92)**	11	14.91 (8.39)
Generate Definition	16	18.68 (13.25)	22	18.15 (10.16)	24	**14.55 (6.43)**
Mean Old		21.77 (9.26)		21.55 (8.55)		16.23 (9.53)
Overall Mean		15.43 (9.66)		15.11 (9.24)		12.73 (8.98)

F (1, 46) = 5.60, MSE = 34.36, p<.023. Thus, while young adults responded equally fast to items from the Read and Generate definition study conditions, old adults responded faster to items from the Generate Definition study condition than to items from the Read study condition.

A summary of all statistical analyses of Experiment 2 data is presented in Table 16.

Discussion

Experiment 2 was carried out because of a suspicion that the material used in Experiment 1 contained too many details and associations (i.e., excessive environmental support) inflating memorability of the old group following the Read study condition. Experiment 2 provided shorter definitions, stripped of most extraneous detail, and expected to find reduced item and source memory levels in the Read study condition of the old group, so that the effect of word generation on source memory would be revealed.

Since the definition was displayed on the computer screen during the Read and Generate Word study conditions, we expected these conditions to be affected by a change in the definition's elaboration. Naturally, no change in memory scores between the two experiments was expected in the Generate Definition study condition, as only the word was displayed on the computer screen and the participant generated a definition to it. The results indeed demonstrate almost identical values in Experiment 1 and Experiment 2 following the Generate Definition study condition, confirming their reliability. Shortening the definitions resulted in reduced memory scores of the old but not the young group. In the young group, despite the shortened definitions, the values of item

Table 16: **Summary of statistical analyses in Experiment 2.**

Dependent Variable	Main Effects			Pairwise Comparisons In Main Effect of Study			Contrasts on S Interaction		
	Study	Group	Interaction	R-GW	R-GD	GW-GD	1	2	3
Total Recognition	S	S	NS	S	S	S			
Correct Source	S	S	S	S	S	S	S	S	S
Source Errors	S	S	S	NS	S	S	NS	NS	S
False Alarms	NS	NS	NS	NS	NS	NS			
Study Time	S	S	NS	S	S	S			
ISI	S	S	S	NS	S	S	S	NS	S

Legend:
S – Significant
NS – Nonsignificant
ISI – Inter-Stimulus-Interval

Contrasts:
1 – Linear trend: is the age difference in Read significantly different from that in Generate Definition
2 – Quadratic trend (departure from linearity): is the age difference in Generate Word significantly different from the mean of Read + Generate Definition
3 – Is the age difference in Generate Definition significantly different from the mean of Read + Generate Word

recognition and correct source attributions in all study conditions were almost identical to those of Experiment 1. In the old group, on the other hand, there was a decrease in both item recognition and source accuracy as a result of the shortened definitions. These findings support the assumption (Craik, 1984; Craik & Jennings, 1992) that in young adults associations and elaborations are automatically and spontaneously produced and that the tendency for spontaneous elaboration is reduced with aging.

The three study conditions produced three levels of item recognition, significantly different from each other. Both groups reacted similarly to the study condition manipulation increasing their recognition scores with increased generation. Since recognition scores of young adults were unchanged between Experiment 1 and Experiment 2, and those of old adults were reduced, the age difference in total recognition became significant in Experiment 2. Nonetheless, young and old participants demonstrated a marked and parallel improvement in total recognition following the Generate Word study condition compared with the baseline Read condition (Young: 23.8%; Old: 20.1%). The greater improvement of the old (16.6%) compared with the young group (6.8%) between Generate Word and Generate Definition conditions is likely due to a ceiling effect in the young. Thus, young and old adults display a similar memorial benefit from the generation effect, at least from word generation.

Correct source attribution was also directly related to the amount of generation and produced three distinct levels, significantly different from each other. As a consequence of reduced recognition and source memory following the Read condition by the older adults, a generation effect following the Generate Word condition, not seen in Experiment 1, was unmasked. Compared with total recognition where young and old had a parallel improvement following word generation, the increase in correct source attribution between the Read and Generate Word study conditions was greater in the young (20.9%) than in the old group (12.9%). This finding is consistent with a weakening of source compared with item memory with advanced age. Young people appear to greatly benefit from generation of a single word while older adults need a larger generative investment in order to reap the full memorial benefits of generation. Similar to total recognition results, the greater improvement of the old (37.5%) compared with the young group (13.7%) between Generate Word and Generate Definition conditions is likely due to a ceiling effect in the young. Age differences following Generate Definition were smaller than in the other two conditions.

Across age groups, fewer errors in source attribution were committed for items from the Generate Definition study condition than the other two conditions which did not differ, congruent with increased memorability of the Generate Definition condition. Older adults committed more errors of source attribution than younger adults. The largest age difference in error scores appeared following the Generate Word study condition and the smallest following the Generate Definition study condition.

As in Experiment 1, false alarm rate was extremely low in both groups reflecting good ability to differentiate studied from nonstudied items. In Experiment 2, the age groups did not differ in false alarms rate, there was no difference in false attributions to any of the study conditions and no interaction of group with study condition.

Young adults were faster than older adults during the study phase and during the recognition test. For both groups, study time increased with increased generation and formed three distinct levels, significantly different from one another. However, ANCOVA revealed that total recognition rates and correct source attribution rates did not covary with study time. By contrast, during the recognition test, ISI for items from the Generate Definition condition was shorter than that of the other two conditions which did not differ. An interaction of group with ISI reflected smaller age differences in ISI for items from the Generate Definition condition than for items from the other two conditions which did not differ.

Taken together, as predicted according to the generation effect, the least memorable item were words from the Read condition, and the most memorable items were those from the Generate Definition study condition, with items from Generate Word condition falling in between. The greater memorability for Generate Definition items was seen in higher total recognition rate, higher correct source attribution rate, fewer source errors, and faster (arguably more certain) responses during the recognition test. The longer study time required to produce a definition was found to be statistically unrelated to recognition scores. It is noteworthy that age differences in item memory, source memory, and error rate, in favor of the young group, were highest following the Generate Word condition and lowest following the Generate Definition condition, in both experiments. These findings are probably a result of the two complementary influences on memorability and age differences, namely the generation effect and the environmental support, the effects of which are further explored in the General Discussion.

GENERAL DISCUSSION

The main purpose of the current study was to examine age differences in item and source memory when young and old are instructed to perform elaborative processing. In addition, the relation between the type and degree of elaboration and the magnitude of item and source memory was investigated. This study was based on Craik's (1984, 1986; Craik & Jennings, 1992) hypothesis that the decline in memory performance of older adults is at least partly due to a tendency to encode information in an impoverished manner. Young adults, on the other hand, tend to encode material in a rich, meaningful, and distinctive manner, incorporating contextual details and activating related associations thereby aiding memory. Older people do not spontaneously engage in elaborative processing, presumably because of reduced cognitive resources of attentional or working memory nature (Craik, 1984, 1986; 1991; Craik & Jennings, 1992; Rabinowitz et al., 1982; Salthouse, 1988b; Zacks & Hasher, 1988). According to Craik's view, the potential for elaborative encoding continues to exist into old age but requires some encouragement in order to be expressed. Craik termed this external encouragement "environmental support", stating that it can be achieved by guiding the older person through task instructions, task materials, or the nature of the task itself toward elaborative, and therefore more beneficial encoding.

The ineffective manner in which older adults encode newly learned information is likely related to their weak source memory. Superficial, impoverished encoding, devoid of contextual details, such as that performed by elderly people, requires fewer cognitive resources but often has the consequence that items lose their distinctiveness or unique attributes. Thus, one occurrence of a target item would be similar to all others. Since the unique attributes and specific circumstances of each encoded item are the cues by which source memory is determined (e.g., Johnson et al. 1993), such a decrease in elaborative processing with aging may in part account for the decline in source memory performance.

In order to reveal the memory potential of older people, a generative processing paradigm was used in this study guiding participants toward more memorable encoding. Thus, an attempt was made to induce elaborative processing in old and young participants with the expectation of decreasing age differences in both item and source memory with increased generative processing. The present study investigated the effect of three encoding conditions on memorability of study items and their source in two age groups. The three study conditions were selected for their potential to induce different kinds of generative processing. The Read study condition was the nongenerative (control) task, requiring participants to read a word and its definition. The two other conditions required self-initiated generative processing. In the Generate Word condition, participants read a definition and generated the word it defined, and in the Generate Definition condition participants read a word and generated its definition.

Based on previous studies, age differences were expected to be greater in memory for source than in memory for items (see Spencer & Raz, 1995, for a meta-analysis). However, source memory was expected to show a parallel improvement with increased elaboration. The results of the present study supported these expectations. Increased elaboration resulted in a parallel improvement of item and source memory, with source memory being consistently poorer. Since young adults spontaneously encode information in an elaborative manner, instructions to perform elaborative processing were expected to enhance older adults' memory performance more than that of younger adults. The results, however, indicated that increased elaborative processing aided both young and old, improving their memory in a similar manner. The interaction between processing condition and age group reached statistical significance only in source memory, source errors, and inter-stimulus-interval (Experiment 2).

The Effect of Processing Condition on Overall Recognition and Source Memory

Both experiments in this study clearly demonstrated that recognition and source memory scores are directly related to the amount of generative processing at encoding, in both young and old adults. The amount of elaborative, semantic processing varied in the three study conditions. The baseline Read condition is fairly automatic for experienced readers, requires a minimum of cognitive resources and can be carried out “mechanically” with limited attention to word meanings. By contrast the type of cognitive operations performed in the two generative conditions cannot occur without semantic involvement and investment of cognitive resources. When provided with a definition, participants need to comprehend it and search in their semantic lexicon for the defined word. Greater elaboration is required when participants are provided with a word and instructed to supply a definition for it. In this condition they are required not only to search in their semantic lexicon for the meaning of the word but also to provide a syntactically correct and semantically coherent description for it. Thus, the study conditions can be thought of as a hierarchy of elaborative processing.

For both item and source memory the least memorable words were those that were read together with their definition, and the most memorable were those for which a definition was generated, with items from the Generate Word condition reaching an intermediate level of memorability. An interesting exception to this finding was seen in

Experiment 1, where the old group did not show better source accuracy with word generation. The reason could not be that older adults fail to show a generation effect, because a strong generation effect was, in fact, seen between Generate Word and Generate Definition. It was reasoned that no improvement was seen between Read and Generate Word because source memory was elevated in the Read condition beyond the minimum required for a baseline. Thus, the added memorial benefit with generation of a word was relatively small. However, in Experiment 2, when stimulus definitions were shortened and stripped of extraneous detail, three distinct levels of source accuracy were obtained in both the old and the young groups. Taken together, a robust memorial benefit of generating a response held for both item and source memory in young and old adults, and was expressed in better recognition scores for the Generate Word compared with Read items, and even more so for Generate Definition compared with Generate Word items.

The introduction of simplified definitions in Experiment 2 resulted in an unexpected finding: recognition scores of old adults were reduced compared with those of Experiment 1, but those of young adults were not affected. Despite the shortened and less elaborate definitions, the young group had recognition and source memory values which were indistinguishable from those in Experiment 1. Old adults, on the other hand, showed diminished recognition and source memory scores for the Read and Generate Word study conditions, where the shortened definitions were provided. The stimulus materials in the Generate Definition condition were identical in the two experiments, and indeed yielded very similar recognition and source memory scores in both age groups, confirming reliability of procedures. This finding indicates the ability of young adults to process material in an elaborative manner spontaneously, making up for the missing details, while older adults depend on receiving elaborately processed material in the form of more detailed definitions. Shortening the definitions and reducing their elaborative details deprived elderly participants of substantial environmental support, resulting in poorer recognition, but yielded no such effect on young adults, showing their independent ability for self-initiated elaborative processing.

Comparing Groups on Recognition and Source Memory

In an attempt to show dissociation of item and source memory and a differential decline in source memory with aging, several studies reported in the literature relied on artificial manipulations to equate recognition levels in the two groups, and then demonstrated than even under equal recognition rates source memory is poorer in the old compared with the young. For example, Schacter et al. used repeated exposures of study material to the older group (1991, 1994), or a shorter delay between study and test for the amnesic group (Janowski et al., 1989; Schacter et al., 1984; Shimamura & Squire, 1987). By contrast, in Experiment 1 of this work, older adults achieved an overall recognition rate that was statistically indistinguishable from that of young adults when performing under precisely the same study conditions. Thus, young and old did not differ in overall recognition, but young participants were more accurate in source attribution. This result supports previous findings of dissociation of item and source memory, and of a steeper age-related decline for source compared with item memory. The high item recognition rate in the old group is attributed to the highly elaborative definitions provided in the Read and Generate Word conditions, and to the ability of generative processing in the Generate Definition condition to induce a strong memory trace.

Although young were better than old in both item and source memory in Experiment 2, a significant interaction was observed: Age differences in source memory were markedly reduced with increased generation, with the smallest age discrepancy for items from the Generate Definition study condition. Improved source accuracy with generative processing was previously found by Mitchell et al. (1986) for both younger and older adults, but not by Slamecka and Graf (1978), or Rabinowitz (1989). Slamecka and Graf (Experiment 2) asked young adults to identify Read/Generate for each recognized item. Surprisingly, proportion source accuracy of generated items (.70) was slightly (but not significantly) lower than read items (.77). Even though the difference was not significant, the expectation would be for *better* source accuracy to accompany better recognition for generated items. Similarly, in both of Rabinowitz's experiments, young adults performed *more poorly* on source accuracy of generated compared with read items, while older adults improved slightly. Although these studies reported a generation effect in overall recognition, neither found improved source accuracy with generation. By contrast, improved source accuracy with increased generation was found in both experiments reported in the present study, over two levels of generative effort, and in old as well as young adults.

Slamecka & Graf (1978) and Rabinowitz (1989) both of whom did not expect source accuracy to improve with generation, testify for an implicit assumption of independence of item and source memory. In the present study, parallel improvement over baseline was found for both item recognition and source attributions. However, this finding reflects not source-item relationships, but rather the nature of the source used in this study. Many kinds of sources have been studied, some more general episodic details involving the experimental setting or the person who conveyed the information (e.g., Bayen & Murnane, 1996; Ferguson et al., 1992; Schacter et al., 1984; 1991; 1994), where the material learned (item) was not related to the source. By contrast, in the present paradigm there is an intrinsic connection between item and source since the source was the cognitive operation performed on the item during study, and important associative material was added by the operation. Items were words that were either read along with their definitions (Read) generated from a definition (Generate Word) or defined (Generate Definition). Under such conditions, it is easy to see why memory for item and memory for source will go hand in hand.

Comparing Groups on Magnitude of the Generation Effect in Overall Recognition and Source Accuracy

It appears that the improvement in item and source memory with word generation (compared with the Read condition) in Experiment 1 was much greater for the young than for the old. In Experiment 2, the greater improvement of the young group with word generation was seen in source accuracy but not in total recognition, where older participants improved almost has much as younger ones. In both experiments the added improvement with generation of a definition appeared smaller in the young, most likely due to a ceiling effect. It could, therefore, be speculated that young adults are more sensitive to the generation manipulation, showing a large improvement over baseline with generation of a single word and, in some studies (e.g., Greenwald & Johnson, 1989; Rabinowitz, 1989), even single letters. It seems as though the ability of older people to benefit from generation is less efficient than for the young, so that they require a greater generative investment in order to reap the full memorial benefits of elaborative processing. A similar result was reported by McFarland et al. (1985), who used multiple-trials of study and free-recall to measure memory following generation of synonyms or rhymes. Older adults improved over baseline in the second and third free-recall trials, while young adults showed a generation effect from the first trial. A parallel between less precise elaborations generated by elderly participants and academically less successful learners was also made by Rankin and Collins (1985). This description of learning as a function of the degree of support in encoding conditions can be illustrated by convex (young) and concave (old) lines that are joined to form a spindle shape. Such a graph was described by Craik and Jennings (1992), as showing that "...young subjects improve their performance to a greater extent initially but then asymptote at a functional ceiling depending on the materials, the subjects' skill, and so forth. Older subjects are less responsive initially, then start to improve, and finally achieve virtually the same level as that shown by the young." (p. 75). The advantage of such a learning curve is that it is able to account for findings of greater benefits to young adults from improved encoding conditions, equal benefits in both groups, and greater gains in the old group.

Such a description is well suited for the results of the present study because the older group initially lagged behind the young (when no elaboration was provided), but with more favorable encoding conditions (greater elaboration) performance levels of the old group caught up with that of the young. The overall magnitude of the generation effect, i.e., the difference between the Read and Generate Definition conditions, was identical in young and old in Experiment 1. Moreover, in Experiment 2, overall magnitude of the generation effect was greater for the old in both item and source memory, with source showing the larger improvement of old over young. The latter finding is partly due to the low recognition and source memory levels of elderly participants following the Read condition, leaving more room for improvement. Taken together, and consistent with previous findings (e.g., Mitchell et al., 1986; Rabinowitz, 1989), both experiments show that older adults benefited at least as much as young from generative processing. This finding is suggestive of a possible rehabilitative approach to memory decline with advanced age.

Comparing Age Differences in the Three Study Conditions

As mentioned above, it was expected that age differences would be reduced with increased generative processing. This expectation was only partly met. Age differences in item and source memory were indeed smaller in the Generate Definition condition than in the Generate Word condition. However, in both experiments, measures of item and source memory and of errors in source attribution showed the largest age differences for items of the Generate Word study condition. Age differences following the Read condition were almost equal to those in Generate Definition condition in Experiment 1, and somewhat larger than the Generate Definition condition in Experiment 2. Thus, contrary to prediction, the condition with no generative processing (i.e., Read) showed a smaller age difference than a condition with generative processing (i.e., Generate Word).

Several factors, which are not mutually exclusive, may be operating to produce such results. As mentioned earlier, according to the environmental support hypothesis (Craik, 1984), "...older subjects perform certain types of mental operations inefficiently, unless the operations are induced and guided by the task, by specific instructions, or by other supportive aspects of the current environment." (p. 10). In the present study, an attempt was made to induce rich, elaborative processing in older adults. Such processing, not spontaneously performed by elderly individuals, was induced by external or internal sources in the different study conditions. External support was given in the form of experimenter-provided detailed definitions, i.e., the Read condition. Internal support was induced by guiding the older participants toward generative processing, best expressed in the Generate Definition condition. As a result, smaller age differences were seen in the Read and Generate Definition conditions compared with the Generate Word condition. In fact, when the external support was very elaborative (the definitions of Experiment 1), recognition scores of old were almost identical to those of the young in both the Read and the Generate Definition conditions.

Second, compared with the Read condition, the Generate Word condition diverts attention from the definition to the search process of finding the defined word. It could be concluded that reduced attention to the details of the definition is a more costly process for the elderly in terms of later memorability, because they have more limited cognitive/ attentional/working-memory resources (Craik & Jennings, 1992; Schacter et al, 1994; Zacks & Hasher, 1988). Even though the external support in the Generate Word condition is almost equivalent to that in the Read condition, age differences increase because less resources are available to register the provided elaboration in memory. Thus, older adults improved less than young adults between Read and Generate Word (leading to increased age differences) due to a trade-off between attention to the word search and attention to definition details.

Another possible explanation for the greater age difference in the Generate Word Condition is that older people can benefit from only one source of support at a time, either external or internal, while young adults are capable of using both simultaneously. This interpretation is in line with the findings of Ferguson et al. (1992) that young adults benefit from multiple cues (i.e., visual, spatial, auditory) in source memory judgments whereas older adults have difficulty in using multiple cues effectively. However, contrary results were obtain by Bayen and Murnane (1996). Simultaneous use of external and internal support by young but not by old adults may also be related to reduced working memory capacity of the older person (e.g., Craik, 1991; Salthouse, 1994; Zacks & Hasher, 1988). In fact, the decline in processing resources with advanced age was interpreted as a decline in working memory capacity. Reduced working memory would limit the amount of information that can be held and manipulated at any given time. Such limitations would explain the difficulty in registering definition details while searching for the defined word in the Generate Word condition.

The findings of reduced age differences with more elaborative processing are in accord with those of Hashtroudi et al. (1989b) who found reduced age differences with generation of precise elaborators compared with experimenter-provided elaborations. The findings are, however, at odds with those of Rankin and Collins (1985, 1986), who found greater age differences when participants generated their own elaborators. The task used by Rankin and Collins and by Hashtroudi et al. involved addition of elaboration, either by the experimenter or by self-generation, to base sentences (e.g., 'The *rich* man showed us the car' (base sentence) 'that was his daughter's birthday present' (elaboration)). A subsequent recall task presented the base sentence with a blank in place of the target adjective. Participants were not instructed to elaborate on the adjective in the sentence (precise elaboration), and therefore could have generated an elaboration that did not relate to the target word (imprecise elaboration). This task seems more complicated than the one used in the present work because the relationship of the target word and the elaboration was indirect, and therefore weaker, compared with the relationship of a word and its definition. In addition Hashtroudi et al. used the more difficult task of cued recall rather than the recognition used in this work. Nonetheless, Hashtroudi et al. found reduced age differences with generation of precise elaborators compared with provision of such elaborators (similar to Generate Definition compared with Read). It is noteworthy that participants' ages in the study by Hashtroudi et al. averaged 65.8 years, which is 10-13 years younger than participants in the two experiments described here. The present study, therefore, extends the age limit in which older adults show benefit from generation.

Error Analyses: Incorrect Source Attributions and False Alarms

Consistent with a decline in source memory with aging, young adults made fewer errors of source attribution than older adults in both experiments and across all conditions. Both groups made the fewest source errors for items from the Generate Definition study condition, supporting greater memorability and distinctiveness of these words. These results complement the recognition findings that Generate Definition items were the most memorable and therefore less likely to be attributed to the wrong source.

False alarm responses were quite rare in both experiments, constituting 3% at most for the three study conditions combined. Young and old did not differ in false alarm rate, implying that both groups where highly confident about words they had not encountered in the experiment. By comparison, on a word-fragment-completion task, Rabinowitz (1989) reported a 20% false alarm rate for older adults and 7% for young participants.

Since a source selection followed each "yes" response on the recognition test, false alarm rates present an opportunity to observe participants' metamemory considerations. When forced to select a source for an item not encountered during study, young and old participants tended to choose the Read and Generate Word condition more frequently than the Generate Definition condition. This finding is in accord with those of Hashtroudi et al. (1989a), who stated that participants usually assume an external source to be less memorable than an internal source. A related conclusion was made by Hoffman (1997) who stated that "Participants attribute false alarms to whichever class of memories has the weakest trace strengths." (p. 371). It could be speculated that participants in the present study were quite certain that they would remember any word for which they generated a definition. Therefore, if they were less confident about a given item, they would conclude that its source must have been a less memorable one, i.e., from the Read or Generate Word conditions.

Processing Time Measures

Across both experiments and age groups, study time was directly related to increased generation; reading took less time than generating a word, and generating a definition required the most time. Importantly, study time did not covary with recognition or source memory scores. It can therefore be concluded that it is not the time spent processing the stimuli that determined memorability but rather the quality of the cognitive process performed. This matter has been previously investigated (Craik & Tulving, 1975) with similar conclusions.

Inter-stimulus-interval (ISI) measured the time between successive items on the recognition test. A significant interaction of ISI with study condition in Experiment 2 reflected a shorter ISI for items from the Generate Definition study condition than items from the other two conditions, consistent with greater memorability of these items.

Target word as cue and as generated response

In the introduction to this dissertation the seminal work of Slamecka and Graf (1978) on the phenomenon of the generation effect was described at length. The authors presented several suggestions in their attempt to explain what makes a generated response more memorable. To them, each explanation had merits and drawbacks, and they concluded that there was not sufficient evidence to support one explanation unequivocally. The experiments conducted in the present study strongly suggest that it is the extensiveness of the cognitive effort involved in generation and invested in producing the response that determines its memorability. The other major finding of Slamecka and Graf was that of better memory for the generated response than for the cue. The findings here clearly demonstrated not only good memory for the cue words but that cue words can be remembered even better than responses if they are the basis for generation of a definition. Memorability of both cues and responses depended on the type of processing during the study phase, what might be called the directionality of generative processing: Target word→ Definition; Definition → Target word. Target word presentation during recognition was always of a single word which had been a cue in the Generate Definition and a response in the Generate Word study conditions. Counterbalanced across subjects, the same words were used as cues and targets and served in all conditions. Recognition and source memory were better in both age groups for those words that were defined during study than for words that were a response to a definition. Thus, the position of the target word as a generating cue or a generated response is not the factor determining memorability; rather, it was the type of processing, amount of elaboration, or cognitive investment involved in producing the response which made it memorable.

Slamecka and Graf believed that definitive proof of memory for cues must use cued recall as a memory test, with the generated responses as cues. They reasoned that memory for cues on either recognition or free-recall tests could occur as an artifact of free recall of generated responses, coupled with pre-existing associations between responses and cues. Following their guidance, Greenwald and Johnson (1989, Experiment 3), tried in vain to eliminate the associations between cues and responses when testing memory of cues. It is suggested here that such an attempt is bound to fail because, by generating a response, an association is formed even if none had existed before. There cannot be a semantic generation process that does not connect cue and response, and an attempt to test for one without it being associated with the other is artificial and does not advance our understanding of the generation process. In the current study, cues and responses were words and their definitions, which are obviously associated in that they describe one another. The recognition test presented the same words (for different subjects) serving either as a generating cue or as a generated response in the study phase. Greatest memorability was seen for the words which were *cues* to generate a definition. It is suggested that Slamecka and Graf did not observe a generation effect for cues because in their paradigm the response was a rhyme which does not required elaborate processing and has only weak semantic associations with the cue. Using a semantic rule of antonym generation, Greenwald and Johnson demonstrated a small but significant generation effect for cues on a cued-recall task in young adults. The present study demonstrated a robust generation effect for cues as the target words in both young and old adults and demonstrated complete reversibility of cue and response. The finding of a generation effect for cues allows for associative interpretations of the generation effect, which were in doubt since Slamecka and Graf's 1978 publication. Greenwald and Johnson were able to deflate those doubts but based their conclusions on rather weak findings. The present study, therefore, strengthens Greenwald and Johnson's conclusion, which attributed the generation effect to "superior processing of cue-response relations" (p. 680), attempts to explain the nature of the cue-response relation in terms of elaborative processing, and extends the findings to include older individuals as well as young adults.

Suggestions for Future Studies

This study presented a number of novel findings about memory in young and old adults which lead us to speculate about directions for future studies. One interesting question is whether the source of studied material is less remembered than the material itself because it is regarded as less important. To address this question the paradigm of the present study could be used with intentional learning instructions, i.e., informing participants that they would later be asked to recognize the target words, and the task they performed when encountering each word. Participants reading a word and its definition, for example, did not necessarily attend to the target word and may have assumed they would be asked about the entire definition or may have had no expectation to be asked about any part of it. Anecdotally, it is interesting to note that participants were surprised by the source task even if they suspected a memory test. Both Slamecka and Graf (1978) and Rankin and Collins (1985, 1986) found that intentional versus incidental learning had no impact on the generation effect. However the effect of intentional learning instructions on age differences in source memory is yet to be investigated.

To allow a fuller expression of age differences in generative processing, it would be beneficial to eliminate the ceiling effect in the young group. This could be accomplished by using a greater number of test stimuli, a less memorable form of generation, a longer delay between study and test, recall instead of recognition, or a distracting task. Such studies would allow a broader generalization of the conclusions reached here. The present study demonstrated two levels of generative processing which resulted in two levels of item and source memory. Other forms of generative processing could be investigated for their potential rehabilitative qualities and compared with the improvement in recognition memory that older adults exhibited following generation of a definition. Examples of other forms of generation are generating a sentence containing the word, generating a personal association to the word, etc. It would be most interesting to devise a nonverbal equivalent of the verbal generation task used here. Although fine-motor difficulties in drawing a response may vary widely between young and old, the present study has shown that the actual response (the quality or length of a definition) was immaterial to later memorability. It was the *attempt* at generating a definition that resulted in higher memory rate, regardless of the quality of the generated definition (see Slamecka & Fevreiski, 1983). A parallel pattern may emerge in the nonverbal task, where regardless of the quality of the drawing, the attempt at producing it will make the object more memorable. It is likely that generation tasks, both verbal and nonverbal, will form a continuum of memorability depending on the amount of cognitive effort invested in producing the response.

The robust improvement in memory scores with generative processing should be investigated for its rehabilitative potential in alleviating age-related forgetfulness as well as people suffering from impaired memory of other etiologies. Such individuals could be taught to engage in generative processing whenever they wish to memorize information. It is doubtful, however, that elaborative processing in older people could become spontaneous due to the age-related tendency to minimize cognitive effort. Unlike younger adults, elaborative processing in the old is likely to remain a deliberate, intentional process.

Several studies have shown dissociation of item and source memory and their dependence on the integrity of temporal and frontal structures, respectively (e.g., Craik et al., 1990; Glisky et al., 1995; Janowsky et al., 1989). However, there necessarily exists some neural connection tying an item with its source. Forgetting the source of remembered information can be due to forgetting the existence of the source or a breakdown in the association of item and source (see also Schacter, 1994). Future studies should attempt to separate these related concepts. It is also possible that different types of source information involve different brain structures. For example, contextual details of time and place involve the frontal lobes while emotional attributes would more likely be processed by the limbic system. fMRI studies following the active structures during source memory tasks may shed light on this issue.

It would be interesting and theoretically important to investigate the possibility of memory for source existing without memory for item. It would likely be simpler do attempt such a demonstration with a source which is not inherently related to the item, such as a person or a place, rather than the type of source used in the current work. It seems quite conceivable that one could remember a friend telling them an important piece of information without remembering what it was. Even contextual details of the setting may accompany the memory trace reflecting a strong memory for the source yet the information conveyed may escape recollection. Such a study may be difficult to design but it would add strong support for the independence of the two memory types.

Appendix A: Experiment 1 – Stimulus List

1. Alligator -- A type of crocodile with a broad snout, found in South-Eastern U.S. (A)
2. Apple -- The round red, yellow, or green fruit of a small tree, America's favorite fruit. (A)
3. Arrow -- A slender feathered and pointed shaft shot from a bow as a weapon or for sport. (A)
4. Balloon -- An inflatable rubber toy or decoration. (B)
5. Barn -- A structure for storing hay or grain, and often for housing livestock. (B)
6. Belt -- A band of flexible material for encircling the waist. (B)
7. Suitcase -- A usually rectangular piece of luggage, especially for carrying clothes while traveling. (S)
8. Book -- A long work printed on paper bound together within covers. (B)
9. Bottle -- A portable container for holding liquids made of glass or plastic. (B)
10. Bread -- A baked food made of a dough containing flour, water, and yeast, usually sliced for eating. (B)
11. Button -- A small circular object serving as a fastener of articles of clothing when inserted through a loop. (B)
12. Camel -- A tall, humped mammal, domesticated in the Old World and used for transportation through the desert. (C)
13. Caterpillar -- The larva of a butterfly or a moth, having a long segmented body with several pairs of legs. (C)
14. Clock -- An instrument, normally larger than a watch, for measuring time. (C)
15. Cloud -- A collection of particles of water suspended in the air, usually high above the earth surface. (C)
16. Crown -- Headgear worn by a monarch, often made of precious metal and set with gems. (C)
17. Desk -- An article of furniture having a broad writing surface, and drawers for papers, writing materials, etc. (D)
18. Doorknob -- The handle by which a door is opened or closed. (D)
19. Duck -- A relatively small and short-necked, web-footed swimming bird, characterized by a broad, flat bill. (D)
20. Elephant -- The largest terrestrial mammal characterized by a long trunk and large tusks. (E)
21. Fish -- A cold-blooded, aquatic vertebrate having gills and fins, and an elongated body covered with scales. (F)
22. Foot -- The terminal part of the leg, below the ankle joint, on which the body stands and moves. (F)
23. Fork -- A table utensil having two or more prongs or tines, for holding and lifting food. (F)
24. Giraffe -- A tall, long-necked, spotted ruminant, the tallest living four-legged animal. (G)
25. Grapes -- A fruit that grows in clusters on vines and is fermented to make wine. (G)
26. Guitar -- A stringed musical instrument with a long neck, a flat, somewhat violin-like body, and six strings. (G)
27. Hammer -- A tool consisting of a solid head, usually of metal, set crosswise on a handle, used for driving nails. (H)

28. Heart -- The organ that keeps the blood in circulation throughout the body. (H)
29. Broom -- An implement for sweeping, consisting of a brush of straw on a long handle. (B)
30. Kangaroo -- A leaping marsupial of Australia, having short forelimbs, powerful hind legs, and a long, thick tail. (K)
31. Kite -- A light frame covered with thin material, to be flown in the wind at the end of a long string. (K)
32. Ladder -- A structure of wood or metal, whose rungs provide a means of climbing up or down. (L)
33. Lion -- A large, usually tawny-yellow cat, of Africa, having a tufted tail and, in the male, a large mane. (L)
34. Moon -- The earth's natural satellite, appearing as an orb or a crescent in different periods of the month. (M)
35. Mountain -- An elevation of land rising more or less abruptly to a summit, with an altitude greater than that of a hill. (M)
36. Necklace -- A piece of jewelry worn around the neck, as a chain or a string of gemstones, pearls, etc. (N)
37. Nose -- The part of the face that contains the nostrils and organs of smell. (N)
38. Orange -- A round, edible citrus fruit of yellow-red color. (O)
39. Nail -- A slender, rod-shaped piece of metal, with a pointed tip and a flat head, made to be hammered as a fastener or support. (N)
40. Pencil -- A slender tube of wood, containing a core of graphite or a solid coloring material, used for writing or drawing. (P)
41. Plug -- An attachment at the end of an electrical cord that is inserted into an outlet or jack. (P)
42. Potato -- The edible tuber of a cultivated plant, the main crop of Idaho. (P)
43. Refrigerator -- A box, room, or cabinet in which food and drink are kept cool by means of ice or by a mechanical process. (R)
44. Ring -- A circular band of gold worn on the finger. (R)
45. Ruler -- An object that has a straight edge marked off in inches or centimeters, used for drawing lines and measuring. (R)
46. Scissors -- An instrument consisting of two blades for cutting paper or cloth. (S)
47. Shoe -- A covering for the human foot, usually of leather, consisting of a stiff sole and a lighter upper part. (S)
48. House -- A building in which people live, a residence. (H)
49. Snail -- A slow-moving mollusk, having a spirally coiled shell and a ventral muscular foot. (S)
50. Spider -- A predatory arachnid bearing eight legs, whose webs serve as nests and as traps for prey. (S)
51. Strawberry -- The red fruit of a stemless plant often made into jam and preserves or eaten fresh with cream. (S)
52. Swan -- A large, stately aquatic bird of the goose family, having a long, slender neck and pure-white plumage. (S)
53. Telephone -- A device for transmission of speech to a distant point. (T)
54. Thimble -- A small cap worn over the fingertip to protect it when pushing a needle through cloth in sewing. (T)

55. Train -- A connected group of railroad cars, usually pushed or pulled by a locomotive. (T)
56. Truck -- A large motor vehicle for carrying quantities of goods and materials. (T)
57. Turtle -- A reptile, either aquatic or terrestrial, with trunk enclosed in a shell. (T)
58. Violin -- A bowed, stringed instrument, held almost horizontally by the player's arm, between the chin and the collarbone. (V)
59. Whistle -- A small device capable of producing a high clear sound when blown into. (W)
60. Window -- An opening in the wall of a building, the side of a vehicle, etc., for the admission of air or light. (W)
61. Airplane -- A heavier-than-air craft kept aloft by the passing of air on its fixed wings. (A)
62. Ashtray -- A receptacle for tobacco ashes of smokers. (A)
63. Ball -- A round object of various sizes and materials, used in many different games. (B)
64. Banana -- An elongated, tapering tropical fruit with soft pulpy flesh enclosed in a soft yellow rind. (B)
65. Bear -- A large, stocky mammal, with thick, brown fur, a very short tail, and a lumbering gait. (B)
66. Bell -- A typically cup-shaped metal instrument, that produces a ringing sound when struck. (B)
67. Bicycle -- A vehicle with two wheels, pedals, handlebars, and a saddle-like seat. (B)
68. Horse -- A large, hoofed, domesticated mammal, used for carrying loads and for riding. (H)
69. Butterfly -- A flying insect, active by day, with antennae, a slender body, and broad colorful wings. (B)
70. Cake -- A sweet, baked food containing flour, sugar, eggs, and baking powder, sometimes topped with icing. (C)
71. Candle -- A long, usually slender piece of wax with an embedded wick that is burned to give light. (C)
72. Carrot -- The orange root of a plant; famously loved by rabbits. (C)
73. Chair -- A seat for one person, with four legs for support and a rest for the back. (C)
74. Church -- A building for public Christian worship. (C)
75. Cigarette -- A narrow, short roll of tobacco wrapped in thin paper, used for smoking. (C)
76. Deer -- A mammal with antlers, smaller than but related to the moose and elk. (D)
77. Doll -- A common child's toy having the shape of a person or a baby. (D)
78. Door -- A movable, solid barrier for opening and closing an entrance, commonly turning on hinges. (D)
79. Dress -- A garment worn by women and girls, consisting of bodice and skirt in one piece. (D)
80. Eagle -- The largest bird of prey, having broad-wings and massive bills and talons. (E)
81. Finger -- Any of the jointed terminal members of the hand. (F)
82. Frog -- A small tailless amphibian with long hind legs used for leaping, and a smooth moist skin, living in damp areas. (F)
83. Glass -- A hard, brittle, transparent substance, used for windows and bottles. (G)

84. Glove -- A covering for the hand made with a separate sheath for each finger and for the thumb. (G)
85. Gorilla -- The largest ape, related to the chimpanzee but less erect and much greater in size. (G)
86. Hair -- Any of the numerous fine filaments growing from the skin of mammals. (H)
87. Skunk -- A bushy-tailed black-and-white member of the weasel family, known for its fetid defensive spray. (S)
88. Kettle -- A container, usually of metal, in which to boil liquids. (K)
89. Knife -- An instrument for cutting, consisting of a sharp-edge metal blade fitted with a handle. (K)
90. Lemon -- The yellowish, acid fruit of a citrus tree. (L)
91. Lettuce -- A leafy, usually green vegetable used for salads. (L)
92. Lips -- The two fleshy parts forming the margins of the mouth. (L)
93. Lock -- When closed, this device secures a door, gate, or drawer. (L)
94. Motorcycle -- A motor vehicle similar to a bicycle but usually larger and heavier. (M)
95. Mouse -- A small rodent, having tiny ears and a long, thin tail, often a household pest. (M)
96. Envelope -- A flat paper container, as for a letter, having a gummed flap or other means of closure. (E)
97. Needle -- A small, slender implement of polished steel, with a sharp point at one end and an eye for thread at the other. (N)
98. Ostrich -- A swift-footed, flightless bird of Africa; the largest of living birds. (O)
99. Pants -- A cover for the legs and lower body, from the waist to the ankles; trousers. (P)
100. Peacock -- The male of the peafowl, distinguished by its long, colorful tail-feathers that can be spread in a fan. (P)
101. Penguin -- A flightless, black and white, aquatic bird of Antarctica, having webbed feet, and wings reduced to flippers. (P)
102. Piano -- A musical instrument in which felt-covered hammers, operated from a keyboard, strike upon metal strings. (P)
103. Pipe -- A tube of wood, or clay, with a small bowl at one end, used for smoking tobacco, opium, etc. (P)
104. Pumpkin -- A large orange fruit, popular at Halloween, and often cooked in a pie. (P)
105. Rhinoceros -- A large, thick-skinned, plant-eating mammal, with one or two upright horns on the snout. (R)
106. Rooster -- The male of domestic fowl; cock. (R)
107. Sandwich -- Two slices of bread with a layer of meat, fish, cheese, etc., between them. (S)
108. Shirt -- A long- or short-sleeved garment for the upper part of the body, lightweight and with a collar and a front opening. (S)
109. Sled -- A small platform mounted on runners for use in traveling over snow or ice. (S)
110. Snake -- A limbless, scaly, elongated reptile, venomous or nonvenomous. (S)
111. Star -- A celestial body that appears as a fixed point of light in the night sky. (S)

112. Stove -- An apparatus that furnishes heat for cooking and uses gas or electricity for fuel. (S)
113. Table -- A piece of furniture at which people sit down and eat. (T)
114. Television -- A set for receiving the broadcasting of images which are viewed on a screen. (T)
115. Trumpet -- A brass wind instrument with a powerful tone, having a cup- shaped mouthpiece at one end and a flaring opening at the other. (T)
116. Umbrella -- A light, portable, circular cover for protection from the rain. (U)
117. Watermelon -- A large, roundish or elongated fruit, having a hard, green rind and a sweet, juicy, red pulp. (W)
118. Wheel -- A circular frame or disk revolving on an axis, as in vehicles or machinery. (W)
119. Toaster -- An appliance for browning sliced bread by means of dry heat. (T)
120. Zebra -- A horse-like African mammal having a characteristic pattern of black and white stripes. (Z)
121. Tree -- A plant having a wooden trunk and branches, usually growing to a considerable height. (T)
122. Ear -- The organ of hearing and equilibrium in vertebrates. (E)
123. Sun -- The star that is the center of the solar system, around which the planets revolve and from which they receive light and heat. (S)
124. Asparagus -- The edible part of this vegetable are green tubular shoots, about 6 inches long and 0.5 inch in diameter, usually eaten cooked. (A)
125. Windmill -- A structure for grinding, pumping, etc., driven by the force of the wind acting upon a number of vanes or sails. (W)

Appendix B: Calculation of Recognition and Source Scores

There are two considerations regarding accuracy measures on the memory tests. It should be noted that in most generation effect studies, the completed target word is displayed shortly (few seconds) after the stimulus word is displayed. This is done in order to assure exposure to the target word. However, Begg et al. (1991) mention in a note that recognition rate was equal in two groups of subjects only one of which received the correct target word following the generation. Thus, once a word is generated there is no added benefit to actually seeing the completed word in print. In this study we did not employ this procedure, i.e., correct answers were not given following the generation attempt. As a consequence, when a definition was displayed on the screen and the participant was asked to read it and name the word it defines, some items received wrong answers or no answers at all. Although the hint given by the first letter of the required answer substantially reduced error rates, some errors or inability to provide any answer did occasionally occur. Such an event could have posed a problem during the recognition task because the participant did not encounter the intended word during the study phase. The procedure is further complicated by the possibility that despite inability to name the right word during the study phase, viewing the word during the recognition phase could have reminded the participant of the correct answer. However, when the answer was not readily given, participants often read and re-read the definition silently or aloud and spent more time on that item than on others. In fact it is our suspicion that those items which posed greater difficulty were sometimes better recalled because of the greater effort afforded by the participant in the retrieval attempt. Our way of dealing with this problem was to closely monitor replies in this study condition and write down those definitions, which received wrong answers or no answers. Recognition responses were then checked to find out whether indeed these words were not recognized. For each participant, the proportion of correct recognition and source answers for items from the Word Generation condition was calculated from the total number of words named correctly in the study phase (out of the possible 20 words in this condition), plus any word that was not named correctly in the study phase but was recognized in the recognition test. Thus, if two words were incorrectly named during the study phase, and then one of them was recognized in the recognition test, proportion correct in the recognition test and source memory for this participant in this study condition was calculated from a total of 19 words.

Second, when a word was presented and the task was to define it, each participant provided their version of a definition and they may even have defined a different meaning of the word than the one intended by the experimenter, e.g., define the word "ball" as "An elegant dance party" rather than "A round object of various sizes and materials, thrown or bounced in many different games." The variety of definitions, however, does not pose any problem regarding accuracy of recognition or source memory because the critical factor is recalling the word and what one had to do with that word during the study phase, and they had indeed seen and read the word. The actual definition generated by the participant was immaterial to the memory measures. Our view is that the mental process of defining the word adds elaboration and various associates to the word and makes it more memorable. In fact, Slamecka and Fevreiski (1983) have shown that a generation *attempt* is sufficient to make a word more memorable, regardless of its success.

Appendix C: Consent Form for Young Adults

INFORMED CONSENT

Name of Research Supervisor: Dr. Wilma A. Winnick
Principal Investigator: Inbahl Heth, M.S., M.A.
Departmental Affiliation with Queens College: Psychology
Title of Project: Age-Related Differences in the Generation Effect and Source Memory in a Word-Definition Task.

The purpose of this study is to determine differences in item and source memory between healthy younger and older adults following three variations in study conditions. The study variations involve reading and defining words.

First I will be asked a few questions to determine if I am in good health. I will then be asked to perform a number of simple tasks on the computer which will involve reading aloud material presented on the screen and responding verbally or by using the computer keyboard. My verbal responses will be recorded on a tape-recorder.

To ensure confidentiality, each participant will be given a number code. Only the Principal Investigator will know which person is associated with each code. Research results, coded by number, will be kept in the Principal Investigator's locked file. The results of several participants may be pooled together for a publication. I have no objection to the use of the results in a publication provided that my anonymity and confidentiality are preserved.

I will receive course credit for my participation. If at any time I feel uncomfortable with the study I am free to withdraw from it, the only consequence being that in this case course credit will not be given.

If I have any questions about the study, I can contact Dr. Wilma Winnick or Inbahl Heth, Department of Psychology, Queens College, Telephone # (718) 997-3251/9. If I should have any questions about my rights as a participant in this study, I may contact the Office of Research & Sponsored Programs at Queens College, Telephone # (718) 997-5400.

I have a right to a copy of this consent form and may inspect a copy of the Institutional Assurance for the Protection of Human Subjects filed by the Research Foundation of CUNY with the U.S. Department of Health and Human Services.

Participant's Name (please print): ____________________

Participant's Signature: ____________________

Date: ____________________

Appendix D: Consent Form for Older Adults

INFORMED CONSENT

Name of Research Supervisor: Dr. Wilma A. Winnick
Principal Investigator: Inbahl Heth, M.S., M.A.
Departmental Affiliation with Queens College: Psychology
Title of Project: Age-Related Differences in the Generation Effect and Source Memory in a Word-Definition Task.

The purpose of this study is to determine differences in item and source memory between healthy younger and older adults following three variations in study conditions. The study variations involve reading and defining words.

First I will be asked a few questions to determine if I am in good health. I will then be asked to perform a number of simple tasks on the computer which will involve reading aloud material presented on the screen and responding verbally or by using the computer keyboard. My verbal responses will be recorded on a tape-recorder.

To ensure confidentiality, each participant will be given a number code. Only the Principal Investigator will know which person is associated with each code. Research results, coded by number, will be kept in the Principal Investigator's locked file. The results of several participants may be pooled together for a publication. I have no objection to the use of the results in a publication provided that my anonymity and confidentiality are preserved.

I am participating in this study voluntarily, of my own free will. If at any time I feel uncomfortable with the study I am free to withdraw from it without any consequences.

If I have any questions about the study, I can contact Dr. Wilma Winnick or Inbahl Heth, Department of Psychology, Queens College, Telephone # (718) 997-3251/9. If I should have any questions about my rights as a participant in this study, I may contact the Office of Research & Sponsored Programs at Queens College, Telephone # (718) 997-5400.

I have a right to a copy of this consent form and may inspect a copy of the Institutional Assurance for the Protection of Human Subjects filed by the Research Foundation of CUNY with the U.S. Department of Health and Human Services.

Participant's Name (please print): ______________________________

Participant's Signature: ______________________________

Date: ______________________________

Appendix E: Demographics Questionnaire

Participant number _______

Please PRINT the following information.

Name: ____

Address: ____

Telephone number: ________________________________

Age: ______________ **Date of Birth:** ________________

Education (number of years completed): __________________

Occupation (past occupation if retired): __________________

Are you a native English speaker? Yes ____ **No** ____

Which is your dominant hand? Left ____ **Right** ____

How would you describe your health (Please circle):

Very Good **Good** **Fair** **Poor**

Have you ever had any of the following conditions? (If yes, please specify).

Neurological disease ________________________________

Emotional disorder ________________________________

Head trauma ____________________________________

Substance abuse ________________________________

Appendix F: Instructions during Study and Test

Study Condition 1: Reading both the word and its definition.

The computer displayed the following:

On the computer screen you will see a word on the top line with its definition on the lines below. Read the word and its definition out loud, SLOWLY AND CLEARLY. When you finish reading, press the SPACE BAR to display the next word and definition.

For example read out loud, slowly, and clearly this word and definition:

Cup

A small, open container, usually with a handle,
used as a drinking vessel for hot beverages. (C)

Are there any questions?
When you are ready to begin, press the SPACE BAR.

Study Condition 2: Reading the definition and generating the word.

The computer displayed the following:

On the computer screen you will see definitions one at a time. Read the definition out loud, SLOWLY AND CLEARLY, and say what you think the word is. The first letter of the required word is given in parentheses as a hint. When you finish, press the SPACE BAR to display the next definition.

For example read this definition out loud, slowly and clearly:

A small, open container, usually with a handle,
used as a drinking vessel for hot beverages. (C)

What is the word?

Are there any questions?
When you are ready to begin, press the SPACE BAR.

Study Condition 3: Reading the word and generating its definition.

The computer displayed the following:

On the computer screen you will see words one at a time. Read the word out loud and supply a short definition for it. After you say your definition press the SPACE BAR to display the next word.

For example, try this word: Cup
Now give a short definition for this word.

Are there any questions?
When you are ready to begin, press the SPACE BAR.

At the end of the study phase the computer displayed the following:

You have completed the first part of the experiment. The next part is a vocabulary task which does not use the computer. Please tell the experimenter that you are ready to begin.

>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<>*<

Once the vocabulary task is completed, press the SPACE BAR to display the next instruction screen.

At the beginning of the recognition/source memory test, the computer displayed the following introduction:

In the final part of the experiment you will see words one at a time. You no longer need to read them out loud. For each word you need to decide whether you saw it earlier in the experiment or not. For those words seen before, you will have to indicate what you were required to do relating to the word.

When you are ready to begin, press the SPACE BAR.

Recognition Test

The computer displayed each word (e.g., Balloon) with the instructions below:

Balloon

Did you encounter this word earlier in the experiment, either by reading it along with its definition, generating it in response to a definition, or defining it?

Yes – press the yellow Y button.

No – press the yellow N button.

Source Memory Test

If the answer to the recognition test was YES, the computer displayed the following:

Balloon

What did you do relating to this word?

- **I Read the word along with its definition – Press the RED R button.**
- **I read the definition and generated the Word – Press the RED W button.**
- **I read the word and generated a Definition to it – Press the RED D button.**

Appendix G: Experiment 2 – Stimulus List

1. Alligator -- A type of crocodile with a broad snout. (A)
2. Apple -- The round red or green fruit of a small tree. (A)
3. Arrow -- A slender shaft shot from a bow. (A)
4. Balloon -- An inflatable rubber toy or decoration. (B)
5. Barn -- A structure for housing livestock. (B)
6. Belt -- A flexible band for encircling the waist. (B)
7. Suitcase -- A piece of luggage for carrying clothes. (S)
8. Book -- A printed work bound together within covers. (B)
9. Bottle -- A glass or plastic container for holding liquids. (B)
10. Bread -- A baked food made of dough and sliced for eating. (B)
11. Button -- A small circular fastener for clothing. (B)
12. Camel -- A tall, humped desert mammal. (C)
13. Caterpillar -- The larva of a butterfly, with a long segmented body and several pairs of legs. (C)
14. Clock -- An instrument, normally larger than a watch, for measuring time. (C)
15. Cloud -- A collection of particles of water suspended high above the earth surface. (C)
16. Crown -- Headgear worn by a monarch. (C)
17. Desk -- An article of furniture with writing surface and drawers. (D)
18. Doorknob -- The handle by which a door is opened or closed. (D)
19. Duck -- A relatively small and short-necked, web-footed swimming bird. (D)
20. Elephant -- The largest terrestrial mammal with a long trunk and large tusks. (E)
21. Fish -- An aquatic vertebrate having gills and fins, and a scaled, elongated body. (F)
22. Foot -- The part of the leg on which the body stands and moves. (F)
23. Fork -- A table utensil having prongs for holding and lifting food. (F)
24. Giraffe -- The tallest living four-legged animal. (G)
25. Grapes -- A fruit that grows in clusters on vines. (G)
26. Guitar -- A popular stringed musical instrument. (G)
27. Hammer -- A tool used for driving nails. (H)
28. Heart -- The organ that keeps the blood in circulation throughout the body. (H)
29. Kangaroo -- A leaping marsupial of Australia. (K)
30. Broom -- An implement for sweeping. (B)
31. Kite -- A type of toy flown in the wind at the end of a long string. (K)
32. Ladder -- A structure of wood or metal for climbing up or down. (L)
33. Lion -- The 'King' of the animals. (L)
34. Moon -- Appears as an orb or a crescent in different periods of the month. (M)
35. Mountain -- An elevation of land rising to a summit. (M)
36. Necklace -- A piece of jewelry worn around the neck. (N)
37. Nail -- A slender piece of metal made to be hammered as a fastener or support. (N)
38. Nose -- The part of the face that contains the nostrils. (N)
39. Orange -- A round, edible citrus fruit of yellow-red color. (O)
40. Pencil -- A slender tube of wood, with a core of graphite, for writing or drawing. (P)
41. Plug -- The part of an electrical cord that is inserted into a jack. (P)
42. Potato -- The main crop of Idaho. (P)
43. Refrigerator -- A metal box in which food and drink are kept cold. (R)

44. Ring -- A circular band of gold worn on the finger. (R)
45. Ruler -- An object used for drawing lines and measuring. (R)
46. Scissors -- An instrument consisting of two blades for cutting paper or cloth. (S)
47. Shoe -- A covering for the human foot, with a stiff sole and a lighter upper part. (S)
48. House -- A building in which people live, a residence. (H)
49. Snail -- A slow-moving animal, having shell and a ventral muscular foot. (S)
50. Spider -- A small animal whose webs serve as nests and as traps for prey. (S)
51. Strawberry -- A small red fruit often made into jam and preserves or eaten fresh with cream. (S)
52. Telephone -- An electric device used for talking to people who are far away. (T)
53. Swan -- A large, aquatic bird having a long, slender neck and pure-white plumage. (S)
54. Thimble -- A small cap worn over the fingertip to protect it when sewing. (T)
55. Train -- A connected group of railroad cars. (T)
56. Truck -- A large motor vehicle for carrying quantities of goods and materials. (T)
57. Turtle -- A reptile having a trunk enclosed in a shell. (T)
58. Violin -- A bowed, stringed instrument, held by the player's arm, between the chin and the collarbone. (V)
59. Whistle -- A small device capable of producing a high clear sound when blown into. (W)
60. Window -- An opening in the wall of a building for the admission of air or light. (W)
61. Airplane -- A jet-propelled craft. (A)
62. Ashtray -- A receptacle for tobacco ashes of smokers. (A)
63. Ball -- A round object thrown or bounced in many different games. (B)
64. Banana -- A tropical fruit with soft pulpy flesh enclosed in a soft yellow rind. (B)
65. Bear -- A large, stocky mammal, having thick brown fur and a lumbering gait. (B)
66. Bicycle -- A vehicle with two wheels, pedals, and handlebars. (B)
67. Bell -- A cup-shaped metal instrument, producing a ringing sound when struck. (B)
68. Horse -- A large, hoofed, domesticated mammal, used for carrying loads and for riding. (H)
69. Butterfly -- A flying insect with antennae, a slender body, and broad colorful wings. (B)
70. Cake -- A typical birthday treat particularly when topped with icing. (C)
71. Candle -- A piece of wax with an embedded wick that is burned to give light. (C)
72. Carrot -- The orange root of a plant; famously loved by rabbits. (C)
73. Chair -- A seat for one person, with four legs for support and a rest for the back. (C)
74. Church -- A building for public Christian worship. (C)
75. Cigarette -- A narrow, short roll of tobacco wrapped in thin paper, used for smoking. (C)
76. Deer -- A mammal with antlers, smaller than but related to the moose and elk. (D)
77. Doll -- A common girl's toy having the shape of a person or a baby. (D)
78. Door -- A movable, solid barrier for opening and closing an entrance, usually turning on hinges. (D)
79. Dress -- A garment worn by women and girls. (D)
80. Eagle -- The largest bird of prey, having broad-wings and massive bills and talons. (E)
81. Finger -- Any of the jointed terminal members of the hand. (F)

82. Frog -- A small tailless amphibian with moist, sometimes green skin, living near ponds. (F)
83. Glass -- A hard, brittle, transparent substance, used for windows and bottles. (G)
84. Glove -- A covering for the hand made with a separate sheath for each finger and for the thumb. (G)
85. Gorilla -- The largest ape. (G)
86. Hair -- The numerous fine filaments growing from the scalp. (H)
87. Skunk -- A black-and-white member of the weasel family, known for its fetid defensive spray. (S)
88. Kettle -- A metal container in which to boil liquids. (K)
89. Knife -- An instrument for cutting. (K)
90. Lemon -- The yellowish, acid fruit of a citrus tree. (L)
91. Lettuce -- A leafy green vegetable used for salads. (L)
92. Lips -- The parts of the mouth used for kissing. (L)
93. Lock -- This device secures a door, gate, or drawer. (L)
94. Motorcycle -- A motor vehicle similar to a bicycle but larger and heavier. (M)
95. Mouse -- A small rodent, often a household pest. (M)
96. Envelope -- A flat paper container, as for a letter. (E)
97. Needle -- A small sewing implement, with a sharp point at one end and an eye for thread at the other. (N)
98. Ostrich -- A flightless bird of Africa; the largest of living birds. (O)
99. Pants -- A cover for the legs and lower body; trousers. (P)
100. Peacock -- The male of the peafowl, distinguished by its long, colorful tail-feathers that can be spread in a fan. (P)
101. Piano -- A musical instrument having a keyboard and pedals. (P)
102. Penguin -- A black-and-white bird of Antarctica, having wings reduced to flippers. (P)
103. Pipe -- A tube with a small bowl at one end, used for smoking tobacco, opium, etc. (P)
104. Pumpkin -- A large orange fruit, popular at Halloween. (P)
105. Rooster -- The male of domestic fowl; cock. (R)
106. Rhinoceros -- A large mammal, with one or two upright horns on the snout. (R)
107. Sandwich -- Two slices of bread with a layer of meat, fish, cheese, etc., between them. (S)
108. Shirt -- A lightweight garment for the upper part of the body, with a collar and a front opening. (S)
109. Sled -- A small platform mounted on runners for use in traveling over snow or ice. (S)
110. Star -- A celestial body that appears as a fixed point of light in the night sky. (S)
111. Snake -- A limbless, scaly, elongated reptile, sometimes venomous. (S)
112. Stove -- An apparatus that furnishes heat for cooking. (S)
113. Table -- A piece of furniture at which people sit down and eat. (T)
114. Television -- A set for receiving the broadcasting of images viewed on a screen. (T)
115. Trumpet -- A brass wind instrument with a powerful tone. (T)
116. Umbrella -- A circular cover for protection from the rain. (U)
117. Watermelon -- A large fruit, having a hard, green rind and a sweet, juicy, red pulp. (W)

118. Wheel -- A circular frame revolving on an axis, as in vehicles or machinery. (W)
119. Toaster -- An appliance for browning sliced bread by means of dry heat. (T)
120. Zebra -- A horse-like African mammal having a pattern of black-and-white stripes. (Z)
121. Tree -- A plant having a wooden trunk and branches, usually growing to a considerable height. (T)
122. Ear -- The organ of hearing and equilibrium in vertebrates. (E)
123. Sun -- The star that is the center of the solar system. (S)
124. Asparagus -- A vegetable with green tubular shoots, usually eaten cooked. (A)
125. Windmill -- A structure driven by the force of the wind acting upon a number of vanes or sails. (W)

REFERENCES

Albert, M., Duffy, F. H., & Naeser, M. (1987). Nonlinear changes in cognition with age and their neurophysiological correlates. *Canadian Journal of Psychology, 41,* 141-157.

Balin, A. K. (Ed.). (1994). *Human biological age determination.* Boca Raton, FL: CRC Press.

Baddeley, A. D. (1986). *Working memory.* London: Oxford University Press.

Baddeley, A. D. (1992). Working memory. *Science, 255,* 556-559.

Bayen, U. J., & Murnane, K. (1996). Aging and the use of perceptual and temporal information in source memory tasks. *Psychology and Aging, 11* (2), 293-303.

Becker, J. T. (1988). Working memory and secondary memory deficits in Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology, 6,* 739-753.

Begg, I., Vinski, E., Frankovich, L., & Holgate, B. (1991). Generating makes words memorable, but so does effective reading. *Memory and Cognition, 19* (5), 487-497.

Begg, I., & Snider, A. (1987). The generation effect: Evidence for generalized inhibition. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 13,* 553-563.

Blatter, D. D., Bigler, E.D., Gale, S. D., Johnson, S. C., Anderson, C. V., Burnett, B. M., Parker, N., Kurth, S., & Horn, S. D., (1995). Quantitative volumetric analysis of brain MR: Normative database spanning 5 decades of life. *American Journal of Neuroradiology, 16,* 241-251.

Blaxton, (1989). Investigating dissociations among memory measures: Support for a transfer-appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 657-668.

Boone, K. B., Miller, B. L., Lesser, I. M., Mehringer, M., Hill-Gutierrez, E., Goldberg, M. A. & Berman, N. G. (1992). Neuropsychological correlates of white-matter lesions in healthy elderly subjects: A threshold effect. *Archives of Neurology, 49,* 549-554.

Bowles, N. L., & Poon, L. W. (1985). Aging and retrieval of words in semantic memory. *Journal of Gerontology, 40* (1), 71-77.

Cabeza, R., Anderson, N., Mangels, J., Nyberg, L., & Houle, S. (1999). *Age-related differences in neural activity during item and temporal-order memory retrieval: A positron emission tomography study.* Manuscript submitted for publication.

Cabeza, R., Grady, C. L., Nyberg, L., McIntosh, A. R., Tulving, E., Kapur, S., Jennings, J. M., Houle, S., & Craik, F. I. M. (1997). Age-related differences in neural activity during memory encoding and retrieval: A positron emission tomography study. *Journal of Neuroscience, 17,* 391-400.

Cabeza, R., McIntosh, A. R., Tulving, E., Nyberg, L., & Grady, C. L. (1997). Age-related differences in effective neural connectivity during encoding and recall. *NeuroReport, 8,* 3479-3483.

Cerella, J. (1985). Information processing rates in the elderly. *Psychological Bulletin, 98,* 67-83.

Cohen, G., & Faulkner, D. (1989). Age differences in source forgetting: Effects on reality monitoring and on eyewitness testimony. *Psychological Bulletin, 90,* 513-546.

Craik, F. M. I. (1983). On the transfer of information from temporary to permanent memory. *Philosophical Transactions of the Royal Society of London, Series B, 302,* 341-359.

Craik, F. M. I. (1984). Age differences in remembering. In L.R. Squire, & N. Butters (Eds.), *Neuropsychology of Memory* (pp. 3-12), New York, NY: Guilford Press.

Craik, F. M. I. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.). *Human memory and cognitive capabilities, mechanisms and performances* (pp. 409-422). North Holland: Elsevier.

Craik, F. M. I. (1991). Memory functions in normal aging. In T. Yanigihara, & R. C. Peterson (Eds.), *Memory disorders: Research and clinical practice* (pp. 347-367). New York: Marcel Dekker.

Craik, F. M. I., & Jacoby, L. L. (1979). Elaboration and distinctiveness in episodic memory. In L. G. Nilsson (Ed.), *Perspectives in memory research* (pp. 145-166). Hillsdale, NJ: Lawrence Erlbaum Associates.

Craik, F. M. I., & Jennings, J. M. (1992). Human Memory. In F. M. I. Craik, & T. A. Salthouse (Eds.), *The Handbook of Aging and Cognition* (pp. 51-110). Hillsdale, NJ: Lawrence Erlbaum Associates.

Craik, F. M. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11,* 671-784.

Craik, F. M. I., Morris, L. W., Morris, R. G., & Loewen, E. R. (1990). Aging, source amnesia, & frontal lobe functioning. *Psychology and Aging, 5,* 148-151.

Craik, F. M. I., & Rabinowitz, J. C. (1984). Age differences in the acquisition and use of verbal information. In H. Bouma, & D. G. Bouwhuis (Eds.), *Attention and* *performance X* (pp. 471-499). Hillsdale, NJ: Lawrence Erlbaum Associates.

Craik, F. M. I., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General, 104 (3),* 268-294.

Crockard-Brown, J., Niinikoski, J., & Warren-Duke, L. (1993). Generation effect and frequency judgment in young and elderly adults. *Experimental Aging Research, 19,* 147-164.

Dell, G. S. (1985). Positive feedback in hierarchical connectionist models: Applications to language production. *Cognitive Science, 9,* 3-23.

Dorfman, J., & Raz, N. (1988, April). *Neuroanatomical correlates of age-related differences in memory for new associations.* Paper presented at the Cognitive Aging Conference, Atlanta, GA.

Drachman, D. A. (1983). How normal aging relates to dementia: A critique and classification. In D. Samuel, S. Algeri, S. Gershon, V. E. Grimm, & G. Toffano (Eds.), *Aging of the brain* (pp. 19-31). New York: Raven.

Ferguson, S. A., Hashtroudi, S., & Johnson, M. K. (1992). Age differences in using source-relevant cues. *Psychology and Aging, 7,* 443-452.

Gardiner, J. M., & Hampton, J. A. (1985). Semantic memory and the generation effect: Some tests of the lexical activation hypothesis. *Journal of Experimental Psychology: Learning, Memory and Cognition, 11,* 732-741.

Gardiner, J. M., & Rowley, J. (1984). A generation effect with numbers rather than words. *Memory and Cognition, 12,* 443-445.

Glisky, E. L., Polster, M. R., Routhieaux, B. C. (1995). Double dissociation between item and source memory. *Neuropsychology, 9(2),* pp. 229-235.

Gold, D., Andres, D., Arbuckle, T., & Schwartzman, A. (1988). Measurement and correlates of verbosity in elderly people. *Journals of Gerontology: Psychological Sciences, 43,* P27-P34.

Golomb, J., Kluger, A., de Leon, M. J., Ferris, S. H., Convit, A., Mittleman, M., Cohen J., Rusinek, H. De Santi, S., & George, A. E. (1994). Hippocampal formation size in normal human aging: A correlate of delayed secondary memory performance. *Learning and Memory, 1,* 45-54.

Golomb, J., Kluger, A., de Leon, M. J., Ferris, S. H., Mittleman, M., Cohen J., & George, A. E. (1996). Hippocampal formation size predicts declining memory performance in normal aging. *Neurology, 47,* 810-813.

Grady, C. L., McIntosh, A. R., Bookstein, F., Horwitz, B., Rapoport, S. I., & Haxby, J. V. (1998). Age-related changes in regional cerebral blood flow during working memory for faces. *NeuroImage, 8,* 409-425.

Grady, C. L., McIntosh, A. R., Horwitz, B., Maisog, J. M., Ungerleider, L. G., Mentis, M. J., Pietrini, P., Schapiro, M. B., & Haxby, J. V. (1995). Age-related reduction in human recognition memory due to impaired encoding. *Science, 269,* 218-221.

Graf, P. (1982). The memorial consequences of generation and transformation. *Journal of Verbal Learning and Verbal Behavior, 21,* 539-548.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 11* (3), 501-518.

Graf, P., Mandler, G., & Haden, P. E. (1982). Simulating amnesic symptoms in normals. *Science, 218,* 1243-1244.

Greenwald, A.G., & Johnson, M. M. S. (1989). The generation effect extended: Memory enhancement for generation cues. *Memory and Cognition, 17* (6), 673-681.

Gunning-Dixon, F. M., & Raz, N. (1999). The cognitive correlates of white matter abnormalities in normal aging: A quantitative review. Manuscript submitted for publication.

Hale, S., Myerson, J., & Wagstaff, D. (1987). General slowing of nonverbal information processing: Evidence for a power law. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 523-538.

Hartley, A. A. (1992). Attention. In F. M. I. Craik, & T. A. Salthouse (Eds.), *The Handbook of Aging and Cognition* (pp. 3-50). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193-225). San Diego: Academic.

Hashtroudi, S., Johnson, M. K., & Chrosniak, L. D. (1989a). Aging and source monitoring. *Psychology and Aging, 4,* 106-112.

Hashtroudi, S., Parker, E. S., Luis, J. D., & Reisen, C. A. (1989b). Generation and elaboration in older adults. *Experimental Aging Research, 15* (2), 73-78.

Hertel, P. T. (1989). The generation effect: A reflection of cognitive effort? *Bulletin of the Psychonomic Society, 27* (6) 541-544.

Hirshman, E., & Bjork, R. A. (1988). The generation effect: Support for a two-factor theory. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 14* (3), 484-494.

Hoffman, H. G. (1997). Role of memory strength in reality monitoring decisions: Evidence from source attribution biases. *Journal of Experimental Psychology: Learning, Memory & Cognition, 2,* 371-383.

Horn, J. L. (1967). Intelligence: Why it grows, why it declines. *Transaction, 4,* 23-31.

Huppert, F. A. (1991). Memory function in older adults: Remembering new information. In F. Boller, & J. Gramfan (Eds.), *Handbook of Neuropsychology.* Amsterdam: Elsevier.

Hyman, B. T., Van Hoesen, G. W., & Damasio, A. R. (1990). Memory-related neural systems in Alzheimer's disease: An anatomic study. *Neurology, 40,* 1721-1730.

Isingrini, M. I., Vazou, F., & Leroy, P. (1995). Dissociation of implicit and explicit memory tests: Effect of age and divided attention on category exemplar generation and cued recall. *Memory & Cognition, 23* (4), 462-467.

Jacoby, L. L. (1978). On interpreting the effects of repetition: Solving a problem versus remembering a solution. *Journal of Verbal Learning and Verbal Behavior, 17*, 649-667.

Jacoby, L. L., Craik. F. I. M., & Begg, I. (1979). Effects of decision difficulty on recognition and recall. *Journal of Verbal Learning & Verbal Behavior, 18,* 585-600.

Jacoby, L. L., & Witherspoon, D. (1982). Remembering without awareness. *Canadian Journal of Psychology, 36,* 300-324.

Jacoby, L. L. (1983). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning and Verbal Behavior, 22*, 485-508.

Janowsky, J. S., Shimamura, A. P., Squire, L. R. (1989). Source memory impairment in patients with frontal lobe lesions. *Neuropsychologia, 27* (8), 1043-1056.

Jernigan, T., L. (1986). Anatomical validation: Issues in the use of computed tomography. In L. W. Poon (Ed.), *Handbook for clinical memory assessment of older adults* (pp. 353-358). Washington, DC: American Psychological Association.

Johnson, M. K., & Raye, C. L. (1981). Reality monitoring. *Psychological Review, 88*, 67-85.

Johnson, M. K., Raye, C. L., Foley, H. J., & Foley, M. A. (1981). Cognitive operations and decision bias in reality monitoring. *American Journal of Psychology, 94*, 37-64.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source Monitoring. *Psychological Bulletin, 114* (1), 3-28.

Kail, R. (1998). Speed of information processing in patients with multiple sclerosis. *Journal of Clinical and Experimental Neuropsychology, 20,* 98-106.

Kausler, D. H., & Pucket, J. M. (1980). Adult age differences in recognition memory for a non-semantic attribute. *Experimental Aging Research, 6,* 349-355.

Kausler, D. H., & Pucket, J. M. (1981). Adult age differences in memory for modality attributes. *Experimental Aging Research, 7,* 117-125.

Kausler, D. H., Salthouse, T. A., & Saults, J. S. (1988). Temporal memory over the adult lifespan. *American Journal of Psychology, 101,* 207-215.

Kemper, T. L. (1994). Neuroanatomical and neuropathological changes during aging and in dementia. In N. L. Albert & E. J. E. Knoepfel (Eds.), *Clinical neurology of aging* (2nd ed., pp. 3-67). New York: Oxford University Press.

Kohler, S., Moscovitch, M., Winocur, G., Houle, S., & McIntosh, A. R. (1998). Networks of domain-specific and general regions involved in episodic memory for spatial location and object identity. *Neuropsychologia, 36,* 129-142.

Kolers, P. A. (1973). Remembering operations. *Memory and Cognition, 1,* 347-355.

Kramer, A. F., Humphrey, D. G., Larish, J. F., Logan, G. D., Strayer, D. L. (1994). Aging and inhibition: Beyond a unitary view of inhibitory processing in attention. *Psychology and Aging, 9,* 491-512.

Kucera, H., and Francis, W. N. *Computational Analysis of present-day American English.* Providence, R.I.: Brown University Press, 1967.

Madden, D. J. (1986). Adult age differences in the attentional capacity demands of visual search. *Cognitive Development, 1,* 335-363.

Madden, D. J. (1987). Aging, attention, and the use of meaning during visual search. *Cognitive Development, 2,* 201-216.

Madden, D. J., Turkington, T. G., Coleman, R. E., Provenzale, J. M., DeGrado, T.R., & Hoffman, J. M. (1996). Adults age differences in regional cerebral blood flow during visual word identification: Evidence from $H_2{}^{15}O$ PET. *NeuroImage, 3,* 127-142.

Madden, D. J., Turkington, T. G., Provenzale, J. M., Denny, L. L., Hawk, T. C., Gottlob, L. R., & Coleman, R. E. (1999). Adult age differences in functional neuroanatomy of verbal recognition memory. *Human Brain Mapping, 7,* 115-135.

McFarland, C. E. Jr., Warren, L. R., & Crockard, J. (1985). Memory for self-generated stimuli in young and old adults. *Journal of Gerontology, 40* (2), 205-207.

McIntyre, J. S., & Craik, F. I. M. (1987). Age differences in memory for item and source information. *Canadian Journal of Psychology, 41* (2), 175-192.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88,* 375-407.

McClelland, J. L., & Rumelhart, D. E. (1985). Distributed memory and the representation of general and specific information. *Journal of Experimental Psychology: General, 114,* 159-188.

McClelland, J. L., & Rumelhart, D. E. (1986). *Parallel distributed processing: Explorations in the microstructure of cognition* (Vol. 2). Cambridge, MA: Bradford.

Meyerson, J., Hale, S., Wagstaff, D., Poon, L. W., & Smith, G. A. (1990). The information-loss model: A mathematical theory of age-related cognitive slowing. *Psychological Review, 97,* 475-487.

Milner, B. (1966). Amnesia following operation on the temporal lobe. In C. W. M. Whitty & O. L. Zangwill (Eds.), *Amnesia.* London: Butterworths.

Mitchell, D. B., & Hunt, R. R. (1989). How much "effort" should be devoted to memory? *Memory and Cognition, 17,* 337-348.

Mitchell, D. B., Hunt, R. R., Schmitt, F. A. (1986). The generation effect and reality monitoring: Evidence from dementia and normal aging. *Journal of Gerontology, 41* (1), 79-84.

Moscovitch, M., & Winocur, G. (1992). The neuropsychology of memory and aging. In F. M. I. Craik, & T. A. Salthouse (Eds.), *The Handbook of Aging and Cognition* (pp. 315-372). Hillsdale, NJ: Lawrence Erlbaum Associates.

Multhaup, K. S. (1995). Aging, source and decision criteria: When false fame errors do and do not occur. *Psychology and Aging, 10,* 492-497.

Murdock, B. B. Jr. (1967). Recent developments in short-term memory. *British Journal of Psychology, 58,* 421-433.

Myerson, J., Hale, S., Wagstaff, D., Poon, L. W., & Smith, G. A. (1990). The information-loss model: A mathematical theory of age-related cognitive slowing. *Psychological Review, 97,* 475-487.

Nebes, R. D. (1992). Cognitive dysfunction in Alzheimer's disease. In F. M. I. Craik, & T. A. Salthouse (Eds.), *The Handbook of Aging and Cognition* (pp. 373-446). Hillsdale, NJ: Lawrence Erlbaum Associates.

Nolde, S. F., Johnson, M. K., & Raye, C. L. (1998). The role of prefrontal cortex during tests of episodic memory. *Trends in Cognitive Sciences, 2,* 399-406.

Nyberg, L., Cabeza, R., & Tulving, E. (1996). PET studies of encoding and retrieval: The HERA model. *Psychonomic Bulletin and Review, 3,* 135-148.

Park, D. C., Puglisi, J. T., & Sovacool, M. (1983). Memory for pictures, words, & spatial location in older adults: Evidence for pictorial superiority. *Journal of Gerontology, 38,* 582-588.

Perlmutter, M., Metzger, R., Nezworski, T., & Miller, K. (1981). Spatial and temporal memory in 20 and 60 year olds. *Journal of Gerontology, 36,* 59-65.

Rabinowitz, J. C. (1989). Judgments of origin and generation effects: Comparisons between young and elderly adults. *Psychology and Aging, 4* (3), 259-268.

Rabinowitz, J. C., Craik, F. I. M., & Ackerman, B. P. (1982). A processing resource account of age differences in recall. *Canadian Journal of Psychology, 36* (2), 325-344.

Ramsey, P. H. (1992). *Intermediate Statistical Methods.* New York: Psychology Department, Queens College, CUNY.

Rankin, J. L., & Collins, M. (1985). Adult age differences in memory elaboration. *Journal of Gerontology, 40,* 451-458.

Rankin, J. L., & Collins, M. (1986). The effects of memory elaboration on adult age differences in incidental recall. *Experimental Aging Research, 12,* 231-234.

Raz, N. (1996). Neuroanatomy of aging brain: Evidence from structural MRI. In E. D.

Bigler (Ed.), *Neuroimaging II: Clinical applications* (pp. 153-182). New York: Academic Press.

Raz, N. (1999). Aging of the brain and its impact on cognitive performance: Integration of structural and functional findings. In F. I. M. Craik, and T. A. Salthouse (Eds.), *Handbook of Aging and Cognition,* (2nd ed., pp. 1-90). Mahwah, NJ: Lawrence Erlbaum Associates.

Raz, N., Gunning-Dixon, F. M., Head, D. P., Dupuis, J. H., & Acker, J. D. (1998). Neuroanatomical correlates of cognitive aging: Evidence from structural MRI. *Neuropsychology, 12,* 95-114.

Roediger, H. L., & McDermott, K. B. (1993). Implicit memory in normal human subjects. In H. Spinnler & F. Boller (Eds.), *Handbook of Neuropsychology*, (Vol. 8, pp. 63-131). Amsterdam: Elsevier.

Roediger, H. D., Weldon, M. S., & Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving* (pp. 3-41). Hillsdale, NJ: Lawrence Erlbaum Associates.

Sabbah, D. (1985). Computing with connections in visual recognition of origami objects. *Cognitive Science, 9,* 25-50.

Salthouse, T. A. (1985a). Speed of behavior and its implications for cognition. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed., pp. 400-426). New York: Van Nostrand Reinhold.

Salthouse, T. A. (1985b). *A theory of cognitive aging.* Amsterdam: North-Holland.

Salthouse, T. A. (1988a). Initiating the formalization of theories of cognitive aging. *Psychology and Aging, 3,* 3-16.

Salthouse, T. A. (1988b). Resource-reduction interpretations of cognitive aging. *Developmental Review, 8,* 238-272.

Salthouse, T. A. (1994). The aging of working memory. *Neuropsychology, 8,* 535-543.

Salthouse, T. A. (1996). The processing-speed theory of adults age differences in cognition. *Psychological Review, 103,* 403-428.

Schacter, D. L., Harbluk, J. L., McLachlan, D. R. (1984). Retrieval without recollection: An experimental analysis of source amnesia. *Journal of Verbal Learning and Verbal Behavior, 23,* 593-611.

Schacter, D. L., Kaszniak, A. W., Kihlstrom, J. F., & Valdiserri, M. (1991). The relation between source memory and aging. *Psychology and Aging, 6* (4) 559-568.

Schacter, D. L., Osowiecki, D., Kaszniak, A.W., Kihlstrom, J. F., & Valdiserri, M. (1994). Source memory: Extending the boundaries of age-related deficits. *Psychology and Aging, 9* (1), 81-89.

Schacter, D. L., Savage, C. R., Alpert, M. M., Rauch, S. L., & Albert, M. S. (1996). The roll of hippocampus and frontal cortex in age-related memory changes: a PET study. *NeruoReport, 7,* 1165-1169.

Schwartz, B. L. (1989). Effects of generation on indirect measures of memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 15* (6), 1119-1128.

Shimamura, A. P., Squire, L. R. (1987). A neuropsychological study of fact memory and source amnesia. *Journal of Experimental Psychology: Learning and Memory and Cognition, 13* (3), 464-473.

Slamecka, N. J. and Graf P. (1978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory, 4* (6), 592-604.

Slamecka, N. J., & Fevreiski, J. (1983). The generation effect when generation fails. *Journal of Verbal Learning and Verbal Behavior, 22*, 153-163.

Spencer, W. D., & Raz, N. (1994). Memory for facts, source, & context: Can frontal lobe dysfunction explain age-related differences? *Psychology and Aging, 9* (1), 149-159.

Spencer, W. D., & Raz, N. (1995). Differential age effects on memory for content and context: A meta-analysis. *Psychology and Aging, 10*, 527-539.

Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review, 99*, 195-231.

Stafford, J.L., Albert, M., Naeser, M. A., Sandor, T., & Garvey, A. J. (1988). Age-related differences in computed tomographic scan measurements. *Archives of Neurology, 45*, 409-415.

Teuber, H. -L., & Milner, B. (1968). Alteration of perception and memory in man: Reflections on methods. In L. Weiskrantz (Ed.), *Analysis of behavioral change*. New York: Harper & Row.

Trott, C., Friedman, D, Ritter, W., and Fabiani, M. (1997). Item and source memory: Differential age effects revealed by event-related potentials. *NeuroReport, 8*, 3373-3378.

Trott, C., Friedman, D, Ritter, W., Fabiani, M., and Snodgrass, J. (1999). Episodic priming and memory for temporal source: Event-related potentials reveal age-related differences in prefrontal functioning. *Psychology and Aging, 14*, 390-413.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving and W. Donaldson (Eds.), *Organization of memory* (pp. 382-404). New York: Academic.

Tulving, E. (1983). *Elements of Episodic Memory*. New York: Oxford University Press.

Tulving, E. (1985). How many memory systems are there? *American Psychologist, 40*, 385-398.

Tulving, E., & Markowitsch, H. J. (1997). Memory beyond hippocampus. *Current Opinion in Neurobiology, 7*, 209-216.

Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning Memory and Cognition, 8,* 336-342.

Tulving, E., & Thompson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80,* 352-373.

Verhaeghen, P., Marcoen, A., & Goosens, L. (1993). Facts and fiction about memory aging: A quantitative integration of research findings. *Journal of Gerontology: Psychological Sciences, 48,* P157-P171.

Verhaeghen, P. & Salthouse, T. A. (1997). Meta-analyses of age-cognition relations in adulthood: Estimates of linear and nonlinear age effects and structural models. *Psychological Bulletin, 122,* 231-249.

Warrington, E. K., & Weiskrantz, L. (1974). The effect of prior learning on subsequent retention in amnesic patients. *Neuropsychologia, 12,* 419-428.

Webster's College Dictionary (1992). New York: Random House

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale - Revised.* San Antonio, TX: Psychological Corporation.

Winnick, W. A., & Daniel, S. A. (1970). Two kinds of response priming in tachistoscopic word recognition. *Journal of Experimental Psychology, 84*, 74-81.

Winnick, W. A., Kooper, F., & Sprafkin, J. (1974). Free recall as a function of type of evoking stimulus. *Journal of Experimental Psychology, 103* (2), 269-273.

Witherspoon, D., & Moscovitch, M. (1989). Stochastic independence between two implicit memory tasks. *Journal of Experimental Psychology: Learning Memory and Cognition, 15,* 22-30.

Zacks, R. T., & Hasher, L. (1988). Capacity theory and the processing of inferences. In L. L. Light & D. M. Burke (Eds.), *Language, memory, & aging* (pp. 154-170). New York: Cambridge University Press.

Zola-Morgan, S., Squire, L. R., & Amaral, D. G. (1986). Human amnesia and the medial temporal region: Enduring memory impairment following a bilateral lesion limited to field CA1 of the hippocampus. *Journal of Neuroscience, 6,* 2950-2967.