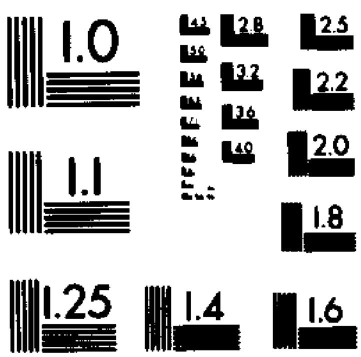

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SEMANTIC MEMORY IN NORMAL AGING AND ALZHEIMER TYPE DEMENTIA

by

DAVID MASUR

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.

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Abstract

SEMANTIC MEMORY IN NORMAL AGING AND ALZHEIMER TYPE DEMENTIA

by

David Masur

Adviser: Professor Jeffrey Rosen

Semantic memory is purported to be that aspect of memory specifically concerned with the representation and organization of word meanings. The present study investigated the structure of semantic memory in a group of normal elderly individuals (mean age = 81.5 years), and in a group of individuals diagnosed as having mild Alzheimer Type Dementia primarily through the administration of a timed sentence verification task. This task required subjects to decide as quickly as possible whether sentences consisting of various exemplar-category relationships were true or false. The original version of this task was introduced by McCloskey and Glucksberg (1979) and provided evidence for a model of semantic memory that is based on the processing of features in a probabilistic manner. An additional goal of the dissertation was the use of the sentence verification task to investigate changes in semantic memory in Alzheimer Type Dementia resulting from the administration of oral

physostigmine, a cholinesterase inhibitor.

The results demonstrated that normal elderly subjects maintained preservation of semantic memory by producing reaction time patterns of sentence verification that were consistent with those predicted by a probabilistic semantic model. In contrast, the Alzheimer group demonstrated anomalous patterns of verification, suggestive of marked semantic disruption. However, a case by case evaluation of the subjects in the Alzheimer group revealed substantial differences in the severity of semantic disruption, despite a careful attempt to include only those subjects with mild cognitive impairment. This observation supports the notion of subgroups of Alzheimer Type Dementia having differential cognitive abilities, and suggests that there is a demonstrable pattern of decline in semantic competence within the classification of mild impairment. Finally, ingestion of oral physostigmine did not improve the overall performance of the Alzheimer group on semantic verification, but did appear to have a positive effect on the ability of these subjects to make decisions regarding certain aspects of semantic information.

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I. INTRODUCTION

A. Statement of the Problem

For many years, the scientific community had accepted the notion that a natural consequence of human aging was the disruption of many cognitive processes. Prominent among the alleged normative changes in cognitive functioning was a decline in the ability to remember. Partly as a result of the observation of reduced cognitive functioning in many aged individuals, as well as the fact that the elderly do complain more about memory difficulty than younger people, senility was seen to be an inevitable by-product of the aging process. More recently, the sharp increase in aging research in both the psychological and the medical arenas, has forged a definite distinction between normal aging and dementia as a pathological process. However, this distinction has at times been blurred as a result of the recent application of more complex and sensitive methodology. Further, it is currently unclear whether any absolute statement can be made concerning the presence of significant decline in memory performance as it pertains solely to aging.

In recent psychological literature, human memory has been thought to consist of at least two rather distinct components; episodic memory and semantic memory (Tulving, 1972). Episodic memory is presumably responsible for the storage of information about episodes or events, and the temporal and spatial relationships between those events. Semantic memory is thought of as a memory system that deals exclusively with the organization and manipulation of words, concepts, relations between words, and word meanings. Thus, it can seen that semantic memory functions mainly within the sphere of language. Cognitive psychologists have worked to develop models which seek to explain how words and categories involving word relationships are organized and stored in the brain. One means of testing these models is through the construction of sentences that can be answered in a true/false manner, and which differ in their subject-predicate relatedness. The measure of interest is the time it takes an individual to verify the correctness or falsehood of these statements. Based on the level of subject-predicate relatedness, particular patterns of reaction times will emerge, thus allowing for the development of either a network or a featural approach to the organization of semantic memory (Smith, Shoben, and Rips, 1974; Collins and Loftus, 1975; McCloskey and Glucksberg, 1979).

Alzheimer Type Dementia is a progressive degenerative disease characterized in its initial stages by impairment of memory, confusion, difficulty with calculations, and mild language dysfunction (McKhann, Drachman, Folstein, Katzman, Price, and Stadlin, 1984). Within the last 10 years, the presence of Alzheimer Type Dementia at autopsy has been strongly linked to marked reductions in acetylcholine, an important brain neurotransmitter (Davies and Maloney, 1976; Davies, 1978). More recently, experimental trials of oral physostigmine, a drug which increases the availability of acetylcholine in brain, have demonstrated improvement of memory in patients with Alzheimer Type Dementia (Peters and Levin, 1979; Thal, Fuld, Masur, and Sharpless, 1983).

The purpose of this thesis is to investigate the structure of semantic memory in 2 groups of individuals: (1) a group of normal elderly ranging in age from 75 to 85 years, and (2) a group of mildly impaired individuals who carry the diagnosis of Alzheimer Type Dementia. It is currently unclear as to whether the organization of the semantic structure in the elderly remains invariant, or whether real change in this system can be detected with aging (Burke and Light, 1981; Smith and Fullerton, 1981). However, recent studies have demonstrated disruption of specific language processes in persons with Alzheimer Type Dementia, and have implicated the breakdown of semantic memory as part of the underlying cause of these observed deficits (Bayles and Tomoeda, 1983; Martin and Fedio, 1983; Grober, Buschke, Kawas, and Fuld, in press). The major objectives of this dissertation are 1) to elucidate further the patterns of breakdown of semantic memory in this dementia group, 2) to compare these patterns with those obtained from the group of normal elderly, and 3) to compare these patterns demonstrated by a group of control subjects matched for age and education. An additional goal of this thesis is to examine the efficacy of oral physostigmine in the treatment of memory deficits in Alzheimer Type Dementia from the perspective of the ability of this drug to ameliorate disruption of the semantic structure in individuals with this disease. These studies will be carried out in part through the administration of tasks which have led to the development of many of the current hypotheses regarding the structure and use of semantic memory.

II. Literature Review

A. Methodological Problems in Aging Research

Recently, the focus of attention of much psychological research has shifted towards an attempt to understand how aging affects mental abilities in general, as well as particular aspects of cognition, such as language and memory. Baltes and Willis (1979), have identified two major approaches by which psychologists have historically addressed these issues: the psychometric approach and the cognitive approach. The psychometric approach relies on the concept of intelligence as that which can be observed through performance on particular standardized test instruments, such as the Wechsler Adult Intelligence Scale. In this case, intelligence is thought of as the compilation of several factors which are assessed through the administration of a variety of subtests. These factors in turn are representative of primary mental abilities (Thurstone, 1938), and thus the administration of tasks rich in these specific factors allow one to make predictions about mental competence (Guilford, 1967). The cognitive approach to intelligence is much more recent in development, and is essentially concerned with the substantive issues of learning, information processing, and memory that need to be understood, regardless of how intelligence is conceptualized (Kintsch, 1974).

The application of the psychometric approach to the question of intellectual preservation or change in normal aging highlights the methodological difficulties encountered when attempting to delineate any kind of age change. The use of varying research strategies has resulted in markedly different interpretations regarding the status of gerontological intelligence. Early studies involving the administration of the Wechsler Adult Intelligence Scale within a cross-sectional paradigm invariably demonstrated the existence of a classic aging pattern of intelligence; the verbal subtests tend to remain stable into the seventies, while the performance subtests begin to show measurable decline as early as thirty-five years of age (Doppelt and Wallace, 1955; Wechsler, 1972).

By contrast, most longitudinal studies have demonstrated intellectual declines much smaller than those seen in cross-sectional studies, and that the decline that is observed does not begin until relatively late in life (Botwinick, 1977). Eisdorfer and Wilkie (1973) conducted a 10 year longitudinal study with two groups of elderly individuals; one group ranged in age from 60 to 69 years, and the second group ranged from 70 to 79 years. Both groups were administered the WAIS four times over the course of the 10 years. The results indicated that while there was an overall loss in Full Scale I.Q. Score for both groups, the loss in the 60-69 year old group was small and was accounted for largely by declines on the performance subtests, as predicted by the classic aging pattern of intelligence. The loss in the 70-79 year old group was somewhat larger but was comprised of equal losses on both the verbal and the performance subtests. The authors then extended the study for another five years and administered the WAIS three additional times to the remaining individuals of each age group. When the scores for the individuals who received all seven WAIS administrations over the course of 15 years were analyzed, it was found that this group did not demonstrate the pattern of decline that was previously seen. These studies illustrate the fact that cross-sectional studies spuriously magnify age decline in intelligence, while longitudinal studies may in fact minimize it (Botwinick, 1977).

The difficulty in detecting true age-related changes in intelligence stems from many subtle but significant variables concomitant to the aging process, which are difficult to adequately control for with standard experimental methodologies. Cross-sectional studies fail to take into account cohort effects, which are differences in year of birth. Thus, individuals born in 1920 were likely to have educational and environmental experiences that were vastly different than those individuals who were born in 1960. These variations in education and experience contribute to the observed performance on intelligence tests, and as such, make results difficult to interpret. Longitudinal studies control for cohort effects by following the same cohort through a series of repeated measurements. However, the results derived from the longitudinal approach may not be generalizable to other cohorts or the aged population as a whole because of differences in historical influences on each cohort (Baltes and Willis, 1979), as well as because of selection bias. When attempting to assess gerontological intelligence, selection bias is known as terminal drop. This refers to the observation that certain individuals in a sample demonstrate a sudden substantial decline in test performance. This sudden decline increases the likelihood of dropping out of the study prior to its completion. Elderly subjects remaining in longitudinal studies then, are those that tend to display relatively preserved intellectual performance, and they contribute to the overall conclusion that intellectual abilities decline in rather minimal fashion (Botwinick, 1977).

The methodological issues briefly described have been circumvented to some extent by the recent development of rather elaborate experimental designs. The ultimate purpose of such designs is to compensate for the fact that age cannot be utilized as an independent variable in the true sense; subjects cannot be assigned to an aging versus a non-aging condition. In order to be able to make inferences about the aging process despite the constraint, a quasi-experimental methodology has been adopted where cohort effects, historical or time of measurement effects, and maturation effects are simultaneously controlled (Costa and McCrae, 1982). The original design was introduced by Schaie (1965, 1977), and involves a systematic combination of both cross-sectional and longitudinal designs. This is accomplished by beginning with a typical cross-sectional sequence, but after a period of time one retests these same subjects in order to obtain longitudinal data. At each retesting, a new group of subjects is recruited from the same age groups as those chosen for the original cross-sectional paradigm. These subjects are then incorporated into the overall design and are also retested at the next sequence. This procedure is followed for each measurement period. The data obtained allows for the comparison of two or more cross-sectional sequences in one design which can control for the effect of birth cohort on age changes. In addition, the comparison of two or more longitudinal sequences addresses the issue of historical or time of measurement effects on particular cohorts. Finally, maturation effects can be controlled for by comparing the age differences between two groups at one time of measurement with age differences observed in the same two groups at a different time of measurement.

Data derived from the few studies which have managed to employ this kind of methodology has led to the belief that there is minimal intellectual deficit in the elderly, and that cohort differences are more pronounced than actual age changes (Schaie and Gribbin, 1975). Nevertheless, criticism of these results has continued by proponents of the position that aging is accompanied by real and measurable intellectual decline, which can be demonstrated when subject selection bias and selective dropout are taken into account (Horn and Donaldson, 1976). Research in developmental design, then, has done much to identify the possible sources of variance in the assessment of gerontological intelligence; but, because of the many sources of variability as well as the impracticality of carrying out these research strategies, research has not yet provided a satisfactory conclusion as to whether intelligence declines with advancing age, and if so, to what extent. To further complicate the issue, Birren, Cunningham, and Yamamoto (1983) have stated that the use of the WAIS as the test instrument to measure intelligence in the aged population may be inappropriate. A more useful instrument, in their view, would be the original Wechsler-Bellevue version since the normative sample used to construct that test is now entering old age and thus would provide a more suitable cohort comparison.

While the status of gerontological intelligence continues to remain a fruitful area of investigation, it has become equally important to attempt to analyze and comprehend the discrete processes that are responsible for the ability of an individual to perceive, to learn, to remember, and ultimately to think. Among the various cognitive modalities, memory may well be the most critical of human abilities. Memory has been thought of as the core of cognition, and the understanding of how memory works is seen as necessary to a more complete comprehension of language function (Smith and Fullerton, 1981). The need to uncover the structure and process of memory has recently begun to take on greater urgency within the context of aging research, as a decline in the ability to remember is a frequent complaint of the elderly (Burke and Light, 1981). Moreover, the fact that memory impairment is one of the necessary criteria for the diagnosis of dementia in general (DSM III, 1981), and Alzheimer's disease in particular (McKhann, Drachman, Folstein, Katzman, Price, and Stadlin, 1984), serves to increase the fear that any perceived disturbance in memory may be pathological in nature.

The investigation of memory functioning in normative aging is subject to some of the same methodological difficulties as those seen in psychometric studies of gerontological intelligence. The large majority of studies involving performance on memory related or problem solving tasks have demonstrated that the performance of elderly individuals is impaired relative to younger individuals (Schaie and Zelinski, 1979; Denny, 1981). However, virtually all studies reporting age differences of this nature have used cross-sectional methodology, thus raising the possibility that true age differences in memory are confounded with cohort effects. A further complication arises when one considers the finding that variability in memory functioning is more frequently encountered in the elderly than in younger adults, and this variability may be due to a variety of cognitive, personality, or environmental factors (Erickson, Poon, and Walsh-Sweeny, 1980). These methodological difficulties have led some investigators to the conclusion that any obtained age differences in memory performance cannot be seen as absolute, but instead exist as a function of the kind of test materials used, the type of processing induced in the subject, and the overall conditions of testing (Craik and Byrd, 1982; Pearlmutter and Mitchell, 1982). Despite the relative lack of clear findings in many studies of memory and aging, considerable progress has been made in the development of the theoretical underpinnings of memory functioning, both in the younger adult and in the aged individual. Of additional critical significance is the fact that extensive studies of memory performance in the elderly allow for better understanding of individual differences in this population and may also provide a basis for crystallizing the distinction between normal and pathological changes (Schaie and Zelinski, 1979).

B. Experimental Models of Semantic Memory

As stated earlier, semantic memory is conceived of as an independent system which functions exclusively within the sphere of language. It is thought of as containing the information possessed by an individual for the organization and manipulation of words, concepts, relations, and meanings. Within the system, the individual invokes cognitive function, such as reasoning and generalization, in order to make effective use of the varied linguistic information contained in this relatively invariant memory system.

The precise construction of semantic memory within the cognitive structure has been investigated through a number of rather narrowly defined lines of research, ranging from individual word recognition (Morton, 1969) to strategies in comprehending text and conversation (Clark and Clark, 1977; Danks and Glucksberg, 1980). One important and well documented approach concerns the method by which word relationships are assimilated, stored, and produced in various situations. This concern has given rise to a considerable amount of research in the area of semantic categorization, which is investigated primarily through the establishment of a variety of categorical statements having a yes/no response set, and measuring the time it takes for an individual to make the appropriate response. The use of semantic classification and verification tasks allow investigators to infer the structure of semantic memory through the analysis of reaction times, since it is the view of many investigators that all speeded classification and speeded verification paradigms depend upon the same underlying cognitive processes (Lachman, Lachman, and Butterfield, 1979). Thus, early researchers in the field (Schaffer and Wallace, 1969) presented pairs of words (Lion/Zinc or Lion/Zebra, for example) and had subjects decide if both words in the pair were living or non-living exemplars and indicate the appropriate response. Other investigators (Smith, Shoben, and Rips, 1974; McCloskey and Glucksberg, 1979) provided the superordinate category as part of the paradigm and required subjects to verify various exemplars (e.g. All apples are fruits). In either case the subject was forced to arrive at an understanding of the relationship between the variables, and therefore had to utilize knowledge of classificatory schema regardless of whether or not the superordinate category was provided. In this way, semantic memory can be viewed as a component of language comprehension, with speeded verification tasks providing a look into the 'mental dictionary' of an individual (Smith, 1978).

The use of semantic verification tasks in the study of linguistic and syntactical processes occurred long before the tasks were conceived of as a mechanism with which to infer cognitive processes. Gough (1965, 1966) presented subjects with a series of sentences of varying grammatical forms, followed by pictures which illustrated various events. The subject had to decide if the sentence read to him was true or false on the basis of the picture presented at the completion of the reading of the sentence. Gough discovered that true sentences were verified faster than false sentences, active sentences (e.g. The boy hit the girl) were verified faster than passive sentences (e.g. The girl was hit by the boy), and affirmative sentences were verified faster than negative sentences. He interpreted these findings as evidence that the speed of understanding of a particular sentence is related in part to its syntactic structure, but also to phenomena that were not accounted for by transformational grammar. This was due to the fact that Gough obtained an interaction effect between affirmation/negation and truth value; true affirmative sentences were verified faster than false affirmative while true and false negatives were verified with equal speed. Since there is a semantic difference between true and false sentences, and the interaction with affirmative and negative sentences was clearly demonstrated, syntactic transformation alone cannot account for reaction time differences between negative and affirmative sentences. Further experiments by Gough (1966) in the investigation of the relationship between syntactic sentence structure and verification revealed that the previously stated findings held true despite manipulation of sentence length (reduction of length of passive sentences relative to active sentences), or of time of presentation of the pictures confirming of disconfirming the sentence. From these results, Gough reasoned that verification time is not related to an individual's ability to decode a given sentence into its underlying semantic structure (basic comprehension), but rather to the processes of verification itself.

The work reviewed here illustrates an orientation within the field of psychological semantics as compared to those of linguistics. For linguists, the analysis of language occurs most readily by first studying language as a structural system unto itself without considering the ways in which language is utilized (Slobin, 1979). In psychology, the major issues revolve around how word meanings are represented in the memory structure, and the processes by which individuals know when to use a particular word (Danks and Glucksberg, 1980). In an attempt to explicate these aims the paradigm of timed verification has allowed for the construction of a number of models which examine the aforementioned relationships between language and cognition. The major semantic models to be discussed are all based upon the analysis of reaction times from speeded verification tasks. The subject is presented with a sentence in the form "An X is a Y" or "All X are Y" where X is generally a category exemplar and Y is a superordinate category of some type. It is the subject's task to decide if the sentence as presented is true or false and so indicate as quickly as possible. (Glass and Holyoak (1975) and McCloskey and Glucksberg (1979) expanded upon this notion by reversing the positions of category exemplar and superordinate category, which will be discussed in more detail.) In addition, all models make the assumption that an individual does gain access to a cognitive representation of a word meaning of a concept whenever he is presented with an instance of that concept. Despite this, the major models of semantic memory differ sharply in their assumptions regarding the structure, storage, and processing of the accessed concept.

The work of Collins and his associates (Collins and Quillian, 1969; Collins and Loftus, 1975) gave rise to a model which posited a network approach to semantic processing. In the network hypothesis, words or concepts are represented as nodes in a network, with the properties of the concepts represented as labeled relational links. Thus, each word belongs to a network of other words and is defined by its relations to these other words. These word concepts are arranged in hierarchical fashion such that a word is closer to its immediate superordinate than to a more distant superordinate. The hierarchical arrangement of a concept such as animal for example would yield the notion that the word "dog" is closer to "animal" than the word "terrier". According to this model an individual verifies the statement "All terriers are dogs" by first entering the semantic memory at the nodes for the words terrier and dog, look for the path that relates the two words, and compare the indicated path with the semantic relationship as described in the sentence. The authors predicted rather rapid verification times for a sentence of this type since there is only one link between terrier and dog to be searched. However, if one presented the sentence "All terriers are animals," the subject is required to search further along the hierarchy and conclude that terrier is in fact indirectly linked to animal through a direct superordinate, in this case dog. This model predicts longer verification times due to the need for an extended search and inference about a relationship between terrier and animal. The predictions regarding the above exemplar/category relationships were confirmed (Collins and Quillian, 1972a), thereby lending some empirical support for the network model of semantic memory.

Another assumption central to a network processing approach in semantic memory concerns the amount of information that is presumed to be stored within the nodal network. Smith (1978), in his seminal review of various theories of semantic memory, viewed network models as being of the prestorage type. This means that the knowledge required to verify sentences already exists in the form of actual relations between category and exemplar. The individual searches through the network and effects a comparison between the stored relations and the information asked for in the experimental sentence and makes his decision. Inferential processes are invoked between stored relations when the subject is required to search the network past the next highest node, as previously discussed. Thus it follows that since the information required to verify a sentence already exists within the network in usable form, the individual needs simply to assimilate the criterial words to be compared (such as terrier and dog) in some Gestalt-like fashion and search for the appropriate information. This approach to the accessing of semantic information differs markedly form the assumptions made by models not dependent upon a network processing paradigm. These differences will become more explicit as other models are presented in detail, and may in fact be one way of gaining a better understanding of language memory function in aging.

Meyer (1970) developed and extensively tested a rather complex model of semantic memory which combined some of the assumptions of the network approach, with those of an attribute, or computational processing strategy (this latter strategy is an exclusive feature of other models, and will be discussed in more detail). Meyer looked at two types of verifiable statements, those quantified by the word "ALL," which were termed Universal Affirmatives (UA), and those which employed the word "SOME," or Particular Affirmatives (PA). A typical UA example would be "ALL rubies are stones," while a PA example would be "Some rubies are stones." Within the framework of the above sentence types, Meyer manipulated the relationship between the subject and predicate of the sentence in a number of ways, and examined the true/false reaction times obtained with each distinct manipulation. The subject relation was defined by the fact that the subject of the sentence was a member of the superordinate category named by the sentence predicate; e.g. All/Some Alps are mountains. The superset relation was the reverse of the above where the subject is now the superordinate category and the predicate is the category exemplar; e.g. All/Some mountains are Alps. The overlap relation occurred when the subject and predicate partially overlap, e.g. All/Some females are writers. The disjoint relation was the case in which the subject and predicate were members of mutually exclusive sets, and thus bore no semantic relationship, e.g. All/Some boats are clothes.

Through the careful analysis of reaction time data in each of the above conditions, Meyer obtained critical findings which provided some insight into the way in which individuals arrive at the correct decision regarding semantic verification. More specifically, for statements that are UA in nature, disjoint statements were verified more rapidly than statements that have some kind of subset relation. However, in the PA condition, disjoint statements were verified even more rapidly than in the UA condition. With respect to the nature of the categories within each sentence to be verified, Meyer found that changing the size of the categories represented by either the subject or the predicate had significant effects on verification reaction time. With disjoint relations, when the predicate size in the disjoint statement was increased, the time taken to appropriately negate the statement was also increased. For example, it took longer to respond to the sentence "All robins are furniture" than to respond to the sentence "All robins are chairs." This category size effect was also found for disjoint PA sentences when the category size represented by the subject rather than the predicate changed. Thus the sentence "Some robins are animals" takes longer to respond to than the sentence "Some birds are animals" by virtue of differences in the time taken to search the category.

In order to account for these findings, Meyer proposed a two stage model of semantic verification, with different kinds of semantic information considered at each stage. In stage I, the predicate intersections stage, the individual conducts a search through all categories and retrieves those that share some commonality with the predicate. This search is an ordered one, which, Meyer reasoned, was conducted on the basis of the number of non-shared exemplars between subject and predicate. Those categories having the least number of non-shared exemplars (smallest category difference) would be searched first. Thus, in the verification of a sentence such as "All robins are animals," it can be seen that both "robin" and "bird" intersect with the predicate "animal," but bird would be accessed before robin. This is due to the existence of a smaller category difference (or less distance if one is thinking along a nodal framework) between animal and bird, as opposed to animal and robin.

After a match is obtained via the search processes of the first stage, the individual then moves on to Stage II processing. In this stage, the intersections derived from the first stage are now given closer scrutiny, where the defining attributes of the subject and predicate are now compared. These attributes are thought to represent the critical aspects of the meaning of both the subject and the predicate. If there is an exact match between each attribute of the subject with each attribute of the predicate, the sentence will be verified. If an exact match cannot be found, then the sentence is disconfirmed. In Meyer's formulation, both the kind of sentence (PA or UA) and the subject- predicate relationship determine whether processing is a two stage phenomenon, or whether a response can be achieved after only the first stage. Disjoint statements are responded to within a single processing stage, since it is the responsibility of the first stage to look for a subject-predicate match. Since there is no match in the disjoint statement, the response is made after single stage processing. As a result of this, disjoint statements are disconfirmed more rapidly than sentences having a subject- predicate relationship of some type, which was what Meyer found. Single stage processing is also sufficient to verify PA type sentences, since the use of "Some" means that any subject-predicate intersection is sufficient for verification of the sentence in the absence of having to compare defining features. Thus the verification of PA subset sentences would be more rapid than UA subset sentences, which always require two stage processing. This is precisely what Meyer found. This model can be thought of as a cross between the idea of hierarchical network processing (prestorage) and that of the comparison of semantic features (computation), and lays the groundwork for a more detailed discussion of the latter approach to semantic memory.

Another major model of semantic memory is termed the feature comparison model (Rips, Shoben, and Smith, 1973; Smith, Shoben and Rips, 1974: Smith, 1978). This model seeks to explain the storage of semantic category information, as well as the means by which one gains access to this information, without reference to a hierarchical network.

The major structural assumption of this model is that concepts are stored as sets of features which can be termed either characteristic or defining in nature. For example, the concept 'robin' can be thought of as having wings and distinctive colors. It can be also be thought of as undomesticated and as living in trees. The first two features of 'robin' are viewed as essential for the definition of the word, whereas the latter two features are not central to the definition but do serve to fill in or concretize the term in question. Thus, while the network model perceives concept definitions as already stored in some logical array, the feature comparison model postulates the existence of a weighted feature list for each concept in semantic memory. The higher weighted features (those critical to the definition of the concept) are the defining features, while the lower weighted features (those which add to the definition but are essential or unique to the concept) are seen as characteristic features. This notion of weighted features gives rise to a two-stage model of processing for semantic verification. When confronted with the sentence "A robin is a bird," the individual first compares all of the features of the subject and predicate nouns and assesses the degree of featural similarity between them. If the featural similarity is very high, as in the given example, or very low as in the example "An apple is a vehicle," the individual terminates processing in the first provides the appropriate speeded response. If the individual is presented with a sentence of intermediate similarity, as in "All bats are birds," a second stage of processing in invoked. In this stage, only the defining features of the subject and predicate are compared, and if an exact match is obtained the subject will respond true. Conversely, if a dissimilarity between the sets of defining features is detected, the subject will respond false.

Individuals enter into the stages of the feature comparison model via a process quite different than that hypothesized in network approaches to semantic processing. While network models emphasize the concept of prestored relations and a search through the nodal network, the feature comparison model involves a computation process in which the relationship between the category exemplar and its superordinate is freshly computed at the time of verification. The computation derives from the analysis of the characteristic and defining features which are assumed to be stored. Thus, this model provides for the storage of discrete attributes, the computation of relations, and a comparison of these relations. In addition, it follows that if one is indeed comparing sets of discrete features of a particular concept, one has decomposed the concept in some manner into component parts which are then ready for analysis. This is again in contrast to network models which appear to view the initial assimilation of concepts in a more holistic or superficial manner. Recent reviews (Smith, 1978) suggest that both decomposed and superficial processing can take place depending upon the semantic interrelationship to be deduced. Kintsch (1980) pointed out that the conditions under which decomposition will or will not occur is poorly understood and poorly explained by current models. However, this processing approach bares the greatest similarity to levels of processing approach (Smith and Fullerton, 1981) often used to explain information processing in the aged. This relates to the individual's ability to process language on either a superficial level (rhyming of words) or by the inspection of word meanings.

The two-stage feature comparison model was seen to have a distinct advantage over hierarchical network models in its ability to predict the various outcomes derived from sentence verification data (Smith, 1978). The model accounts for most semantic findings through the singular notion that similarity of concept features will result in a decrease in reaction time to true statements (single stage processing only) and, for false statements, an increase in reaction time for disconfirmation (first and second-stage processing necessary). In the latter instance, the false statement "A bat is a bird" would take longer to disconfirm than the sentence "A shoe is a bird" due to the need for close examination of the common defining features associated with second-stage processing. In the second false example, a fast disconfirmation time can be elicited since first stage examination of the features of the respective exemplars would be sufficient to insure dissimilarity. In addition to the parsimonious explanation for correct responses to true and false items, the model also provides a cogent explanation for subject errors that are sometimes encountered in the administration of this paradigm (Lachman, Lachman and Butterfield, 1979). This happens when the subject is misled by the similarity of the characteristic features during stage-one processing and thus emits a fast but incorrect response without proceeding to stage-two processing. Similarly, less common members of a superordinate category may have too few characteristic features which causes a rapid false response, again, without examination of the defining features in isolation.

Perhaps the most salient feature of this model lies in the fact that its use of characteristic and defining features developed from important corollary work in semantic distance (Rips, Shoben, and Smith, 1973) production frequency (Battig and Montague, 1969) and typicality of category exemplars (Rosch, 1975; Rosch, Mervis, and Gray, 1976). This body of work showed that certain categories did not adhere to the hierarchical assumptions of earlier models, namely that concepts are arranged in a discrete nodal fashion. Concepts such as bear, pig, and cow were thought to be represented at the same level of the nodal network, and were included within the class of mammal. However, the network model was unable to satisfactorily explain why it consistently took subjects longer to verify the statement "A pig is a mammal" than the statement "A cow is a mammal," if these two exemplars occupy the same relative position within the taxonomic category. Instead, it turns out that category exemplars are not at all equal in how they are utilized by individuals as representative of categories; each category has its own prototypical example around which other category members are organized (Rosch, 1975). Individuals are more likely to give these prototypical responses in production frequency tasks whether they are young (Battig and Montague, 1969) or senior citizens (Howard, 1980). More importantly, these highly dominant class members are recognized as category members more rapidly than low dominance members, which are described by Rips, et al (1973) as greater in semantic distance. The feature comparison model incorporated the assumptions of both typicality and semantic distance and accurately predicted the variance in verification times with degree of category membership. Thus, the greater associative strength of the noun 'cow' to 'animal' allows for more rapid verification than the noun 'pig', due to the lower dominance of the latter exemplar. This finding provides the feature comparison model with its greatest advantage, since it is an observation that is not readily explainable through the basic logic of class relations.

An updated version of the network search model has been constructed specifically in response to the feature comparison model. This is generally known as the marker search model, developed by Glass and Holyoak (1975). As with other network models, the marker search model assumes that specific relations among categories are directly stored in memory. In this model, each word concept is directly associated with a single defining model. The concept 'dog' then, is represented by the marker 'canine'. In addition, markers are seen to be interrelated in such a way so that any marker can dominate a set of further markers that are associated with it. For example, the marker for 'collie' implies canine which in turn implies 'animate', which itself is a defining marker for animal. As in previous models, verification takes place via a search through a nodal network. However, the difference in this case is that the search does not necessarily proceed in a hierarchical fashion. Depending on the circumstance, individuals can access a more abstract marker first by choosing an alternative shortcut pathway between non-adjacent markers. In the sentence, "All chickens are animals," Glass and Holyoak posited the existence of two pathways; the usual markers from chicken to avian (bird) and from avian to animate (animal), and a second shorter pathway from chicken directly to animate. According to the model, since differences in semantic decision time are based upon the order in which the markers are searched and some pathways are searched sooner than others, then it can be seen that the sentence "All chickens are animals" could be verified more rapidly than the sentence "All chickens are birds". This is because the search would proceed in parsimonious fashion through the more direct pathway. Thus, the Glass and Holyoak model abandons the notion of a hierarchical ordered search and accounts for reaction times of both true and false sentences by means of variations in search order.

Glass, Holyoak, and O'Dell (1974) devised a method by which predictions could be made concerning the order of marker search and thus the speed of sentence verification. They had subjects provide one word completions for sentences such as "All robins are _____." They then determined the frequency with which different words were given as predicates. The critical assumption is that the greater the frequency of a word given to complete the sentence, the greater the probability of access to its corresponding defining marker within the system of the specific subject matter. It follows then, that true sentences with high production frequency will be verified more rapidly than sentences with a lower production frequency, and these findings were confirmed (Glass, et al, 1974; Glass and Holyoak, 1975). The marker search model, then successfully accounts for many of the predictions of the feature comparison model by maintaining the prestorage and ordered search tenets of network models. In addition, it incorporates the notions of typicality and strength of association of categories and their exemplars through mechanisms other than similarity of features.

Perhaps the most significant difference between the marker search model and the feature comparison model concerns the predictions of the speed necessary to reject false sentences. While the feature comparison model predicts slower rejection of false statements with the subject and predicate semantically close to one another, the marker search model takes the opposite view. As with true sentences, the basic assumption is that the speed of sentence rejection is dependent upon how quickly one accesses a marker which produces a contradiction between the subject and predicate. Glass and Holyoak (1975) examined two types of false sentences, which were termed "contradictory" and "counterexample" in nature. A contradictory sentence was one in which the predicate directly contradicted the subject, as in "All birds are dogs." In a counterexample sentence, there was no direct opposition of subject and predicate, thus yielding a sentence such as "All birds are robins." Production frequencies were again employed as an indicator of the speed of marker search, with high frequency indicating more rapid search and hence speedier disconfirmation of false sentences. With this approach, Glass and Holyoak found that high frequency false sentences such as "All robins are chickens" (subject and predicate more closely related in meaning) are rejected more rapidly than low frequency false sentences such as "All robins are dogs." In the case of counterexample sentences, a statement such as "All birds are robins" is disconfirmed more rapidly than the sentence "All birds are bats" due to the relative ease with which a marker can be uncovered in the former sentence which contradicts the predicate "robin." The marker search model, then, is able to account for reaction time data of true statements as efficiently as any previous model. In addition, it contributes a more detailed theoretical approach to the problem of rejection of false statements, and offers data in stark opposition to the predictions of the feature comparison model.

The most updated featural model of semantic memory was proposed by McCloskey and Glucksberg (1979). The attraction of this simple property comparison model is that it has accounted for most of the findings in the semantic verification literature in a parsimonious manner, and has produced experimental evidence for the rejection of both the feature comparison and the marker search approaches to the cognitive representation of word meanings. Specifically, McCloskey and Glucksberg examined the reaction times of a variety of subject-predicate relationships of both true and false value. These sentences were evaluated within the context of two different sentence lists; a) related false (RF), in which false sentences retained subject-predicate relatedness, and b) unrelated false (UF), in which all false sentences were devoid of any subject-predicate relatedness. McCloskey and Glucksberg found that verification reaction time for all sentence types was consistently slower in the RF condition than in the UF condition, thus demonstrating that sentences with the same subject-predicate relatedness are affected by the context within which they are verified. These findings cannot be accounted for by either the feature comparison or the network processing approach, since both models assume that each sentence alone contains the information sufficient to confirm or disconfirm its truth value. McCloskey and Glucksberg referred to these two approaches as models that invoke a determinate processing strategy. This strategy cannot account for the obtained context effects solely by reliance on the assumption that the information used to determine the truth value of a sentence does not vary as a function of its context.

From these findings, McCLoskey and Glucksberg argued that individuals must employ a probabilistic rather than a determinate decision process in accessing the truth value of category membership statements. Towards this end, the authors proposed a property comparison model in which the meanings of each concept are represented as a set of properties, with each property consisting of an attribute and a set of values for that attribute. It is assumed that the values that are stored are only the typical values for each attribute shared by the exemplars of a concept. The sentence verification process is accomplished by retrieving and comparing the properties of the subject and predicate. Each property comparison produces either positive evidence or negative evidence of the statement's truth value. As comparisons continue, the positive and negative evidence accumulates until there is sufficient data to exceed a true or a false criterion. Thus, the probability of deciding that a sentence is either true or false is based upon the number of property comparisons made. This model accounts for semantic relatedness in the following manner. For true sentences with high subject-predicate relatedness (All apples are fruits), the evidence from the property comparisons should be mostly positive. Therefore, fewer comparisons are needed to exceed the decision criteria, which then results in a faster reaction time. Sentences of lower semantic relatedness will require more comparisons to reach criterion, thus yielding a longer reaction time. For false sentences which are low related, more negative comparisons are obtained and thus a faster reaction time. Similarly, high related false sentences will have a need for greater numbers of negative comparisons to offset some positive comparisons, and hence a longer reaction time is necessary. These confirmed predictions agree with the Smith et al (1974) predictions for false sentence verification and contradict the Glass and Holyoak (1975) analysis regarding shorter latencies for high related false sentences. Finally, the property comparison model accounts for the observed context effects by predicting a more difficult and thus longer probabilistic decision process for true sentences when the proportion of positive evidence expected for concomitant false sentences is greatest. This is precisely the situation encountered in the RF condition and as previously discussed, the reaction times in this condition are indeed longer.

The utility of a semantic model based upon probabilistic rather than determinate notions is consistent with recent research findings that view semantic category boundaries as fuzzy rather than well defined. Oden (1977) described fuzzy set theory as a conceptualization in which many items are neither clearly members nor clearly not members of a set. Natural categories are seen as falling within this domain, suggesting that membership of many category exemplars is a matter of degree. Oden demonstrated that individuals were competent processors of fuzzy information in that they were able to reliably judge the truth value of various subject-predicate relationships across a variety of different categories. McCloskey and Glucksberg (1978) directly examined the issue of fuzzy versus well defined categories by giving subjects a series of exemplar-category pairs (e.g. chair- furniture) and asked them to decide if the exemplar was a member of the category. The results indicated significant disagreement between subjects in their decisions as to which exemplars belonged to a given category. There was also considerable inconsistency within subjects as to how they rated the typicality of each exemplar across categories. McCloskey and Glucksberg argued that the ambiguous ratings of many exemplars support the notion of a lack of a clear boundary separating category members from non-members. Category fuzziness lends itself more readily to a probabilistic model of semantic memory, since this model treats membership in a category as varying continuously depending upon the proportion of positive and negative properties explicated in a given situation. Category fuzziness in the context of a property comparison approach is further enhanced by the fact that an exemplar could be a member of not one but many superordinate categories which bear little relation to each other. For example, the exemplar "shirt" is a member of the superordinate category "clothing", but is also a member of such categories as common birthday presents (Miller and Glucksberg, in press). The existence of numerous possibilities for categories and subsequent exemplar membership supports the property comparison model as the most parsimonious method by which to infer how such information is stored in long term memory. To be sure, the feature comparison model does not attempt to account for typicality and hence degree of category membership (Smith, 1978), but still specifies the conditions necessary for category membership by virtue of its dependence upon defining features as the ultimate process by which to judge an exemplar.

C. Age Differences in Semantic Memory

Researchers have attempted to uncover the etiology of observed age-related changes in memory by proceeding from a variety of theoretical perspectives. One approach to this problem considers the act of remembering to consist of first, encoding or learning the necessary information; second; storage, or maintaining the information for some period of time; and third, retrieving the information according to the demand characteristics of a particular situation. Investigators have used this framework in order to try to pinpoint the source of the memory deficit as seen in elderly individuals (Smith, 1980; Smith and Fullerton, 1981), and to determine if these deficits affect the processing of episodic or semantic information (Burke and Light, 1981).

Age differences in encoding ability are most frequently described through a levels of processing approach to memory (Craik and Lockhart, 1972). In this approach, individuals can encode all incoming information in a variety of ways. For example, a relatively shallow level of processing might be induced if the subject is merely asked to decide if two words differ in appearance. Thus, one might ask a subject to differentiate between a word presented in upper case letters and one presented in lower case. An intermediate level of processing may be induced when the task requires the subject to provide a word that rhymes with the target word. Finally, the deepest level of processing is represented by having the subject deal with the meaning of a target word by asking if it is an exemplar of a particular superordinate category. As one descends from the shallow processing necessary to encode simple structural features of words to deep processing where the semantic aspects of the target word are assimilated, a more elaborate and hence more stable memory trace is laid down. Deeper processing, then leads to better recall since the memory trace at this level is more resistant to forgetting. This hypothesis has been verified in college age students (Craik and Tulving, 1975).

The application of this procedure to the analysis of memory functioning in the normal aged population has led to a viable explanation for the deficits generally observed in this group, particularly during paradigms requiring free recall. Since it has been demonstrated that deeper processing is more difficult to achieve due to the need for greater effort on the part of the subject (Eysenck, 1974; Simon and Craik, 1979), aged individuals fail to spontaneously carry out processing at the deepest levels and consequently do not perform as well on memory tasks. Eysenck obtained these results by systematically testing recall at various levels of processing in young (18 to 30 years) and older (55 to 65 years) individuals, by having them count letters, generate rhymes, provide adjective, or just learn a group of words. Not only did the recall of the older group decline relative to the younger group with each increased level of processing required, but the older subjects demonstrated the greatest impairment when they were required to learn the words on their own. Eysenck interpreted this finding as evidence that the elderly do not spontaneously carry out deeper processing under normal learning conditions because they have lost the ability to engage in deep semantic processing. The resulting impairment in memory performance is thus seen by Eysenck to be the consequence of a processing deficit.

A second position stemming from the use of the levels of processing approach is termed the production deficit hypothesis. The main distinction revolves around the notion that deep processing in the elderly is inefficient rather than defective, and that if supplied with the appropriate resources the elderly can engage in deep processing, thereby eliminating any meaningful age related decrement in recall. Perlmutter (1978; 1979(a)) performed a study in which young and old groups of subjects were exposed to two conditions in which they were to memorize words. In the intentional learning condition, the subjects were expressly told that they would be asked to recall the word lists. In the incidental learning condition, the subjects were simply asked to provide free associations to each of the words on the lists, but were not told that their memory would be tested. All subjects were evaluated in both conditions by use of both free recall and recognition paradigms. The results revealed the expected dramatic age differences in free recall of the words in the intentional condition. However, Perlmutter found that when recall is replaced by recognition in the intentional condition, the age differences become attenuated to a large extent. From these data, it was hypothesized that the large retrieval support provided by recognition benefits the elderly to a greater extent than the younger group and thus compensates for one aspect of the apparent deficit demonstrated by the aged subjects. More striking, however, was the finding that during the incidental learning condition, the use of the recognition paradigm eliminated previously observed age differences in performance. By having subject generate associations to the words on the list, they were, in essence, directing their encoding towards deeper levels of processing. Thus, the simultaneous use of controlled procedures for both encoding and retrieval served to equate the memory performance of a young student group and an aged group, thereby lending support to the production deficit hypothesis.

Further evidence for the notion of a production deficit in the aged groups was provided by White (cited in Craik, 1977(a)). He employed a strategy in which he asked subjects to make judgments about common words on the basis of their physical appearance, their ability to rhyme with other words, or whether they were members of particular superordinate categories. In the fourth condition, White asked the subjects to learn the words in any manner they chose. Each subject was then tested for retention by free recall and by recognition. The results demonstrated that age differences in memory were again eliminated in the condition that employed semantic orientation (category judgments) and recognition. It is important to note that, according to these studies, memory performance in the elderly can be fully restored only if processing is guided both at encoding and at retrieval.

Despite the apparent existence of strong evidence for the production deficit hypothesis, other investigators have challenged the validity of these findings with regard to a strict interpretation of this theory. Burke and Light (1981) pointed out that no study has ever demonstrated the elimination of age differences in memory during free recall despite the use of orienting tasks which purportedly control processing during encoding. In their view, the failure of semantic tasks to accomplish this means that the elderly are unable to benefit solely from the application of semantic controls, and thus must possess real semantic deficits. Simon (1979) jointly manipulated encoding and retrieval through a cued recall paradigm in which she told young, middle age, and old subjects that they would be cued for recall either with phonemic cues, semantic cues, or no cues. While all groups benefited from phonemic cues, only young subjects were able to benefit from semantic cues. Simon concluded that the older individuals do not encode semantically, thus leading to the notion that semantic orienting tasks that are provided to facilitate processing at encoding probably exert far less control at this stage than is generally assumed. Simon's explanation for this finding centers on her belief that successful semantic encoding is highly specific and thus becomes part of the encoding context. Older adults are not as heavily influenced by context and will tend to demonstrate similarities in encoding style regardless of the situation in which they are asked to perform. In this case, semantic encoding tasks would do little to change their memory performance.

Salthouse (1982) has argued that successful performance by the elderly on recognition memory tasks in the face of relatively poorer performance on recall does not necessarily mean that memory difficulty in this group is solely attributable to retrieval processes, with encoding judged to be intact. Since recognition tasks are easier than free recall tasks, many experiments often confound amount of retrieval with level of difficulty. When this happens, it cannot be reliably determined if inadequate recall in the elderly is actually due to the need for a greater amount of retrieval, or because recall paradigms are simply more difficult than recognition paradigms. Perhaps the most compelling reason as to why it is still unclear to what extent depth of processing is compromised in the elderly is the fact that the ability to retrieve an item successfully depends heavily on the nature of the encoding of that item in the first place, much as the location of a document depends upon the filing system that is employed. Salthouse (1982) believes that if this is so, then the basic distinction between encoding and retrieval processes cannot be made crystal clear, and thus attempts to localize memory dysfunction in the elderly as discretely belonging to either one or the other of these processes may well prove futile.

Further efforts to understand the nature of possible encoding and retrieval deficits in the elderly have revolved around the investigation of semantic memory in this age group. If there is a real loss in the ability to process information at deep levels, then is a change in the organization and structure of the semantic system responsible for this deficit? The finding that verbal subtests on the Wechsler Adult Intelligence Scale, particularly those which measure vocabulary and information do not decline with age seems to support the notion that the amount of material contained within semantic memory in a generic way is quite stable and resistant to forgetting throughout the lifespan (Kausler, 1982). However, this observation does not address the issue of change in semantic organization. Evidence of change in semantic organization with increasing age is derived in part from a study by Riegel (1968). He noted that despite an increase in vocabulary store with increasing age, elderly people were more idiosyncratic and concrete in their performance on free association tasks, as evidenced by their tendency to provide more syntagmatic than paradigmatic responses. Botwinick, West, and Storandt (1975) found that the quality of the vocabulary responses given by older individuals on standardized tests was inferior to those obtained from young subjects, despite the fact that these differences do not appear in quantitative comparisons of vocabulary ability. Stones (1978) studied structural differences in semantic memory in a group of young (mean age=17 yrs.) versus middle-aged (mean age=49 yrs.) adults by administering tests of vocabulary, verbal fluency by category retrieval, and verbal fluency by cueing with initial consonants. His results indicated that there was a greater consistency in the performance of the young subjects across all 3 tasks, while the middle-aged group demonstrated greater variability and thus less relationship between aspects of semantic memory. Stones concluded that this data may provide some evidence for the loosening and diversification of the semantic structure with increasing age. However, it is difficult to draw definitive conclusions from this study with respect to the elderly, since the oldest group tested had a mean age of only 49 years.

There have been relatively few investigations of changes in both the quality and the speed of retrieval on particular semantic tasks. Eysenck (1975) gave young (18 to 30 years) and older (55 to 65 years) adults two semantic tasks; in one task both groups were required to recall a category instance beginning with a particular letter. In the recognition portion of the study, the groups were to decide if a word was a member of a specific category. Eysenck found that both groups performed equally during the semantic recall phase of the study, and that the differences in response latency for high and low typicality category items was less for older subjects than for the younger subjects. He suggested that older individuals are as capable of directed search through semantic memory as younger individuals and may actually be more efficient than the younger group by virtue of less difference in the latency of response to high typicality vs low typicality items. Most striking, however, was Eysenck's additional finding that the older group was considerably slower than the younger group when they simply had to recognize category-instance relationships. This was thought reflect the need for the older group to engage in a longer decision process in order to determine the appropriate response. Thus, search and decision processes in semantic memory may be differentially affected by aging. More recently, Mueller and colleagues (Mueller, Kausler, Faherty, 1980; Mueller, Kausler, Faherty and Oliveri, 1980) investigated speed of access to semantic memory by presenting groups of young and old subjects with 3 different types of word pairs. In the first type, subjects decided if the word pairs were physically identical; in the second type, subjects decided if the word pairs were acoustically identical; and in the third type, subjects decided if the word pairs belonged to the same taxonomic category. In all cases, a two choice response was elicited, with both the young and the elderly groups asked to decide if the word pairs were the same or different. Of interest was the fact that while the elderly group responded uniformly more slowly than the younger group to all three types of word pairs, they were not proportionately slower in making semantic decisions. Both groups demonstrated similar rates of increased latencies as the task shifted from identifying the word pairs on the basis of their physical characteristics to making decisions based upon semantic categorization. These results were interpreted as corroborative of Eysenck's (1975) finding that the elderly demonstrate no deficits in access or search through semantic memory, and that any observed decline in this area may instead be due to faulty utilization of decision strategies.

One additional finding from the Mueller, et al. study (1980) was an apparently significant age difference in situations where the subject made a category decision that led to a "no" response. Elderly subjects required an unusually long amount of time to decide that two words did not belong to the same superordinate category, leading to the possibility that the decision criteria for inclusion or exclusion within a category changes with increasing age. Mueller, Kausler, Faherty, and Oliveri (1980) sought to examine the notion that category boundaries change with aging, perhaps by becoming less well defined (McCloskey and Glucksberg, 1978). Young and old subjects verified a series of category-exemplar pairs, with the exemplars ranging from highly typical instances of category membership to atypical or "remote" instances of membership. There was no significant difference between the groups in the verification latencies of atypical exemplars relative to the verification time of prototypical exemplars. The authors concluded that the mechanism by which decisions are made about category membership in semantic memory is essentially the same for both young and old.

The ability of individuals to provide a correct and speedy response in a semantic reaction time task has been shown to depend heavily on the way in which semantic material is organized in memory. The same may be said of performance on tasks which purport to analyze retrieval from superordinate categories (See previous section on models of semantic memory). From this perspective, there is some evidence that the organization of semantic material is similar in both young adults and in the elderly. Howard (1980) recorded the responses of young, middle aged, and elderly individuals to the superordinate categories originally employed by Battig and Montague (1969) in the determination of retrieval norms for younger adult subjects. There were very high correlations between typical category responses provided by the young adults in the Battig and Montague sample and the aged group in her sample. The proportion of idiosyncratic responses that occurred on the initial response to a superordinate category was the lowest in the elderly group. These results suggest that the organization of categorized information is similar in both young adult and in older populations. However, it is important to note that the elderly group may still have difficulty in the retrieval of particular exemplars, as evidenced by Howard's further finding that the mean number of response per category was lowest in the oldest group. However, in a recent study, Howard (1983) investigated changes in semantic structure by requiring subjects from six different age groups (20-29; 30-39; 40-49; 50-59; 60-69; 70-79) to make a variety of judgments about pairs of animal names, such as dog-lion. They were presented with a series of line scales and were asked to rate the animal names according to the dimensions represented by their scales. The subjects in the 70-79 age range tended to emphasize dimensions in their ratings that were perceived as more concrete, such as size, while subjects aged 20-59 were more likely to rate the animal pairs on the basis of abstract features such as predativity and domesticity. These results led Howard to postulate a subtle but real change in semantic structure with increasing age.

Other evidence regarding the relative preservation of the semantic network in aging comes from recent studies purporting to measure the speed of access to the information contained within the network. This determination is typically made by measuring the time required to decide whether or not pairs of letter strings are words. The critical finding in this type of experiment rests upon the well established observation that subjects are faster in deciding that a letter string is a word if that string is preceded by a semantically related word as opposed to an unrelated word (Meyer and Schvaneveldt, 1971; 1976). If normal elderly failed to demonstrate this facilitative or priming effect on lexical decision tasks of this type, then it could be theorized that the aged have relatively greater difficulty in entering the semantic network. Such a finding would provide a basis for further study of semantic deficits in this population (Bowles and Poon, 1985).

The results of the majority of recent studies however, support the preservation of priming effects in the normal aged population. Howard (1981; 1983(b)) presented young (mean age=31.1 yrs.) and aged (mean age=69.5 yrs.) subjects with two sets of letter strings. The subject was instructed to press a key labeled "yes" only if both strings were words; otherwise, he was to press the key labeled "no". In the "yes" condition, the letter strings were composed either of word pairs having varying degrees of relatedness (bird-robin; bird-bat), or word pairs that were unrelated (bird-linen). In the "no" condition, subjects saw letter strings that contained one word and one non-word, or two non-words. The results revealed that the aged group demonstrated as much semantic priming as the younger group, even when the stimuli were low in semantic relatedness. In addition, Howard found no significant correlations between the magnitude of the priming effect and the age of the subjects. Cerella and Fozard (1984) tested a group of young subjects (mean age=24.3 yrs.) and elderly subjects (mean age=73.1 yrs.) on a word pair identification task, with the pairs of words either related or unrelated. Both groups of subjects were tested in two conditions; in condition 1, the groups were instructed to silently read a prime which appeared for 500 milliseconds. After a 500 millisecond interval, the target word appeared and subjects were told to read the target word aloud. Latency was measured from the time of visual onset of the target word to the verbal identification of that word. In the second condition, all subjects read the target word silently as before, and after a 500 millisecond delay, read the same word aloud. True lexical access was defined as the difference between the time necessary to identify and pronounce target words in the first condition, and the time required to just pronounce the preidentified words. Within this framework, a difference of about 200 milliseconds was obtained for both the young and the elderly group, suggesting that access to the lexical network remains relatively unaffected by age.

In summary, while it is clear that elderly people do appear to have some memory difficulty in comparison to younger individuals, it is not at all certain whether changes take place either in the structure of semantic memory or in the ability of the elderly to gain access to these structures with the same efficiency as that observed in young adults. While some authors (Smith and Fullerton, 1981; Salthouse, 1982) have tentatively concluded that the available evidence suggests an absence of change in underlying semantic organization with increasing age, others, (Burke and Light, 1981) maintained that the documented variability in both quantity and quality of response to semantic processing tasks provides evidence for the opposite conclusion. To be sure, some developmental psychologists place semantic memory at the center of the cognitive system, and, as such, semantic memory is conceived of as a dynamic, developing structure which constantly evolves through its interaction with the environment (Naus and Halasz, 1979). If this is the case, then the detection and quantification of change within semantic memory may well contribute important information towards the understanding of memory function in both normal as well as pathological aging.

D. Disruption of Semantic Memory in Alzheimer Type Dementia

Marked disturbances in cognitive functioning that are most frequently observed in the middle to later years are thought to be non-normative in nature, and may be the result of dementing disorders. Dementia is currently defined as the progressive loss of mental function due to organic brain disease (Tomlinson, Blessed and Roth, 1968; Wells, 1977). While there are a wide variety of etiologies, ranging from nutritional deficiency to cerebral degeneration, that can produce the symptoms of dementia, the most common cause is dementia of the Alzheimer type. Of the estimated 1.3 million cases of severe dementia that currently exist in people over the age of 65, 50 to 60 percent are estimated to be Alzheimer's disease, a figure based upon data from various post-mortem studies (Terry and Katzman, 1983). Further, it is estimated that the prevalence of mild to moderate dementia in individuals over the age of 65 is 11 percent, a figure which contributes 3 million additional mild to moderate cases to the total current severe dementia population (Schneck, Reisberg, and Ferris, 1982). Thus, it can readily be seen that Alzheimer Type Dementia is a serious health problem that may soon reach epidemic proportions (Plum, 1979).

Clinically, Alzheimer Type Dementia can often be quite difficult to diagnose, since in various stages it can be confused with depression, psychosis, or dementias of a vascular nature (Katzman, 1981). The final diagnosis of Alzheimer Type Dementia is made histologically, based upon the presence of senile plaques and neurofibrillary tangles. In addition marked reductions of cholinergic activity from particular brain regions have been associated with these histopathological changes (Terry and Davies, 1980). The recent explosion of research in dementia has tended to support the idea that Alzheimer Type Dementia is a disease entity that is, by and large, independent of changes associated with normal aging. However, it has been suggested that there is some relationship between possible declines in functioning in so-called normal elderly, and those declines that are documented in dementia. Kral (1978) has proposed the clinical entity of Benign Senescent Forgetfulness which, in his view may characterize the relatively mild memory deficit that accompanies normal aging, and is thus differentiated from the more pervasive deficit which is symptomatic of Alzheimer Type Dementia. Kral has speculated that this dichotomy does not necessarily imply two distinct pathological processes, but could instead be the result of a singular process which either tends to spare hippocampal structures in most individuals, or severely affect those same structures in the unfortunate few. Terry (1978) pointed out that on a neuropathological level, many of the differences between normal aging and dementia are quantitative in nature, since the neuritic plaques and neurofibrillary tangles, which are diagnostic of Alzheimer Type Dementia on autopsy have been found to a lesser extent in the brains of normal elderly. Thus, Alzheimer Type Dementia may be one extreme point on a continuous spectrum which encompasses normal cognition and dementia, and is related to a level of neuropathological and perhaps neurochemical change that occurs at a certain threshold. These speculations, as well as the fact that the incidence of Alzheimer Type Dementia is a strongly age-related phenomenon (Tower, 1978), make comparisons between the cognitive processes of normal elderly and mildly impaired Alzheimer's patients a potentially worthwhile endeavor.

While the appearance of deficits in cognitive ability in otherwise well-functioning adults immediately raises the question of dementia, there is evidence that the particular pattern of impairment may be helpful in differentiating Alzheimer's Disease from other common dementing disorders (Perez, 1978; Fuld, 1984). Patients with Alzheimer Type Dementia ultimately demonstrate deficits in visuospatial skills, reasoning ability, and arithmetic competence (Rosen, 1983). However, impairment of memory is usually taken to be the most prominent symptom early in the course of the disease, and is probably the best documented deficit. Despite this, the precise nature of the memory deficit in Alzheimer Type Dementia is not clear. Miller (1977; 1981) performed a series of experiments in which he presented a list of words to demented subjects on three occasions. After a period of interference, he tested for retention of the material by either free recall, forced-choice recognition, or cueing with partial information of the words to be remembered. He found that the demented subjects demonstrated severe impairments on both recall and recognition with respect to controls, but when they were provided with partial information about the words, their performance dramatically improved. Miller concluded that while it is possible that inefficient encoding may be partially responsible for the memory deficit in dementia, the major problem lies in the retrieval of information, rather than in its acquisition. This issue is made even more problematic if one accepts the criticism of Salthouse (1982) that it is methodologically difficult to distinguish between encoding and retrieval processes, as discussed in the previous section.

Other investigators have suggested that individuals with Alzheimer Type Dementia are unable to make appropriate use of semantic cues in order to retrieve verbal information (Wilson, Kaszniak, and Fox, 1981). Similarly, Alzheimer's patients do not demonstrate superiority for rare words as opposed to common words on recognition memory as is usually the case in normal populations (Wilson, Kramer, Fox, and Kaszniak, 1983). This finding was interpreted as further evidence of the failure of this group to properly encode the featural aspects of the rare words to the extent that normal individuals can accomplish this task. It is reasonable to suggest then, that the memory deficit that accompanies Alzheimer Type Dementia may include substantial disruption of the semantic structure.

Additional evidence for semantic disorganization in Alzheimer Type Dementia has emanated from recent investigations of language functioning in this disorder. Rosen (1980) administered two tests of verbal fluency to a group of normal aged, a group with mild dementia, and a group with moderate to severe dementia. Verbal fluency was impaired in individuals with mild dementia, and that fluency declined with the progression of the disease. The quality of the retrieval obtained from the groups led Rosen to speculate that mildly impaired subjects may have difficulty in gaining access to subsets of semantic categories, but at the same time demonstrate preservation of the ability to retrieve high typicality exemplars from these same categories. However, with progression of the disease, impairment extends as well to retrieval of the best examples of a category. Thus, it appears that category structure is disrupted in Alzheimer Type Dementia, and the severity of the disease may play a role in the determination of the level at which this structure becomes disturbed.

Naming ability has been found to be substantially compromised in Alzheimer Type Dementia, even in subjects who are early in the course of the disease (Appell, Kertesz, and Fisman, 1982; Kirshner, Webb, and Kelly, 1984), and despite the presence of preserved vocabulary and abstract reasoning (Martin and Fedio, 1983). One explanation for the cause of such impairment has been traced to the breakdown of the semantic system. Bayles and Tomoeda (1983) found that 92 percent of the misnamings of objects made by their sample of Alzheimer subjects were semantically related to the stimulus. This non-random relationship between the target object and the response suggests that the dementia causes an erosion of the category boundaries of items stored in the semantic network. Martin and Fedio (1983), in the most comprehensive study of the problem to date, administered tests of naming, fluency, and single word comprehension to a group of subjects with mild Alzheimer Type Dementia. Although these individuals demonstrated surprising preservation of knowledge of category membership as measured by the Similarities subtest of the Wechsler Adult Intelligence Scale, they were markedly more impaired than normals in their ability to retrieve items from within the same categories. In the presence of an overall reduction of verbal fluency, Alzheimer subjects were able to provide broader categorical information. For example, they were able to give "Fruits" or "Vegetables" when asked to name items that could be purchased in a supermarket. However, these subjects had much greater difficulty in accessing a particular category to give specific exemplars. Second, Martin and Fedio (1983) also found a larger number of semantic-paraphasic errors in their sample on object naming, a finding that corroborates the results obtained by Bayles and Tomoeda (1983). From these data, the authors hypothesized that Alzheimer Type Dementia produces a clear disruption of semantic memory, which may be characterized by either the loss of semantic information, and/or by the inability to utilize specific semantic attributes.

In contrast to the conclusions derived from studies of naming ability, Nebes, Martin, and Horn (1984) examined semantic memory in a group of subjects with mild to moderate Alzheimer's Disease through the administration of a semantic priming task. This task consisted of 20 pairs that were semantically associated, and 20 pairs that were unrelated. The authors examined the effect of the relationship between word pairs on the time it took subjects to name the second word in the pair. While the Alzheimer group was considerably slower than matched controls in naming the words in either condition, the magnitude of the priming effect from the related condition was the same for both subject groups. This finding was interpreted as evidence of a grossly intact semantic structure in Alzheimer subjects, since normal entrance time into the lexicon was preserved. It was noted, however that since the associative strength of the primes was not varied, the results could not be taken as evidence that semantic relationships in dementia were as intact as those seen in the normal elderly.

To summarize, there is considerable evidence that the deficit in memory, which is the hallmark of Alzheimer Type Dementia, has as a major component a disturbance within the structure and organization of semantic memory. This evidence is derived mainly from studies of language functioning, where Alzheimer subjects are found to be defective on tasks of fluency and of naming ability. Other studies have suggested the presence of encoding and retrieval deficits as contributing to the clinical picture of memory impairment. While it is likely that continued progression of the dementia translates into more profound disruption of the semantic system, individuals with mild impairment may (Martin and Fedio, 1983) or may not (Nebes, Martin, and Horn, 1984) demonstrate these deficits. A comparison of semantic memory in normal elderly and in mildly impaired individuals with Alzheimer Type Dementia, may, through the use of well developed experimental methodology, provide worthwhile information in order to help further delineate the nature of the deficit in both groups.

E. Cholinergic Treatment of Memory Dysfunction in Alzheimer Type Dementia

Current efforts to develop an effective drug treatment for Alzheimer Type Dementia are based substantially on the inference that persons with this disease suffer from marked reductions in acetylcholine, a critical neurotransmitter substance. The cholinergic system involves the synthesis of acetylcholine by the enzyme choline-acetyl-transferase (CAT), and its subsequent destruction by acetylcholinesterase (ACHE). This neurotransmitter system is quite ubiquitous, with high levels of CAT activity measurable in many areas of the brain (Cooper, Bloom, and Roth, 1978). Davies and Maloney (1976) first reported what is now a well documented finding that relative to age-matched controls, subjects with histopathologically confirmed diagnoses of Alzheimer Type Dementia have significantly reduced activity of CAT in histological samples of their cerebral cortex. Further studies (Davies, 1978; 1979) found that the reductions of CAT were most severe in the areas of the hippocampus, the mid-temporal gyrus, the parietal cortex, and the frontal cortex. Indeed, it has been shown (Davies, 1979) that in some severe cases, the amount of CAT present in some cortical regions was less than 10 percent of what is normally expected. It is important to note that some investigators have questioned the potency of these findings, since substantial reductions of CAT have also been found in some of the same cortical regions in healthy elderly (McGeer and McGeer, 1975). However, in a recent review of all of the work done to date on the measurement of CAT activity, Bartus, Dean, Beer, and Lippa (1982) observed that a majority of studies have failed to find decreased CAT activity in the brains of healthy elderly. Thus, they concluded that the severe and consistent reductions of CAT in Alzheimer Type Dementia are likely to be a disease-specific phenomena.

Other evidence for the relationship between Alzheimer Type Dementia and cholinergic deficits come from morphological and behavioral studies. Perry, Tomlinson, Blessed, Bergmann, Gibson, and Perry, (1978) demonstrated a significant correlation between reduced CAT and senile plaques, a significant histological marker for the presence of Alzheimer Type Dementia. Drachman and Leavitt (1974) found that college-age subjects who were given scopolamine, a cholinergic blocker, exhibited memory deficits which seemed to resemble those observed in normal elderly subjects, thus suggesting the involvement of the cholinergic system in memory. Further work by Drachman (1978) demonstrated that a scopolamine induced dementia could be reversed by the administration of physostigmine, an ACHE inhibitor. These findings led to speculation that physostigmine might improve the memory deficit associated with Alzheimer Type Dementia. While some studies have failed to demonstrate improvement in cognition, either by administration of cholinergic precursor (Thal, Rosen, Sharpless, and Crystal, 1981), or by ingestion of physostigmine and lecithin (Wettstein, 1982), other studies in this area have provided encouraging results. Augmentation of memory has been shown with subcutaneous injection (Davis, Mohs, and Tinklenberg, 1979; Peters and Levin, 1979), intravenous infusion (Mohs and Davis, 1982), and more recently with oral physostigmine (Thal, Fuld, Masur, and Sharpless, 1983). Clinical trials with oral physostigmine are continuing in hope of further evaluating the efficacy of this drug on memory and activities of daily living over the course of several months.

HYPOTHESES

The following predictions can be made with regard to semantic memory in normal aging and in Alzheimer Type Dementia.

1a. If normal elderly subjects maintain preservation of semantic memory as described by the property comparison model, then they will be expected to perform in the following manner; they will demonstrate typicality effects through the more rapid verification of high prototypical true and false sentences as compared with the verification of low prototypical true and false sentences. They will also demonstrate context effects as predicted by the model through faster verification of high and low prototypical true sentences in the unrelated false (UF) condition than in the related false (RF) condition.

1b. If normal elderly subjects demonstrate preservation of response to contextual information in sentence verification, then these findings should extend to frequency of occurrence information. Thus, normal elderly subjects will perform as well as younger spouse controls in the recognition of words presented with varying frequency.

1c. The relative preservation of semantic memory in normal elderly subjects should result in the production of exemplars from semantic categories at a rate which is unchanged from that of younger spouse controls.

2a. If subjects with mild Alzheimer Type Dementia demonstrate disruption in the processing of contextual information, then they will be unable to consistently provide faster verification of high and low prototypical sentences within the UF condition as compared with the RF condition. Further, if mildly impaired Alzheimer subjects possess a partial disruption of semantic memory, then they will fail to consistently maintain appropriately rapid verification of high as opposed to low prototypical true sentences as predicted by the property comparison model.

2b. If the inability of mild Alzheimer subjects to adequately process contextual information in sentence verification is ubiquitous, then then it is expected that they will perform worse than both spouse controls and mormal aged in word frequency recognition.

2c. Disruption of semantic memory in mild Alzheimer subjects will also result in a deficiency in the production of semantic category exemplars relative to both spouse controls and to normal aged subjects.

3. If the use of an optimal dose of oral physostigmine improves memory functioning in mildly impaired Alzheimer subjects, then it is expected that these subjects will experience the reappearence of context effects and typicality effects as described by the property comparison model.

III. Method

A. Subjects

A group of normal elderly subjects was recruited from a longitudinal study of risk factors in the aged (Bronx Aging Study) currently underway at the Albert Einstein College of Medicine. All subjects were between 75 and 85 years of age and were enrolled only after passing an extensive battery of medical and neurological tests, including chest x-ray, CT scan, EEG, and blood tests. Normal cognitive status for entrance into the Bronx Aging Study was defined as a performance of 8 or less errors on the Fuld adaptation of the Blessed Mental Status Test (Fuld, 1978). For purposes of the study described here, only individuals with Blessed scores of less than 3 errors were asked to participate.

The subjects with Alzheimer Type Dementia were tested as part of their participation in an outpatient study of the effects of oral physostigmine on memory impairment and social functioning. All subjects received a diagnosis of Alzheimer Type Dementia based upon the research diagnostic criteria of Eisdorfer and Cohen (1980). Only individuals who were considered to have mild impairment were chosen for entry into the drug study. This decision was based on history, a score of less than 15 errors on the Blessed Mental Status Test commensurate with age, interviews with the subject and significant other, and the subject's ability to perform on a difficult 12 item, 12 trial test of recall using the procedure of selective reminding (Buschke and Fuld, 1974). Adequate performance on this test was not defined by a specific score; rather, the subject had to be able to place at least some words into long term storage and demonstrate consistent retrieval of these items.

The study sample consisted of 11 subjects in each of the three experimental groups. All subjects were right-handed volunteers with corrected vision of 20/40 or better. The control group was matched to the Alzheimer group for age, education, and socioeconomic status through the use of spouses in nine of the eleven cases. The remaining two Alzheimer subjects were matched to appropriate community volunteers.

B. Materials

1. Lexical Decision- Sixty-four test sentences were extracted from the original group of sentences constructed by McCloskey and Glucksberg (1979). This was done in a pilot study of the original test lists with a group of college-age subjects. The sentences chosen from the pilot study were those that had the lowest error rates and most stable reaction times. The sentences were selected so that they duplicated the design of the McCloskey and Glucksberg experiment as described below. However, the task was shortened in length in order to facilitate performance in elderly and cognitively impaired subjects by eliminating the need to focus attention for long periods of time. Thus the

sixty-four sentences were divided equally into 2 conditions; thirty-two sentences were given in the Related False (RF) condition, and thirty-two sentences were given in the Unrelated False (UF) condition. Each condition was comprised of the following types of sentences; in the RF condition there were 8 high-related true sentences (HT), 8 low-related true sentences (LT), 8 high related false sentences (HF), and 8 low related false sentences (LF). In the UF condition, there were 8 HT sentences, 8 LT sentences, and 16 unrelated false (UF) sentences. Both the RF and the UF conditions were identical except for the substitution of the 16 UF sentences for the 8 HF and 8 LF sentences (see appendices).

All test sentences were in the form of "All X are Y", where X is an exemplar and Y is a superordinate category in the case of HT and LT sentences, or X is a superordinate category and Y is an exemplar in HF and LF sentences. The test sentences, regardless of experimental condition differed only with respect to the semantic relationship between exemplar and category. HT sentences were characterized by a relationship of high typicality between the exemplar and the category. An example of this kind of sentence is "All Apples are Fruits". LT sentences utilized relatively low typicality exemplars of particular categories; an example is "All Figs are Fruits". HF contained an exemplar and a category having a high typicality relationship, but with the presentation of the exemplar and the category reversed, thereby resulting in a False Sentence. An example of this is "All Gems are Diamonds". LF sentences are identical in structure to HF sentences, but had instead a low typicality exemplar as the target word. An example of a LF sentence is "All Gems are Zircons". UF sentences have no semantic relationship between category and exemplar, as depicted in the example "All Shoes are Birds". All categories and exemplars were chosen by McCloskey and Glucksberg in the following manner from the Battig and Montague (1969) category production norms. High typicality exemplars were those instances most frequently produced as category members, while low typicality exemplars were instances which were given with low frequency in these production norms.

2. Category Retrieval- All subjects were given a category retrieval task in which they were asked to provide as many exemplars as possible from a variety of superordinate categories. Subjects received 8 categories which were taken from Howard's (1979) report of category retrieval norms for young and old adults. The 8 categories chosen were animals, birds, fish, flowers, fruit, furniture, insects, and vegetables.

3. Frequency Memory- Subjects were administered a task in which they were asked to recognize a series of single words which differed in the frequency of their

presentation. This task provides a prototypical demonstration of automatic processing (Hasher and Zacks, 1979), and was chosen so as to compliment the effortful processing required during sentence verification.

C. Procedure

1. Lexical Decision Task- All subjects were tested in a quiet and comfortable room devoid of visual or auditory distraction. Subjects were first seated in front of a television monitor which was connected to an Apple II computer. To the left of the monitor and directly in front of the subject was a box with a toggle switch that could be moved either up or down. Subjects were instructed to focus their attention on the monitor, where they were shown a fixation point followed by the presentation of a test sentence. The instructions were to decide as quickly as possible with as few errors as possible if the sentence on the monitor was true or false, and to indicate their response by moving the toggle switch up for true, or down for false. The words 'true' and 'false' were clearly printed above and below the toggle switch, respectively, in order to facilitate the decision process. Subjects were given 15 practice sentences in which to become comfortable with the apparatus. The practice sentences consisted of a random mix of each type of sentence that would be encountered during the test session. Immediate feedback was provided as to the correctness of the response to the

practice sentences. At the end of the practice, subjects were again reminded to respond as quickly as possible, but with a minimum of errors.

The presentation of the stimuli, as well as the recording of reaction times and of error rates was controlled by the Apple II computer. The rate of stimulus presentation was determined by the subjects' capabilities in that a new fixation point and stimulus appeared 3 seconds after the previous response. In the event of no response (failure to respond via toggle switch), the stimulus would automatically offset after 25 seconds of exposure, and a new stimulus would appear. All subjects received a one minute rest period after the first 32 test sentences. The test conditions were counterbalanced so that one-half of the subjects received the RF condition first (Appendix 1), while the other half were given the UF condition first (Appendix 2).

Alzheimer subjects underwent the same procedure as described above, but were evaluated twice with this task. Initial testing occurred at baseline, while the second testing took place after they had been titrated up to their best dose of physostigmine. This was defined as the maximum dose that did not result in side effects. Because this was a double blind study, one-half of the Alzheimer's patients received oral physostigmine, and one-half received placebo. Titration to maximum dose was normally accomplished within six weeks of the baseline evaluation by gradually administering successive doses of 1, 1.5, and 2 milligrams. Counterbalancing of the sentence conditions was achieved by giving either test list 1 or test list 2 at baseline, and then reversing the procedure during testing at maximum dose.

2. Category Retrieval- For this task, a subject was told that the examiner wanted to see how quickly he could think of some words. He was presented with a category name and was told to give as many items as he could that belonged to the category. Subjects were encouraged to respond for 60 seconds for each category presented. Responses were recorded by the examiner in the exact order provided by the subject. Timing of response productivity was kept for intervals of 20, 30, and 60 seconds.

3. Episodic Frequency Task- Subjects were seated in front of a screen where they viewed a series of words flashed at 5 second intervals. The presentation of the stimuli was regulated by a Kodak Carousel slide projector. Subjects were told that they were going to see a series of words, and that some of the words would be repeated. They were directed to study the words carefully since they were going to be asked about them after they have seen all of the stimuli. The subjects viewed a total of 80 slides, and were then presented with index cards, each of which contained two words. The subject had to indicate which of the two words

on the card occurred most frequently. Eighteen pairs of words were presented, with both the choice of words and the frequency of their presentation patterned after the study conducted by Grober, (1984). Thus 9 words appeared five times, 9 words appeared three times, and 9 words appeared once. The order of the words was presented in a random fashion and repetitions were separated by 3 to 5 items.

RESULTS

The results will be organized into four sections. Section I will describe the overall comparisons between the Alzheimer group, the control group, and the normal aged group. Section II will report results obtained by analysis of the groups on an individual basis. Section III will report findings resulting from a case by case analysis of the Alzheimer group. Section IV will report the results of a double-blind trial of oral physostigmine on the performance of the Alzheimer group. Table 1 presents a summary of the characteristics of the study sample, as well as T-tests which confirm the lack of significant differences between the groups with respect to education. A significant age difference was obtained between the normal aged group and the Alzheimer group ($T=5.80$, $p<.001$), and between the normal aged group and the spouse control group ($T=5.35$, $p<.001$).

Since much of the results are based on the analysis of reaction time data having considerable variability, certain procedures were adopted in order to provide as reliable a data base as possible. For all subjects, two kinds of reaction time scores were eliminated from the analysis; a) those responses that were incorrect and b) those responses that were greater than two standard deviations from the overall mean reaction time for each subject (Shoben, 1978). Thus, each subject was left with a specific number of valid

Table 1

Characteristics of the Subject Sample

	Alzheimer	Control	Aged
n	11	11	11
sex			
female	4	6	9
male	7	5	2
mean age (yrs.)	68.40 (±6.67)	66.72 (±8.54)	82.62 (±3.37)
mean education (years of schooling)	13.00	12.09	11.45

T - tests

	Alzheimer vs. Control		Alzheimer vs. Aged		Control vs. Aged	
	T	P	T	P	T	P
Age	.502	.61	5.80	.001	5.35	.001
Education	.429	.65	.889	.38	.496	.64

cases upon which subsequent analyses were based (Table 2).

I. Overall Between Group Comparisons

A. Sentence Verification

Mixed model ANOVAs were performed to test for the overall presence of typicality and context effects. This was accomplished by first, analyzing separately the typicality effect in each situation; and second, analyzing the RF and UF conditions together so as to evaluate the context effect. In the RF condition, an ANOVA utilizing the factors of group and sentence type (HT, LT, HF, LF) revealed a significant overall group effect for speed of verification; $F(2, 30) = 7.35$, $p = .003$. The Alzheimer group took significantly longer to respond ($x = 4325$ milliseconds, $sd = 1500$) than either the spouse control group ($x = 2607$, $sd = 1030$) or the normal control group ($x = 2757$, $sd = 898$; Table 3). There were no significant differences in the verification speed by sentence type ($F<1$), nor was there a significant group X sentence type interaction ($F = 1.66$, $P = .14$). True and false sentences within the RF condition were also analyzed with a two-way ANOVA performed on factors defined as truth value (true vs false sentences) and probability (high relatedness vs low relatedness). There were no significant differences between the groups in speed of verification on the dimension of true vs false sentences ($F<1$), or on amount of relatedness which is independent of

Table 2

Number of Valid Cases by Subject for All 3 Experimental Groups *

(maximum = 64)

Alzheimer				Spouse Control				Aged			
Subject	No. Correct Responses	No. Deleted	Valid Cases	Subject	No. Correct Responses	No. Deleted	Valid Cases	Subject	No. Correct Responses	No. Deleted	Valid Cases
AB	49	3	46	HG	64	3	61	BS	62	3	59
BR	45	3	42	EB	64	3	61	RD	60	2	58
CR	59	2	57	ER	60	3	57	ES	63	2	61
DB	54	3	54	JC	64	3	61	JG	53	3	50
LF	47	2	45	MR	60	2	57	SM	60	2	58
MC	61	3	58	NK	62	3	59	MP	63	4	59
PW	45	4	41	EF	61	1	60	EG	64	2	62
FH	63	3	60	CH	61	4	57	OF	62	2	60
JH	49	1	48	FP	52	4	48	DD	61	3	58
JP	52	5	47	NG	44	1	43	BF	60	3	57
HS	43	2	41	DH	61	3	58	MM	62	4	58

* Valid cases equals the number of usual responses after elimination of RT greater than 2SD above the mean RT per subject.

Table 3

Overall Mean Reaction Time

For Combined True and False Sentences by Condition

Condition	Alzheimer Group	Spouse Control Group	Aged Group
RF	4325 ± 1095	2607 ± 1030	2757 ± 868
UF	3939 ± 1613	2293 ± 934	2405 ± 718

truth value (F<1). There was no significant interaction between truth value and relatedness (F= 2.58, P= .11). Thus this analysis was unable to uncover an overall typicality effect in the RF condition.

In the UF condition, a significant group effect was again found for overall speed of verification; F(2,30)= 6.99, P= .004. Once again, the Alzheimer group was significantly slower (x= 3939, sd= 1613) than either the spouse controls (x= 2293, sd= 934) or the normal aged (x= 2405, sd= 718; Table 3). There was no overall effect of sentence type or typicality (F<1). nor was there a group X sentence type interaction (F= 1.37, P= .25). A repeated measures ANOVA which compared speed of verification of identical true sentences in the RF and UF condition revealed significant group effects for both speed; F(2, 30)= 7.52, P= .003, and context; F(1, 30)= 7.69, P= .01. The Alzheimer group was significantly slower in the verification of true sentences regardless of condition (x= 4181, sd= 1587) than either spouse controls (x= 2387, sd= 881) or normal aged (x= 2618, sd= 941). In addition, both HT and LT sentences were verified more rapidly in the UF condition than in the RF condition by all 3 experimental groups (Table 4). There was no significant interaction either for group X typicality (F= 1.96, P= .16), or for group by context (F= 1.23, P= .30).

Overall group effects were further investigated by a series of one way repeated measure ANOVAS in which each of

Table 4

Mean Reaction Time For Identical

True Sentences By Condition

RF Condition	Alzheimer Group	Spouse Control Group	Aged Group
HT	4600	2263	2724
LT	4467	2636	2938
UF Condition			
HT	3902	2122	2309
LT	3756	2526	2502

the 64 test sentences was studied across all three experimental groups. This analysis revealed that sentences purporting to represent the same sentence type differed in their ability to significantly discriminate between the groups. Those sentences that were found to discriminate between the groups at the .05 level were then subjected to post-hoc analysis using Duncans Multiple Range Test (Bruning and Kintz, 1968). For every case in which there was a significant post-hoc comparison, the differences were between the Alzheimer group and either the normal aged and/or the spouse control groups. In no case were differences observed between the spouse controls and the normal aged (Tables 5 and 6). Thus, the results of this analysis reveal that a) the Alzheimer group was significantly slower in the verification of the majority of sentences than either the spouse controls or the normal aged; and b) there were no differences between spouse controls and normal aged in the speed of verification of any of the 64 test sentences. A secondary finding of the ANOVA was the detection of an anomalous sentence within the verification task. The low related true sentence, "all wigwams are dwellings" provided an inordinate amount of difficulty for all three groups in both the RF and the UF conditions, resulting in a disproportionately high error rate and too few data points for each group (Tables 5 and 6). This sentence was removed from the subsequent individual

Table 5

Discrimination of Experimental Groups by Sentence

Related False (RF) Condition

		TYPE*	N	Post Hoc Comparisons: Control vs. Aged	Alz. vs Control	Alz. vs Aged
1.	All mosquitoes are insects	HT	30	N.S.	.05	.05
2.	All sleds are vehicles	LT	21	N.S.	N.S.	N.S.
3.	All weapons are cannons	HF	31	N.S.	.05	N.S.
4.	All carrots are vegetables	HT	31	N.S.	.05	.05
5.	All fish are shad	LF	32	N.S.	.05	.05
6.	All penguins are birds	LT	21	N.S.	N.S.	N.S.
7.	All torpedoes are weapons	HF	27	N.S.	N.S.	N.S.
8.	All fish are tuna	LF	29	N.S.	.05	.05
9.	All gems are zircons	LF	24	N.S.	.05	.05
10.	All screwdrivers are tools	HT	28	N.S.	.05	.05
11.	All elms are trees	HT	26	N.S.	.05	N.S.
12.	All birds are geese	LF	28	N.S.	.05	N.S.
13.	All tools are anvils	LF	27	N.S.	.05	.05
14.	All relatives are aunts	HF	28	N.S.	N.S.	N.S.
15.	All sons are relatives	LT	26	N.S.	N.S.	N.S.
16.	All flowers are carnations	HF	26	N.S.	.05	.05
17.	All peaches are fruits	HT	31	N.S.	.05	N.S.
18.	All weapons are rifles	HF	27	N.S.	N.S.	N.S.
19.	All begonias are flowers	LT	29	N.S.	N.S.	N.S.
20.	All fruits are figs	LF	28	N.S.	.05	.05
21.	All crimes are forgeries	LF	28	N.S.	.05	.05
22.	All vegetables are onions	LF	24	N.S.	.05	.05
23.	All wigwams are dwellings	**LT	12		LACK OF CASES	
24.	All haddock are fish	LT	30	N.S.	.05	N.S.
25.	All murders are crimes	HT	26	N.S.	.05	N.S.
26.	All trout are fish	HT	32	N.S.	N.S.	N.S.
27.	All gems are sapphires	HF	29	N.S.	.05	.05
28.	All turnips are vegetables	LT	29	N.S.	.05	N.S.
29.	All crimes are robberies	HF	23	N.S.	N.S.	N.S.
30.	All dwellings are mansions	HF	29	N.S.	N.S.	N.S.
31.	All blouses are clothes	HT	26	N.S.	.05	.05
32.	All dwellings are wigwams	LF	28	N.S.	N.S.	N.S.

* = HT - High Related True
LT - Low Related True
HF - High Related False
LF - Low Related False

** Removed from further group analysis

Table 6

Discrimination of Experimental Groups by Sentence

Unrelated False (UF) Condition

				Post Hoc Comparisons		
		TYPE*	N	Control vs. Aged	Alz. vs Control	Alz. vs Aged
33.	All gems are bananas	UF	29	N.S.	.05	.05
34.	All vegetables are prisons	UF	31	N.S.	.05	.05
35.	All haddock are fish	LT	29	N.S.	N.S.	N.S.
36.	All fruits are wigwams	UF	30	N.S.	.05	.05
37.	All insects are cannons	UF	32	N.S.	.05	.05
38.	All begonias are flowers	LT	29	N.S.	.05	.05
39.	All carrots are vegetables	HT	29	N.S.	.05	N.S.
40.	All trout are fish	HT	31	N.S.	N.S.	N.S.
41.	All murders are crimes	HT	23	N.S.	N.S.	N.S.
42.	All wigwams are dwellings	**LT	14		LACK OF CASES	
43.	All dwellings are hammers	UF	32	N.S.	.05	.05
44.	All sons are relatives	LT	29	N.S.	.05	.05
45.	All blouses are clothes	HT	29	N.S.	N.S.	N.S.
46.	All vehicles are sons	UF	32	N.S.	.05	.05
47.	All crimes are haddock	UF	28	N.S.	.05	.05
48.	All weapons are geese	UF	33	N.S.	.05	.05
49.	All flowers are murders	UF	31	N.S.	.05	.05
50.	All sleds are vehicles	LT	23	N.S.	N.S.	N.S.
51.	All flowers are murders	UF	31	N.S.	N.S.	N.S.
52.	All mosquitoes are insects	HT	32	N.S.	.05	.05
53.	All torpedoes are weapons	LT	29	N.S.	.05	.05
54.	All trees are shirts	UF	31	N.S.	.05	.05
55.	All penguins are birds	LT	26	N.S.	N.S.	N.S.
56.	All dwellings are daughters	UF	28	N.S.	N.S.	N.S.
57.	All birds are diamonds	UF	32	N.S.	.05	.05
58.	All turnips are vegetables	LT	28	N.S.	N.S.	N.S.
59.	All peaches are fruits	HT	33	N.S.	.05	.05
60.	All fish are trucks	UF	33	N.S.	.05	.05.
61.	All screwdrivers are tools	HT	31	N.S.	.05	.05
62.	All gems are uncles	UF	33	N.S.	N.S.	N.S.
63.	All elms are trees	HT	29	N.S.	.05	.05
64.	All fish are oaks	UF	31	N.S.	.05	N.S.

* = HT - High Related True
LT - Low Related True
UF - Unrelated False
LF - Low Related False

** Removed from further group analysis

group analysis, thereby leaving the low related true condition with seven sentences rather than the optimal eight sentences for each subject.

B. Category Retrieval and Word Frequency Recognition Tasks

All but one of the subjects received 60 seconds of retrieval from each of eight semantic categories. The single exclusion was a member of the spouse control group who refused further testing. Pairwise T-tests revealed that the Alzheimer group produced significantly fewer exemplars in category retrieval as compared to both spouse controls ($T=5.82$, $p<.001$) and to normal aged ($T=5.43$, $p<.001$). There was no significant differences in category retrieval between spouse controls and normal aged ($T=.38$, $p>.67$). In the word frequency recognition task, the Alzheimer group again performed significantly worse than either spouse controls ($T=4.21$, $p<.001$) or normal aged ($T=4.00$, $p<.001$). Again, there were no differences between spouse controls and normal aged in word frequency recognition ($T=.394$, $p=.66$).

In summary, the analysis of between group data on sentence verification yielded an overall effect solely with regard to context, and thus lends only partial support to hypothesis 1A regarding the preservation of semantic memory in the aged population. However, analysis of category retrieval and word frequency recognition data confirm both hypotheses 1B and 1C, that normal aged will perform as well as younger spouse controls on these tasks. The findings also confirm hypotheses 2B and 2C regarding the inability of mildly impaired Alzheimer subjects to perform as well as spouse controls or normal aged.

II. Overall Within Group Analysis

As a result of the powerful finding of no differences between spouse controls and normal aged in speed of verification on any of the 64 test sentences, the two groups were merged for the purposes of further analysis. Thus, the Alzheimer group and the spouse-aged group were each subjected to repeated measures ANOVA'S in order to more clearly investigate typicality effects and context effects in sentence verification.

In the merged spouse-aged group, an ANOVA analyzing typicality effects in the RF condition was done by utilizing the component factors of truth value (true versus false sentences) and probability (high related versus low related sentences). A highly significant truth value X relatedness interaction was obtained; $F(1,21) = 18.064$, $p<.001$. There was a tendency towards significance for sentence relatedness alone, $F(1,21) = 3.88$, $p=.066$, but not for truth value; $F(1,21)<1$. Thus, the presence of the interaction suggests that the typicality effect is influenced by the amount of category-exemplar relationship as well as the position of the category and the exemplar within the sentence (Figure 2). Analysis of sentence verification involving the same HT and LT sentences for the merged spouse-aged group in the RF and UF conditions was significant for context; $F(1,21) = 5.94$, $p=.024$, and highly significant for sentence type; $F(1,21) = 15.41$, $p=.001$. There was no context X sentence

Figure 1

Mean RT By Sentence Type In RF Condition

(After McCloskey and Glucksberg, 1979)

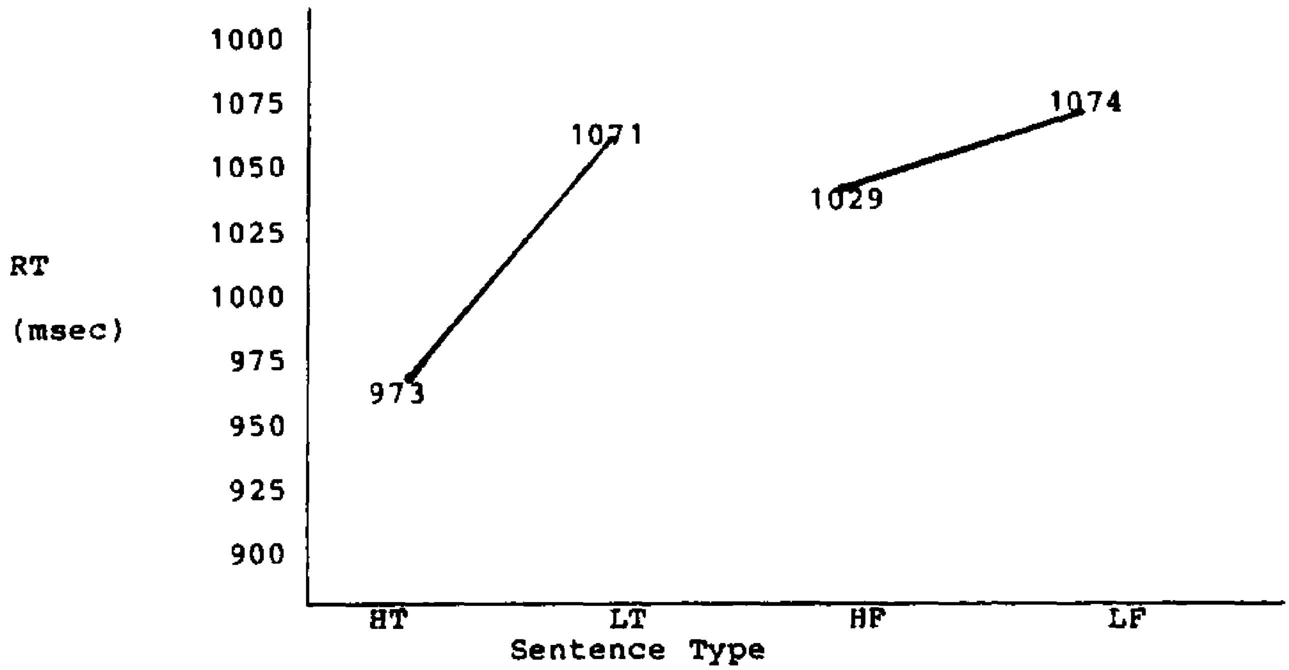
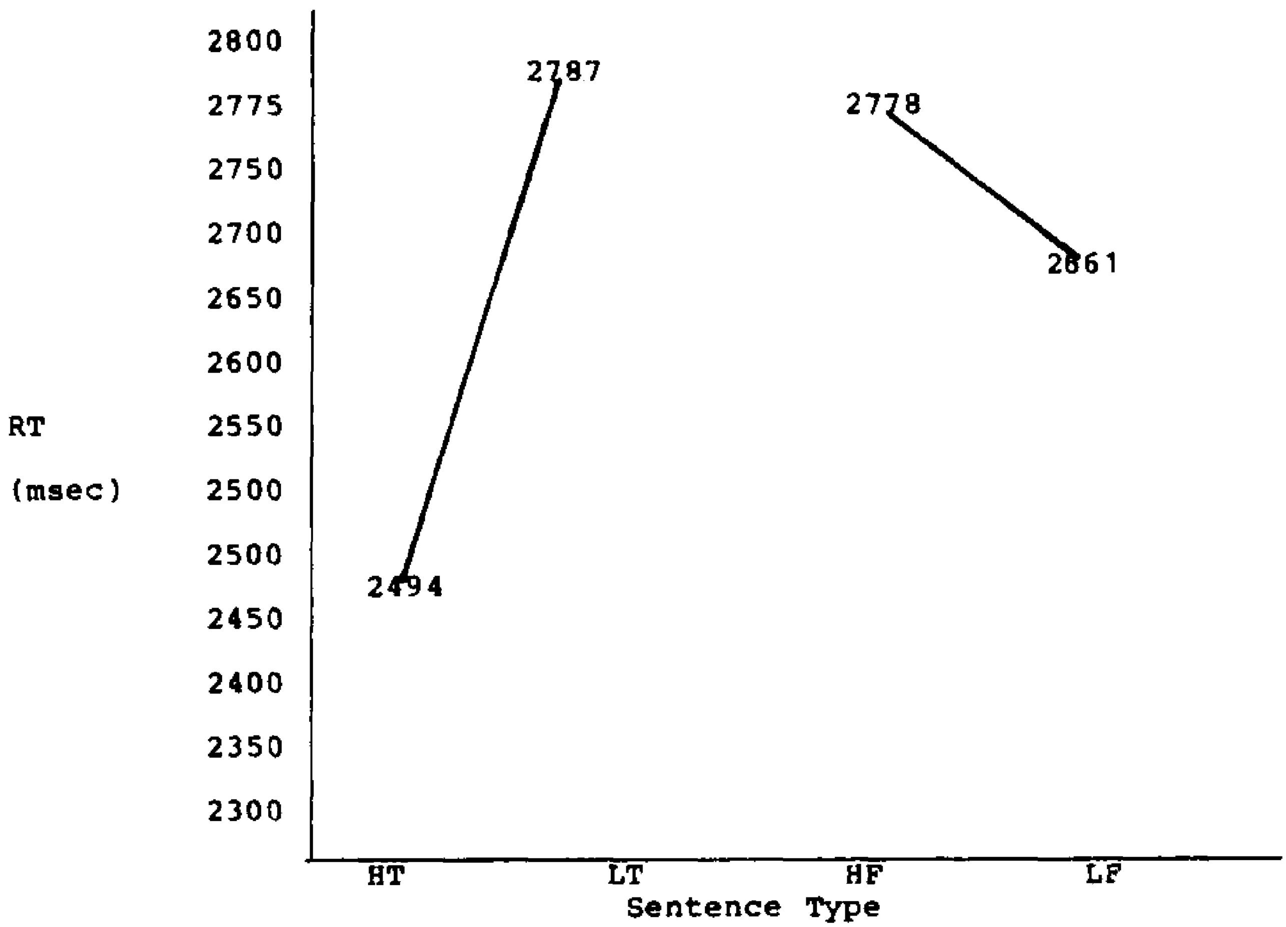


Figure 2

Mean RT By Sentence Type In RF Condition

For Merged Spouse - Aged Group



type interaction; $F(1,21)<1$. This finding demonstrates that the same true sentences have different speeds of verification depending upon the environment within which they are presented. In addition, a significant effect for sentence type in the UF condition demonstrates the ubiquity of the typicality effect regarding the more rapid verification of high related true sentences when compared with low related true sentences (Figure 4). The finding of significant typicality effects and context effects in the analysis of the merged spouse-aged group support the preservation of semantic memory, as described in hypothesis 1A of the experimental predictions.

Further analysis of semantic memory in the merged spouse aged group was made through comparison of semantic processing time. Inspection of Figure 3 depicts the relative time required for young normals to verify HT and LT sentences in the RF and UF conditions. Comparison of the RT values in this manner allows for the examination of that portion of the overall RT which contributes to the magnitude of the context and typicality effects. Thus, for the young subjects in the McCloskey and Glucksberg study (1979), the typicality effect (LT-HT) was 98 milliseconds in both the RF and UF conditions, and the context effect (HTRF-HTUF; LTRF-LTUF) was 101 milliseconds for HT and LT sentences. These values can be taken to represent the amount of processing time needed to make a decision about either

Figure 3

Mean RT For HT And LT Sentences By List Condition

(After McCloskey and Glucksberg, 1979)

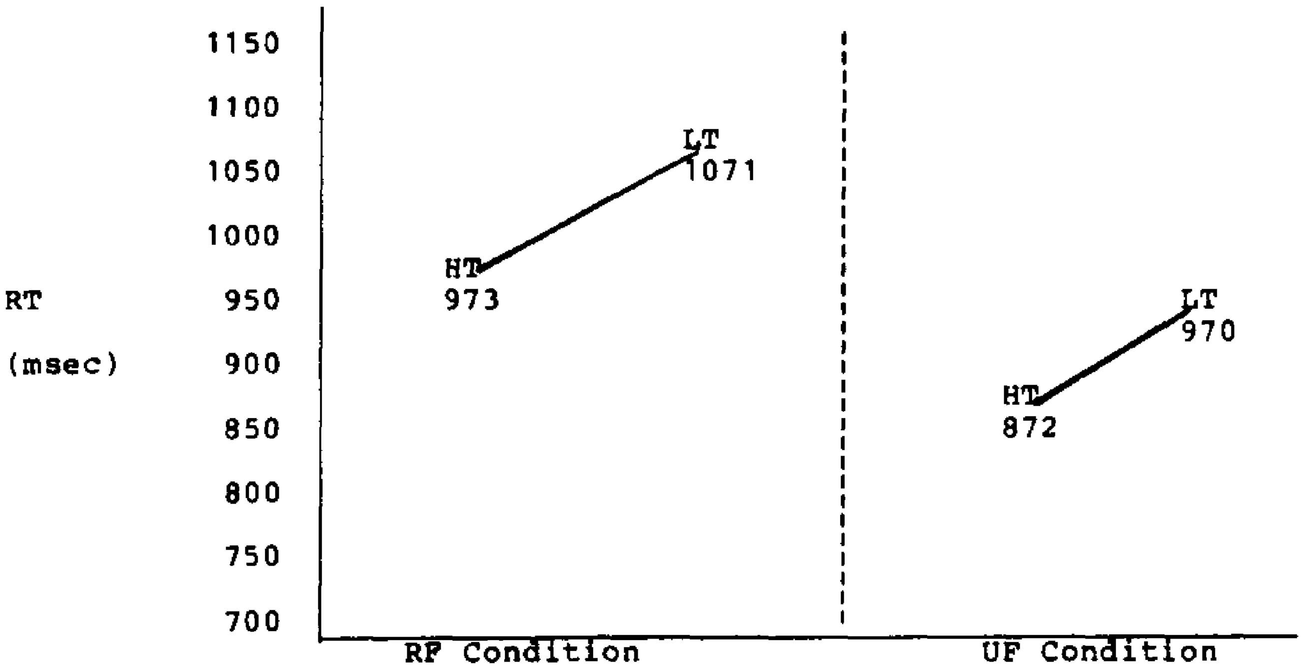
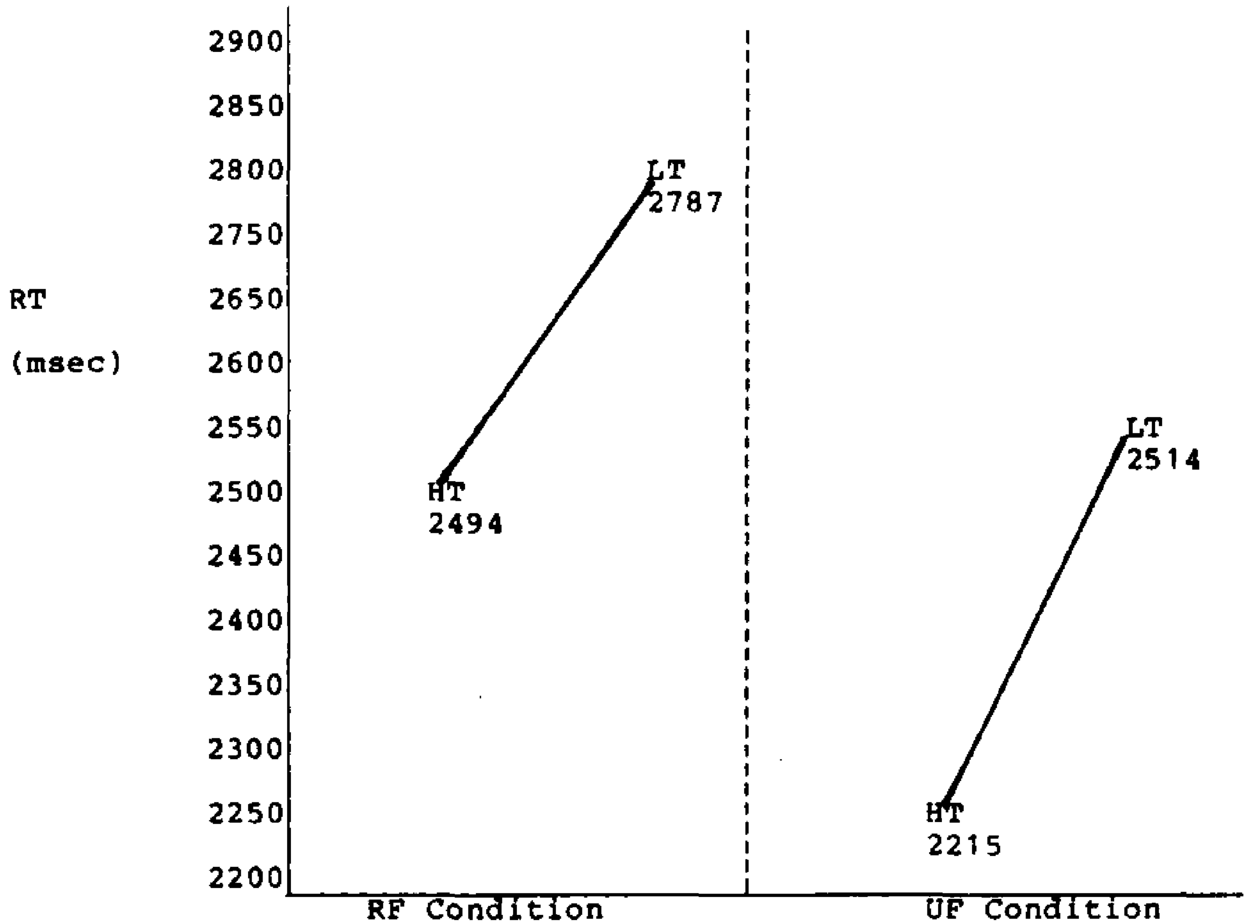


Figure 4

Mean RT For HT And LT Sentences By List Condition

For Merged Spouse - Aged Group



typicality or context. The performance of the merged spouse-aged group is illustrated in Figure 4. It can be seen that this group demonstrates the same pattern of verification of true sentences as the young normal subjects. Here, a typicality effect of 273 milliseconds was obtained in the RF condition, and a typicality effect of 299 milliseconds was observed in the UF condition. The context effect was 279 milliseconds for HT sentences, and 273 milliseconds for LT sentences. A direct comparison between the two groups showed that as expected, the overall RT's for the spouse-aged were considerably slower than those of the young students in the McCloskey and Glucksberg study. This finding supports the generally accepted view of behavioral slowing with increasing age (Birren, Woods, and Williams, 1980). Of greater interest is the fact that the absolute decision time for typicality and context effects is markedly longer in the spouse-aged group, a finding which may reflect less efficiency of semantic processing.

A somewhat different conclusion may be drawn when one looks at the decision stage as a percentage of the overall response time. Tables 8A and 8B describe the percent of total RT occupied by the decision stage for both context and typicality effects. Percent processing was derived by taking the mean of the sentences from which the magnitude of the particular effect was obtained and divide by the size of the effect. For example, in the student sample, the context

Table 7

Summary of Significant Test Sentences Which Discriminate Alzheimer's From Aged and Controls

RF Condition

Alzheimer's vs Aged	Alzheimer's vs Controls	Total for RF Condition
HT = 4	HT = 8	12
LT = 0	LT = 1	1
HF = 2	HF = 3	5
LF = 7	LF = 7	14
TOTAL 13	TOTAL 19	TOTAL 32

UF Condition

Alzheimer's vs Aged	Alzheimer's vs Controls	Total for UF Condition
HT = 4	HT = 4	8
LT = 3	LT = 4	7
UF = 12	UF = 13	25
TOTAL 19	TOTAL 21	TOTAL 40

Table 8A

Context and Typicality Effects As A Percentage Of Overall RT

Young normals (McCloskey and Glucksberg, 1979)

Effect	Type of Comparison	Magnitude	Mean RT	Percent
Context	HTRF-HTUF	101	922.5	10.9
Context	LTRF-LTUF	101	1020.5	9.8
Typicality	HTRF-LTRF	98	1022	9.6
Typicality	HTUF-LTUF	98	921	10.6

Table 8B

Merged Spouse-Aged Group

Effect	Type of Comparison	Magnitude	Mean RT	Percent
Context	HTRF-HTUF	279	2354.5	11.8
Context	LTRF-LTUF	273	2650.5	10.2
Typicality	HTRF-LTRF	273	2640.5	10.3
Typicality	HTUF-LTUF	299	2364.5	12.6

Table 8C

Alzheimer Group

Effect	Type of Comparison	Magnitude	Mean RT	Percent
Context	HTRF-HTUF	699	4251.5	16.4
Context	LTRF-LTUF	711	4111.5	17.3

effect for HT sentences was 101 milliseconds (HTRF - HTUF). The mean RT for these two groups of sentences was 922.5 milliseconds (HTRF + HTUF/2). Dividing the mean RT by the size of the context effect yields 10.9. This figure represents the percent of total response time taken up by the decision stage in determining the context effect for HT sentences. Identical calculations were made for all components of the context and typicality effects, with Table 8A listing the results for the student sample and Table 8B reporting the findings for the spouse-aged group. It can be seen that the range of percent processing of the decision stage for the student sample was between 9.6 and 10.9, while the spouse-aged sample varied between 10.2 and 12.6 percent. Thus, even though the aged group had decision times that were longer than those observed in McCloskey and Glucksbergs' young subjects, these decision latencies comprised approximately the same proportion of the overall RT as in the student sample. It appears then, that the semantic decision stage latencies for normal elderly are increased, but that this increase is in proportion to the overall elongation of response times in semantic verification for this population.

In the Alzheimer group an ANOVA which investigated for the presence of typicality effects in the RF condition was not significant, either for truth value; $F(1,10) = 1.08$, $p=.32$; or for sentence type ($F<1$). A repeated measures ANOVA for context effects was also not significant; $F(1,10) = 3.18$, $p=.10$. Thus, analysis of the Alzheimer group in this manner indicates the absence of both context effects and typicality effects in sentence verification, suggesting a marked disruption of semantic memory. Further evidence of semantic disruption in the Alzheimer group appears from examination of the decision stage during the generation of context effects. Figure 6 presents the verification pattern of HT and LT sentences in the RF and UF conditions. The decision stage for typicality effects cannot be adequately evaluated due to the faster verification of LT in comparison to HT sentences, a finding which will be discussed in greater detail. The decision time for context effects was 699 milliseconds for HT sentences, and 711 milliseconds for LT sentences. The decision stage in both cases was almost 3 times longer than the decision stage for context effects within the spouse -aged group. In addition, the HT decision stage occupied 16.4 percent of total processing time, while the LT decision stage was 17.3 percent of total processing time. Both figures are substantially longer than those obtained for the spouse -aged group, indicating that Alzheimer subjects were constrained to use a proportionately longer amount of response time in an attempt to make use of impoverished semantic information. These data, however, fail to support hypothesis 2A, which predicts partial preservation of semantic memory in the Alzheimer group

Figure 5

Mean RT By Sentence Type In RF Condition

(Alzheimer Group)

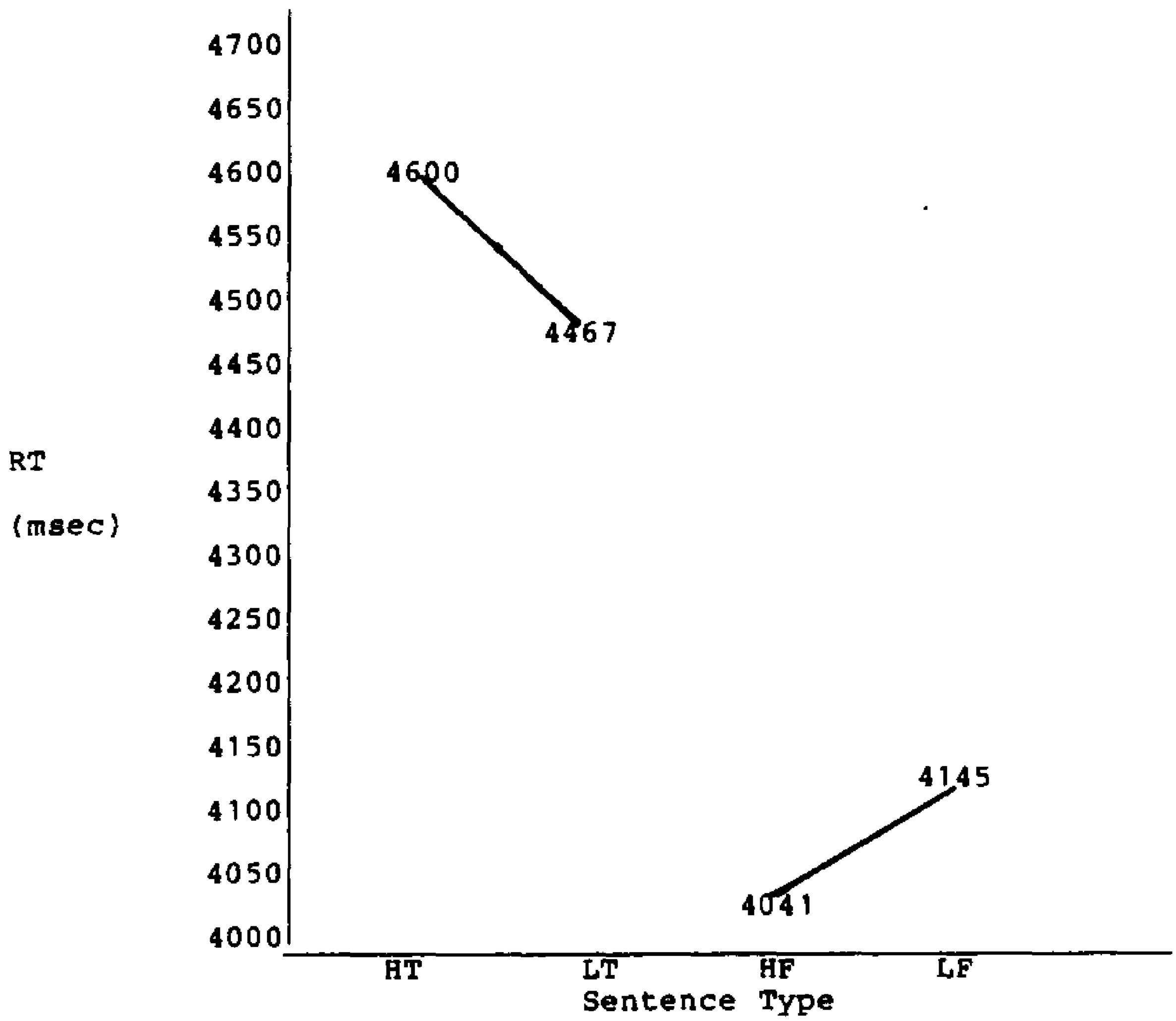
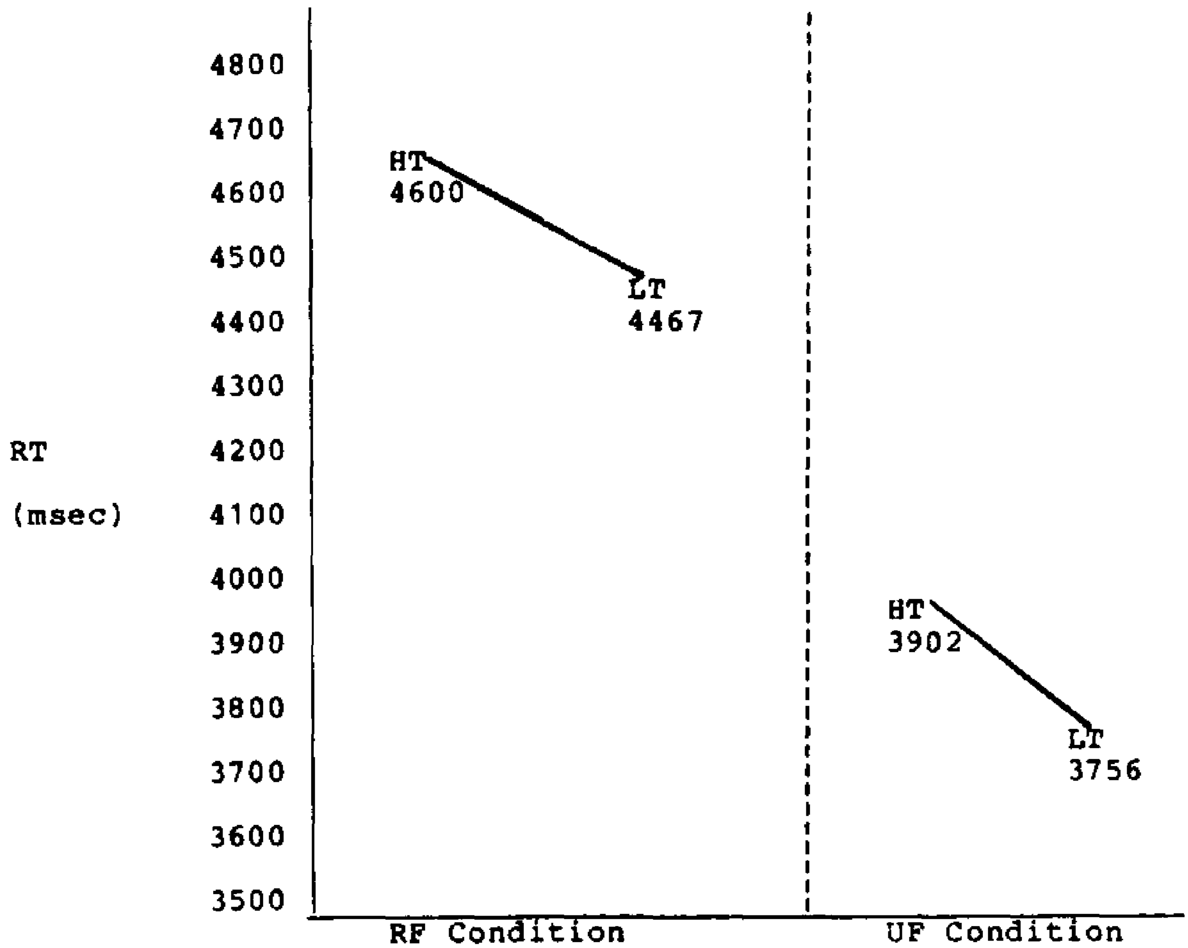


Figure 6

Mean RT For HT And LT Sentences By List Condition

(Alzheimer Group)



through the retention of some degree of typicality effect.

III. Case by Case Analysis of the Alzheimer Group

A rigorous effort was made to obtain as homogeneous a group of Alzheimer subjects as possible by including only those individuals who were thought to be early in the course of the disease. Despite this attempt, many of the subjects were substantially different in their performance on the test battery with respect to each other. While some of the subjects appeared to be fast in their response times and make relatively few errors, others were extremely slow and much more error prone. Similar variability of performance was noted for category retrieval as well as for word frequency recognition. These observations raised the possibility of describing distinct subgroups of subjects within the classification of mild impairment who possess varying degrees of preservation of semantic memory.

The Alzheimer subjects were individually evaluated for the amount of preservation of semantic memory in the following manner. A list was generated which contained, for each Alzheimer subject, the mean reaction times for each sentence type in both the RF and UF conditions. Operational criteria were established with regard to the presence or absence of typicality effects and context effects, and each subject was rated as to the existence of these two factors (SEMCON rank). For a subject to be rated as having complete preservation of typicality effects, the mean RT of the high related true (HT) sentences had to be less than the mean RT of the low related true (LT) sentences in both the RF and UF conditions. A subject was rated as having partial preservation of typicality effects if HT < LT was observed in one of the two conditions. If HT < LT was absent from both the RF and UF conditions, the subject was rated as being devoid of typicality effects. Context effects were rated as either present or absent in accordance with the following observations; HT (UF condition) < HT (RF condition) *and* LT (UF condition) < LT (RF condition). For context effects to be defined as present, the performance of the subject had to satisfy both portions of the above equation.

Table 9 displays the mean RT's for each subject by sentence type and condition, along with the amount of preservation of typicality effects as described by the above criteria. The results indicate that only two of the eleven Alzheimer subjects (subjects PW and JH) had a complete absence of both typicality effects and context effects. The remaining nine subjects demonstrate varying degrees of preservation as follows; complete retention of both effects (subjects BR and JT), retention of context effect and partial typicality effect (subjects AB and DB), retention of either complete typicality effect *or* context effect (subjects MC and FH), and retention of a partial typicality effect only (subjects CR, LF, and MG). From the perspective

Table 9

Mean RTs and Semantic Context Rankings by Subject in Alzheimer Group

	Related False				Unrelated False			SEMCON Rank*
Subject	HT	LT	HF	LF	HT	LT	UF	
AB	7828	7255	4968	4416	3620	4275	5786	2
BR	2526	2623	2588	2588	1913	2287	2801	1
CR	1897	1799	2041	2009	1594	2030	1887	4
DB	5164	6364	2929	3354	3503	2952	3813	2
LF	6658	5883	6432	6135	6238	7298	5995	4
MC	2740	3105	2665	3516	2742	3516	3125	3
PW	5931	4237	5590	5173	6559	2681	4688	5
FH	3129	2784	2545	3036	2633	2444	2314	3
JH	6993	5523	4399	5320	6069	5918	7521	5
JT	3701	4852	6056	5522	2560	3291	3148	1
MG	4041	4720	4761	4532	5494	4633	4672	4

* Rankings established as follows:

1 - complete typicality and context effect

2 - partial typicality effect and context effect

3 - complete typicality effect or context effect

4 - partial typicality effect only

5 - no effects

of this analysis, there appears to be a clear distribution of the amount of preservation of semantic memory within this sample of mildly impaired subjects having Alzheimer Type Dementia.

In order to quantify these findings, a simple numerical ranking system was employed in the following manner; a ranking of 1 was assigned to the subjects who demonstrated complete preservation of both typicality effects and context effects, a ranking of 2 was given to subjects who retained partial typicality effects along with the context effect, a ranking of 3 was given to subjects retaining either complete typicality effects <u>or</u> context effects, a ranking of 4 was obtained by subjects who demonstrated only a partial typicality effect, and a ranking of 5 was given to subjects who failed to retain either typicality effects or context effects.

The second step in the analysis of the Alzheimer subjects was to rank them in order of their scores on the major components of the test battery. Each subject was assigned a ranking beginning with 1 (best performance) down to and including 11 (worst performance) for each of the following variables; mean overall RT, number of valid cases in sentence verification, word frequency recognition score, and the total score for sixty seconds of retrieval from 8 categories (Table 10). As can be seen from Table 10, the overall mean rank reveals considerable discrepancies between

Table 10

Overall Rankings of Alzheimer Group

Subject	x rt	rank	Valid cases	rank	Word Fre-quency score	rank	60 second cat/retrieval	rank	x rank*
MC	3048	(4)	58	(2)	17	(2)	67	(1)	2.25
FH	2648	(3)	60	(1)	14	(5)	60	(2)	2.75
JT	3679	(5)	47	(6)	15	(3.5)	48	(5)	4.87
DB	3914	(6)	51	(4)	17	(7)	51	(3)	5.0
BR	2486	(2)	42	(9)	18	(1)	38	(8)	5.0
CR	1902	(1)	57	(3)	10	(9.5)	46	(7)	5.12
AB	5639	(9)	46	(7)	12	(7)	47	(6)	7.25
JH	6237	(10)	48	(5)	12	(7)	32	(9)	7.75
MG	4714	(7)	41	(10.5)	10	(9.5)	49	(4)	7.75
LF	6327	(11)	45	(8)	15	(3.5)	17	(10)	8.12
PW	5207	(8)	41	(10.5)	9	(11)	13	(11)	10.12
							Overall Mean Rank		5.24

*Subjects are listed in order of increasing level of impairment based on overall cognitive performance.

subjects in cognitive performance, suggesting the existence of subgroups within an ostensibly homogeneous group of subjects labeled as mildly impaired.

A comparison was made between the subject rankings derived from the overall test performance of the Alzheimer subjects, and those rankings which reflect degree of maintenance of typicality and context effects in the sentence verification task. A Spearman correlation performed between the two ranking systems was significant (Rho=.67, p=.02). This finding suggests that greater preservation of semantic memory as defined by the property comparison model is associated with those subjects who are the least impaired overall.

Further investigation of the Alzheimer group was accomplished with a multiple correlation matrix of the individual tests that comprised each subjects overall ranking. Thus, a matrix was obtained which contained the variables age, sex, education, mean RT, number of valid cases, word frequency recognition score, and category retrieval. Table 11 reveals significant positive correlations between the number of valid cases and the amount of category retrieval (Rho=.61, p=.02), and also between sex and category retrieval (Rho=.54, p=.04). A significant negative correlation was obtained between level of education and word frequency recognition score (Rho= -.60, p=.025). An additional series of Spearman

Table 11

Spearman Correlation Coefficients

AGE	-0.0598	AGE	0.0046	AGE	-0.3909	AGE	0.4146	AGE	0.0876
WITH	N(11)	WITH	N(11)	WITH	N(11)	WITH	N(11)	WITH	N(11)
SEX	SIG .431	EDUC	SIG .495	TIME	SIG .117	VALIDS	SIG .102	FREQUENT	SIG .399
SEX	-0.4242	SEX	-0.4781	SEX	0.0898	SEX	0.3939	SEX	0.5379
WITH	N(11)	WITH	N(11)	WITH	N(11)	WITH	N(11)	WITH	N(11)
EDUC	SIG .097	TIME	SIG .068	VALIDS	SIG .398	FREQUENT	SIG .115	CATEGORY	SIG .044
EDUC	0.3534	EDUC	-0.6028	EDUC	0.0369	TIME	-0.4419	TIME	-0.2212
WITH	N(11)	WITH	N(11)	WITH	N(11)	WITH	N(11)	WITH	N(11)
VALID	SIG .143	FREQUENT	SIG. 025	CATEGORY	SIG. 457	VALIDS	SIG .087	FREQUENT	SIG .257
VALIDS	0.2471	VALIDS	0.6150	FREQUENT	0.2581				
WITH	N(11)	WITH	N(11)	WITH	N(11)				
FREQUENT	SIG .232	CATEGORY	SIG .022	CATEGORY	SIG .222				
AGE	0.2727								
WITH	N(11)								
CATEGORY	SIG .209								
EDUC	-0.1751								
WITH	N(11)								
TIME	SIG .303								
TIME	-0.4545								
WITH	N(11)								
CATEGORY	SIG .080								

correlations was performed between the subject rankings for typicality and context effects (SEMCON) and the test variables enumerated in the previous correlation matrix. Table 12 summarizes these findings, with the major result a significant negative correlation between SEMCON and word frequency recognition score (Rho= -.63, p= .036).

IV. <u>The Effect of Oral Physostigmine on Semantic Memory in Alzheimer Type Dementia</u>

Best dose sentence verification data was collected on 10 of the 11 subjects that comprised the Alzheimer group, with the data of one subject lost due to computer malfunction. Seven of the ten subjects with viable data received oral Physostigmine, while the remaining three subjects received placebo. The assignment of subjects to either the drug or placebo condition was made in random fashion at the time of the subjects entrance into the study. However, current analysis of the baseline data revealed that the three subjects who were assigned to the placebo condition were among the poorest in terms of overall performance on the test battery, and thus were near the bottom of the group with regard to their overall ranking (subjects JH, MG, and LF; see Table 10). This discrepancy made it likely that the drug group and the placebo group were not equal at baseline in terms of the cognitive functioning of the participants, thereby precluding meaningful comparisons with regard to performance on

Table 12

Spearman Correlation Coefficients For SEMCON Rankings

SEMCON	-0.1872	SEMCON	-.2367	SEMCON	0.4297	SEMCON	-0.6304
WITH	N(11)	WITH	N(11)	WITH	N(11)	WITH	N(11)
AGE	SIG .58	SEX	SIG .488	TIME	SIG .185	FREQUENT	SIG .036
SEMCON	-0.4575	SEMCON	0.1948	SEMCON	-0.1492		
WITH	N(11)	WITH	N(11)	WITH	N(11)		
CATEGORY	SIG .54	EDUC	SIG .568	VALIDS	SIG .354		

sentence verification. The seven subjects who received drug and who had baseline sentence verification data were evaluated for changes in semantic memory by applying the SEMCON ranking system as described in the previous section. Prior to the assignment of ranks subject RT's were normalized in the same manner as those obtained during the baseline evaluation; i.e., only correct responses were used, and RT's greater than two standard deviations from each subjects mean overall RT were deleted. Each subject was then given a SEMCON rank based upon his performance on the sentence verification task during best dose. These ranks were then directly compared with the SEMCON ranks obtained by these same subjects during baseline evaluation (Table 13). If oral physostigmine affected semantic memory in a dramatic way, then it would be reasonable to expect that the SEMCON rankings at best dose would decrease, thereby reflecting the retention of typicality and context effects. A Wilcoxon signed ranks test was unable to detect significant differences between the two sets of ranks, ($z=.31$, $p=.68$). It is concluded that the current data failed to support hypothesis 3, that Alzheimer subjects who are tested on their optimal dose of oral Physostigmine will demonstrate improvement of semantic memory through the reappearance of typicality and context effects.

While the overall SEMCON rankings demonstrated little change, the examination of each sentence type provides a

Table 13

Baseline vs. Best Dose Comparison of

Typicality and Context Effects

Subject	Condition B=Baseline D=Drug	Related False HT	LT	HF	LF	Unrelated False HT	LT	UF	SEMCON Rank
MC	D	3054	3553	3352	3620	3208	4060	2884	3
	B	2740	3105	2665	3516	2742	3516	3125	3
FH	D	3037	3678	2440	2275	2866	3039	2199	1
	B	3129	2784	2545	3036	2633	2444	2314	3
JT	D	4801	4391	6753	5425	2940	4242	3380	2
	B	3701	4852	6056	5522	2560	3291	3148	1
BR	D	2064	1571	1698	2014	2056	2502	2314	4
	B	2526	2623	2588	2588	1913	2287	2801	1
DB	D	3329	2785	2664	2990	2708	2107	2156	3
	B	5164	6364	2929	3354	3503	2952	3813	2
AB	D	9035	7199	7622	7390	7288	4374	5067	3
	B	7828	7255	4968	4416	3620	4275	5786	2
PW	D	4384	4727	5822	3798	4549	4976	3721	3
	B	5931	4237	5590	5173	6559	2681	4683	5
Improvement by Sentence Type		3/7	4/7	3/7	5/7	2/7	1/7	6/7	

qualitative indication of the differential improvement of certain aspects of semantic processing. Further examination of Table 13 revealed that LF and UF sentences were associated with the greatest frequency of improvement. In the physostigmine condition 5 of 7 subjects improved in the verification speed of LF sentences, and 6 of 7 subjects similarly improved on UF sentences. Lesser rates of improvement were observed for the remaining sentence types.

One additional unexpected finding emerged from observations of the number of correct responses in sentence verification. All seven subjects receiving oral physostigmine improved in the absolute number of correct responses during evaluation on best dose. Although the magnitude of improvement was small, with increases ranging from 1 to 4 correct responses, a T-test for related samples was highly significant ($T=2.25$, $p=.005$). By comparison, two of the three subjects who received placebo got fewer correct when retested during best dose (Table 14). Comparison of the two groups with a Fisher Exact Probability Test indicated a strong tendency toward a significant difference in performance on this variable ($p=.066$). It is possible that the improved performance on the drug was due to excessive practice gained as the result of repeated administration of the verification paradigm; however, this is unlikely since a) the time between baseline and best dose was about 6 weeks, b) the sentence verification task was counterbalanced

Table 14

Number of Correct Responses Before and After

Administration of Physostigmine

Subject	Condition	Baseline Correct	Best Dose Correct	Differences
AB	Drug	49	51	+2
BR	Drug	45	48	+3
DB	Drug	54	58	+4
MC	Drug	61	62	+1
PW	Drug	45	49	+4
FH	Drug	63	64	+1
JT	Drug	52	53	+1
LF	Placebo	48	43	-5
JH	Placebo	53	49	-4
MG	Placebo	41	46	+5

with respect to condition, making it almost impossible for a subject to anticipate the type of sentence that would appear on the screen, and c) due to the progressive nature of the disease, one would logically expect either no change or a decline in judgment. It is more reasonable to argue that comparison of the drug group with the placebo group is not meaningful since the latter group was shown to be more impaired at baseline. Under these circumstances, the placebo group subjects might be declining at a more rapid rate and will therefore perform worse on retesting. Despite this, it can be concluded that oral Physostigmine may improve the judgment or decision making capabilities of mildly impaired Alzheimer individuals.

DISCUSSION

I. The Preservation of Semantic Memory in Normal Aging

The overall results of this study lend strong support to the position that normal elderly individuals suffer no decline in their ability to utilize semantic memory as measured by a sentence verification task. There was no difference in performance between a sample of normal elderly (mean age=81.6 yrs.) and significantly younger controls (mean age=66.7 yrs.) in overall speed of verification, semantic category retrieval, or word frequency recognition. As previously described in the results section, there were no significant differences in RT between the spouse controls and the normal aged on any of the test sentences. On the basis of studies examining the speed of behavioral response (Birren, Woods, and Williams, 1980; Cerella, 1985), one would expect that a decline in RT resulting from the use of higher functions extends into the 7th and 8th decades of life. Therefore, the normal aged group (mean age= 81.6 yrs.) should have been appreciably slower than the spouse control group (mean age= 66.7 yrs.). Two alternative explanations can be proposed before this data can be taken as an indication of the cessation of the slowing of higher order processes from 60 to 80 years of age. One explanation concerns the possibility that the individuals comprising the spouse control group were depressed because of the burden of having to care for an Alzheimer patient. This could have resulted in poorer performance than would normally be expected for this age group. Secondly, the subjects in the normal aged group may indeed have been "supernormal" since they were selected from a large population of normal aged on the basis of superior scores on mental status testing. Thus, these subjects might have produced a better performance than is thought to be representative of this cohort.

The observation that both normal elderly and younger controls verify high related true (HT) sentences more rapidly than low related true (LT) sentences replicated a finding that is ubiquitous in major models of semantic memory (Smith, Shoben, and Rips, 1974; Glass and Holyoak, 1975; McCloskey and Glucksberg, 1979). The demonstration of more rapid verification of both of these sentence types when they are embedded in an unrelated false contextual environment supports the probabilistic decision process described by the property comparison model of semantic memory (McCloskey and Glucksberg, 1979). It is important to note that these subtle differences in reaction time can be reliably produced in normal subjects that come from a cohort vastly older (and different) than the population of college undergraduates normally used to develop models of cognitive processes. Thus, the findings which give rise to the property comparison model extend comfortably into the world of normal aging, thereby allowing for the use of this model as a framework with which to explore preservation and change of semantic structure in this population.

The integrity of the semantic structure in the elderly can be further described by the pattern of reaction times that emerges during verification of true and false sentences. The data obtained from college students (McCloskey and Glucksberg, 1979) revealed a pattern of verification such that HT sentences were verified most rapidly, high related false sentences (HF) were disconfirmed second fastest, and LT and low related false sentences (LF) had the longest latencies to verification and disconfirmation, respectively (Figure 1). Inspection of the graph in Figure 1 depicts an interactive relationship in that both the prototypicality of the category-exemplar relationship and the truth value of the sentence contribute to the observed RT. The results from the spouse -aged group similarly demonstrated a strong interaction effect between prototypicality and truth value, but the speed of verification of the two kinds of false sentences was reversed (Figure 2). In the present study, LF sentences were verified more rapidly than HF sentences, a finding which is consonant with the predictions of the property comparison model but which was not clearly observed in the original results. Figures 3 and 4 represent in graphic form the influence of context upon the verification of HT and LT sentences in college students and in the spouse- aged group. The graphs reveal that the pattern of response is virtually identical in both groups, clearly highlighting the presence of contextual differences in RT. The merged spouse-aged group demonstrates the more rapid verification of sentences that are: a) highly prototypical in category-exemplar relationship; b) in the context of semantically unrelated false sentences; and c) are LF as opposed to HF. Determinate processing models of network origin (Glass and Holyoak, 1975; Collins and Loftus, 1975) would predict no context dependent difference in the verification time of true sentences, since in this model all the information necessary for verification is always prestored and available via the access of particular nodes. The network model would also predict more rapid discomformation of HF as compared with LF sentences, due to the shorter pathway (hence quicker access) between the category and a high frequency exemplar node. The current data contradicts these predictions and therefore provides clear evidence for a semantic structure in normal aging that is intact by virtue of its emulation of a model based on the probabilistic comparison of semantic features.

Much of the rationale for concluding that normal elderly individuals possess unimpaired semantic memory derives from studies of semantic priming. The results of this work generally support the existence of a strong semantic priming effect, leading to the implication that the elderly have experienced no decline in the ability to gain access to lexical information. Thus, they have maintained preservation of an important component of semantic memory (Howard, 1983; Cerella and Fozard, 1984; Bowels and Poon, 1985). It is interesting that the most frequent explanation for the basis of priming derives from network models of semantic memory. Meyer and Schvaneveldt (1976) hypothesized that the facilitative effects of semantic priming are the result of the spread of excitation to a nodal word detector from the detector of a related word occupying a nearby node in the network. With this view, semantic priming experiments have demonstrated the preservation of lexical access to pre-stored information, since the basis of the network approach lies in the assumption of the existence of discrete categories and exemplars which occupy space along a nodal pathway (Smith, 1978). In addition, Simpson (1984) pointed out that priming tasks are relatively pure tasks of lexical access and are not generally affected by post-lexical or decision processes. Furthermore, even though both network and feature models assume that information must be retrieved prior to the decision stage, feature comparison models emphasize the decision stage as the primary source of differences in verification time, while network models pinpoint retrieval as the key factor in verification (Hampton, 1984). It would appear then, that exploration of differences in semantic verification provides a sound basis for the examination of changes in the decision stage of semantic processing in the elderly.

While priming studies have generally concluded that there are no age-related differences in speed of access to the semantic structure (Cerella and Fozard, 1984), the present semantic verification study demonstrates that the decision stage within semantic memory is slowed in the normal elderly. This suggests that in absolute terms the efficiency of semantic memory in the elderly may be reduced in that it took longer to retrieve the semantic properties necessary to make the exemplar-category decision. However, this change in decision time does not imply marked change or breakdown in semantic decision strategy. If such was the case, then one might expect a disproportionate increase in the amount of total response time usurped by the decision stage in an effort to make property comparisons with faulty bits of semantic information. This was not observed, since the relative percent processing was about the same in both the students and the elderly. The integrity of the semantic structure in the elderly is further solidified by the finding that they produced patterns of sentence verification which closely match the patterns predicted by featural semantic models. If the long decision stage found in the elderly was the consequence of semantic breakdown, then the result would be the disruption of these verification patterns. For example, a marked increase in the decision time of HT or LT sentences in the UF condition would serve to eliminate the context effect for that sentence type, thereby negating one of the more robust predictions emanating from this semantic model. However, this was not the case, and thus the semantic verification data provides strong support for the integrity of semantic memory in the aged, despite changes in processing time.

II. Semantic Memory in Alzheimer Type Dementia

The significance of the property comparison model with regard to the evaluation of semantic memory has been shown for the normal aged population. Until now, disruption of semantic memory in Alzheimer Type Dementia has been documented primarily through observations of deficits in verbal fluency (Rosen, 1980; Martin and Fedio, 1983) and naming ability (Bayles and Tomoeda, 1983; Martin and Fedio, 1983; Kirschner, Webb, and Kelly, 1984). These studies suggested that impaired semantic memory in this population could be the result of the loss or ineffective use of semantic features. If this is true, than a featural or property approach to the investigation of semantic structure is most helpful in attempting to explain such a loss, since the theoretical basis for these models is the comparison of specific properties involved in exemplar-category relationships (Zingeser and Grafman, in press).

Examination of the reaction times obtained by the

Alzheimer group in sentence verification (Figure 5) revealed marked slowing of response relative to the spouse-aged group, regardless of the type of sentence. These results confirm findings reported by Pirozzolo, Christensen, Ogle, Hansch, and Thompson (1981) of significantly slower response by Alzheimer subjects as compared with matched aged controls on a choice RT task. More importantly, the Alzheimer group had a pattern of RT's that deviated markedly from the pattern demonstrated by the merged spouse- aged group. Two striking differences emerged; 1) false sentences, regardless of whether they were high related or low related in content were disconfirmed far more rapidly than high or low related true sentences; and 2) HT sentences, which in normal populations have been consistently shown to have the fastest verification times of any sentence type, produced the slowest response times in the Alzheimer group. More significantly, HT sentences took longer to verify than LT sentences, a finding also not observed in any previous study of normals and contradictory to the assumptions regarding the effect of prototypicality on exemplar- category relationships. It should be pointed out that the failure to obtain the expected typicality effect between HT and LT sentences was not due to the context in which the sentences were verified, since the identical result was obtained in both the RF and UF conditions (Figure 6).

The inability of Alzheimer subjects to provide faster verification for HT as opposed to LT sentences may be explained in the following ways. The first explanation is consistent with an argument recently advanced by Grober, Buschke, Kawas, and Fuld (in press) that the differential weighting of features deemed critical to the understanding of a concept and its relationships has somehow been altered or reduced. If this were the case, then the salient properties that contribute to an exemplars' high prototypical status within a category may become no more important than any other category property. This would have the effect of eliminating the production of faster RT's for HT sentences. Grober, et al suggested that the reduction in weight of certain important features changes the organization of semantic information, thereby making the semantic structure more inefficient. However, the theoretical assumptions of the property comparison model upon which the current study is based reject the distinction between characteristic and defining features, a distinction which presumes that some features are more important than others in effecting rapid exemplar - category verification (Smith, Shoben, and Rips, 1974; Smith, 1978). Instead, all properties of a concept are characteristic of that concept, and fast RT's are obtained through the rapid accumulation of positive (or negative) evidence when the properties of the exemplar are systematically compared to the properties of the category (McCloskey and Glucksberg, 1979). When enough positive (or negative) matches are made to exceed criterion, then the sentence is either verified (or disconfirmed). Thus, if the weighting of semantic features is only probabilistically related to concept membership (Smith and Medin, 1981), then the inability of Alzheimer subjects to produce more rapid verification of HT sentences may be due to a shift in the criterion for the number of true comparisons necessary for a fast response. If the meaning of certain semantic information were lost, then an individual would have to continue to make comparisons between exemplar and category properties, thereby increasing the response time for verification.

An independent explanation for the anomalous RT pattern of HT and LT sentences is that the Alzheimer subjects were responding too quickly to LT sentences because of a speed/accuracy tradeoff. Table 15 describes the error rates by the subjects in the two experimental groups for each type of sentence. In the Alzheimer group, the error rate for the LT sentences were much higher than that for the HT sentences. This discrepancy occurred in both the RF and the UF conditions, and suggests that these subjects might have been less careful when required to process LT sentences. In the case of the spouse-aged group, the LT sentences were also responsible for producing the highest error rates, but the observed RT's were longer than for the HT sentences, as expected. This indicates that even though some of the LT

Table 15

Percent of Error By Sentence Type

Alzheimer Group			Spouse-Aged Group		
Sentence	Condition	Percent Error	Sentence	Condition	Percent Error
HT	RF	15.9	HT	RF	8.5
LT	RF	25.9	LT	RF	10.4
HF	RF	26.1	HF	RF	3.9
LF	RF	23.8	LF	RF	5.1
HT	UF	14.7	HT	UF	2.8
LT	UF	25.9	LT	UF	8.4
UF	UF	9.0	UF	UF	1.7

sentences proved troublesome for the normal group, the majority of these sentences were verified through appropriate mechanisms of property comparison. The longer RT's for the LT sentences would be justified by the need to effect more comparisons in order to gain the amount of positive evidence necessary for the exemplar- category match. In the Alzheimer group, the high error rate coupled with the abnormally rapid processing time of LT sentences points to the loss or disruption of multiple types of exemplar property information. On some LT sentences, impaired subjects were unable to generate enough positive information about the exemplar to reach the criterion for verification; on others, positive comparisons were made so efficiently that criterion for verification was attained in unexpectedly rapid fashion. This observation, in conjunction with the previous explanation regarding the slow verification of HT sentences strongly implies that the disruption of semantic information is erratic and may involve properties which describe exemplars at any level of category. If this is true, then the breakdown of semantic information in early Alzheimer's disease does not follow the same pattern as that observed in the developmental acquisition of category exemplars. Mervis and Rosch (1981) reported that category membership appears first for the most representative exemplars, while membership of low prototypicality exemplars occurs at a later stage of development. If this heirarchy were to reverse itself during disease as is sometimes the case (the more rapid loss of the most recently acquired language, for example), then early Alzheimer's subjects should have experienced the loss of low prototypicality items first. This was not the case, since both HT and LT sentences displayed evidence of semantic disruption.

High error rates were also characteristic of the related false sentences in the Alzheimer group. The relatively rapid disconfirmation of HF and LF test items in the context of numerous errors suggests inconsistencies in the comprehension of these difficult sentences. Specifically, these subjects failed to process the reversal of the position of the category and exemplar, a necessary requirement for appropriate disconfirmation. Inability to deal with the exemplar-category reversal may result in the development of a rapid perseverative mode of "yes" responding. By contrast, the spouse -aged group had relatively modest error rates for the related false sentences, as well as a pattern of disconfirmation predicted by featural models. Thus, the Alzheimer group seemed incapable of perceiving the exemplar -category reversal, and then engaging in appropriate semantic processing.

The above results, as well as those which revealed abnormalities in semantic processing time, are in conflict with the finding of Nebes, Martin, and Horn (1984) that there is no basic defect in the organization of semantic memory in Alzheimer Type Dementia. Their conclusion was predicated on the discovery of a semantic priming effect in Alzheimer subjects that was relatively unchanged from that of a group of matched controls. This led to speculation that the semantic system in dementia was at least grossly intact by virtue of normal access to lexical information. However, the current study demonstrates that semantic information is disrupted at every level of the system, so that even purportedly normal entry into the semantic network still results in a disproportionately long and unsuccessful semantic decision stage.

One additional point concerns the interpretation of the above results within the context of automatic versus effortful processing. Hasher and Zacks (1979, 1984) have advanced the notion that certain fundamental operations within memory occur in automatic fashion and are not dependent upon concious effort or intention to process information. These automatic processes are thought to be basic in nature and are not affected by age, practice, or other attentional and processing demands. Processes such as frequency of word occurrence (Kausler and Puckett, 1980; Attig and Hasher, 1981), frequency of spatial-temporal location (Hasher and Zacks, 1984), and priming (Posner and Snyder, 1975; Nebes, Martin, and Horn, 1984) are thought to operate automatically and as such are generally resistant to distruption.

Nebes, Martin, and Horn (1984) suggested that their findings of general preservation of semantic memory in dementia stem from the continued ability of Alzheimer individuals to engage in the automatic processing of semantic information, a mechanism which is responsible for semantic priming. This implies that automatic processes must be intact in these subjects. However, the present study revealed that many of the subjects in the Alzheimer group performed very poorly on the frequency of occurrence recognition task which was administered as part of the cognitive battery. As previously mentioned, the ability to encode frequency information is generic to the mechanism of automatic processing, and as such should likewise have been preserved. In Table 16, it can be seen that the performance of the Alzheimer group on word frequency recognition ranges from a low of 9 of 18 correct to a perfect score of 18 of 18 correct (mean = 13.09, S.D.= 2.94). By comparison, the scores for the spouse control group ranged from 15 to 18 (mean = 17.20, S.D.=.979), and from 14 to 18 for the normal aged group (mean = 17.00, S.D.=1.34). It appears from this data that automatic processing is disrupted to varying degrees in the Alzheimer group. This observation fails to corroborate the contention of Nebes, et al that the general preservation of semantic memory in Alzheimer Type Dementia can be verified through tasks that primarily utilize

Table 16

Word Frequency Recognition Scores

For Each Experimental Group

Alzheimer Group		Spouse Control Group		Aged Group	
Subject	Score	Subject	Score	Subject	Score
BR	18	NK	18	DD	18
MC	17	JC	18	BS	18
JT	15	DH	18	EG	18
LF	15	HG	18	MP	18
FH	14	EB	17	MM	18
AB	12	MR	17	RD	17
DB	12	NG	17	OF	17
JH	12	FT	17	JG	17
MG	10	EF	17	BF	17
LR	10	ER	17	SM	15
PW	9	EH	15	ES	14

automatic processes, since they do not readily deteriorate. The present study has shown that, even in subjects who are early in the course of the disease, automatic as well as effortful (semantic verification) processing can be disrupted, resulting in the marked disorganization and probable loss of information from all levels of semantic memory.

The performance of the Alzheimer group on the word frequency recognition task exemplified the marked variability observed in a group of carefully chosen mildly impaired subjects. Looking again at Table 16, it is evident that the scores on word frequency recognition distribute themselves in a substantially skewed fashion. One-half of the impaired group scored in the range that approximated a normal performance (14 to 18 correct), while the remaining subjects performed very poorly on this task (13 or less correct). This unexpected distribution of scores made it reasonable to assume that some of the Alzheimer subjects were considerably less impaired overall and thus might have more intact semantic memory than that seen in the evaluation of the group as a whole.

Documentation regarding the heterogeneity of cognitive performance in Alzheimer Type Dementia has been difficult to obtain, although occassional individuals who histopathologically turn out to have the disease present initially with atypical features (Crystal, Horoupian, Katzman, and Jotkowitz, 1982). Variations in type and severity of clinical presentation may indeed be related to the age of the individual at onset, despite the relative abandonment of nomenclature which distinguished between presenile and senile forms of the disease (Terry and Davies, 1980). Loring and Largen (1985) found significantly worse performance on tests of intelligence, speed, concentration and perception in subjects with earlier (before 65) as opposed to later (after 65) onset. These differences were significant despite controlling for the duration of the disease and level of education. Mayeux, Stern, and Spanton (1985) retrospectively studied the cases of 121 patients who met diagnostic criteria for Alzheimer Type Dementia and found that distinct subgroups could be formed, based upon the presence of specific clinical symptoms. Specifically, patients who had evidence of extrapyramidal symptoms deteriorated more rapidly in both cognition and function than patients described as typical in presentation. Similarly, the authors discovered a "benign" group who in the course of a 4 year follow-up demonstrated only minimal decline in cognitive ability. It appears then, that Alzheimer Type Dementia may be a disease that consists of subgroups, one of which is the typical clinical presentation, and that the severity and course of the disease is influenced by chronological and neurological factors.

The data from the present study provides support for the notion of heterogeneity in Alzheimer Type Dementia, as differences in performance on rather subtle measures of cognition were noted in subjects with ostensibly equivalent mental status. The ranking system shown in Table 10 summarizes the relative level of performance for each Alzheimer subject. While there was no clear delineation of subgroups, there were subjects whose overall performance was far better than others in the group (subjects MC and FH compared with LF and PW). In a recent review of the literature concerning dementia and semantic memory, Zingeser and Grafman (in press) cited ambiguity in subject selection as a major methodological problem. However, even with rigorous diagnostic criteria, cursory screening of mental status is not enough to insure homogeneous cognitive performance, even when the sample is limited to those with mild impairment. Despite these stated difficulties, the comparison of the SEMCON ranks for the maintainence of context and typicality effects (Table 9) with the rankings of overall performance for each Alzheimer subject (Table 10) produced a moderate but significant correlation (Rho =.67, p=.02). This suggests that greater preservation of semantic memory is associated with subjects having the least overall impairment. It is interesting to note that two of the Alzheimer subjects had complete preservation of context and typicality effects (subjects BR and JT), thus resembling the performance of the spouse -aged group. Of additional importance was the finding of a significant negative correlation between SEMCON rank and score on word frequency recognition (Rho = -.63, p=.036). This implies that preservation of automatic processing does play an important role in contributing to the integrity of the semantic system. To illustrate this point, subjects BR and JT, who appeared to have preserved semantic memory, also performed within normal limits on word frequency recognition with scores of 18 and 15, respectively.

Disruption of semantic memory, while quite evident in most of the Alzheimer group was found to be strikingly preserved in two subjects. In order to investigate this phenomenon, graphic illustration of patterns of semantic disruption were obtained by dividing the Alzheimer subjects into two groups based upon their overall cognitive rank as shown in Table 10. The grand mean of the ranks was calculated and the six subjects who had ranks below the grand mean were compared with the five subjects who had ranks above the grand mean rank. Thus, the Alzheimer subject group was partitioned so as to allow for a comparison of semantic disruption between those individuals that were observed to have less cognitive impairment as opposed to those that had more substantial deficits.

Figures 7 and 8 revealed the patterns of sentence verification in the RF condition for the groups having the least and the greatest cognitive impairment, respectively. A comparison of the graphs demonstrated striking differences in these patterns which allowed for the observation of the mechanisms which eventually lead to complete semantic breakdown. The verification pattern of the Alzheimer group with relatively minimal impairment (Figure 7) was similar to the patterns produced by young normals (Figure 1) and the spouse-aged group (Figure 2), specifically with respect to the preservation of the typicality effect. This effect was illustrated through the more rapid verification of HT as opposed to LT sentences. Thus, Alzheimer subjects with the least overall cognitive impairment appeared to strongly retain a property that is essential to the preservation of semantic memory. The maintenence of the typicality effect in this group was also found in the UF condition, thereby corroborating the consistency of the finding (Figure 9). Nevertheless, further inspection of the verification patterns in the minimally impaired Alzheimer group revealed that the deterioration of the semantic system had begun, as evidenced by a change in the verification of HF and LF sentences. In Figure 7, the speed of verification of HF sentences has fallen slightly below that of HT sentences, whereas both of the young normals and the spouse-aged groups demonstrated verification of HT sentences that is consistenly more rapid than HF sentences. This observation suggests that the failure to maintain the above pattern of

Figure 7

Mean RT By Sentence Type in RF Condition

For Alzheimer Subjects Having The Least Cognitive Impairment

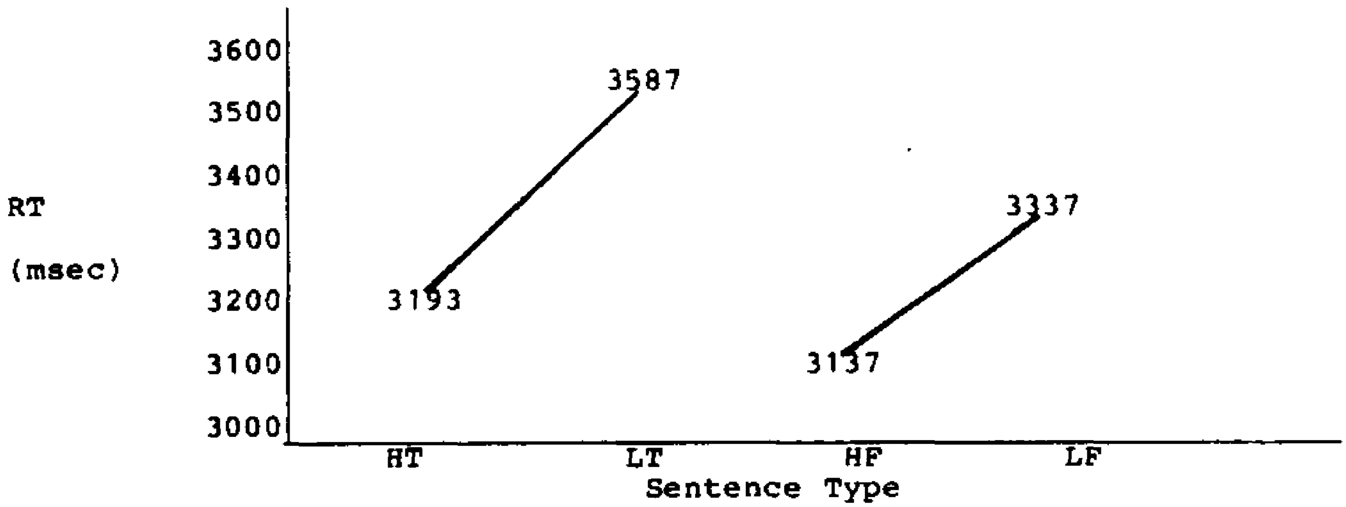


Figure 8

Mean RT By Sentence Type in RF Condition

For Alzheimer Subjects Having The Greatest Cognitive Impairment

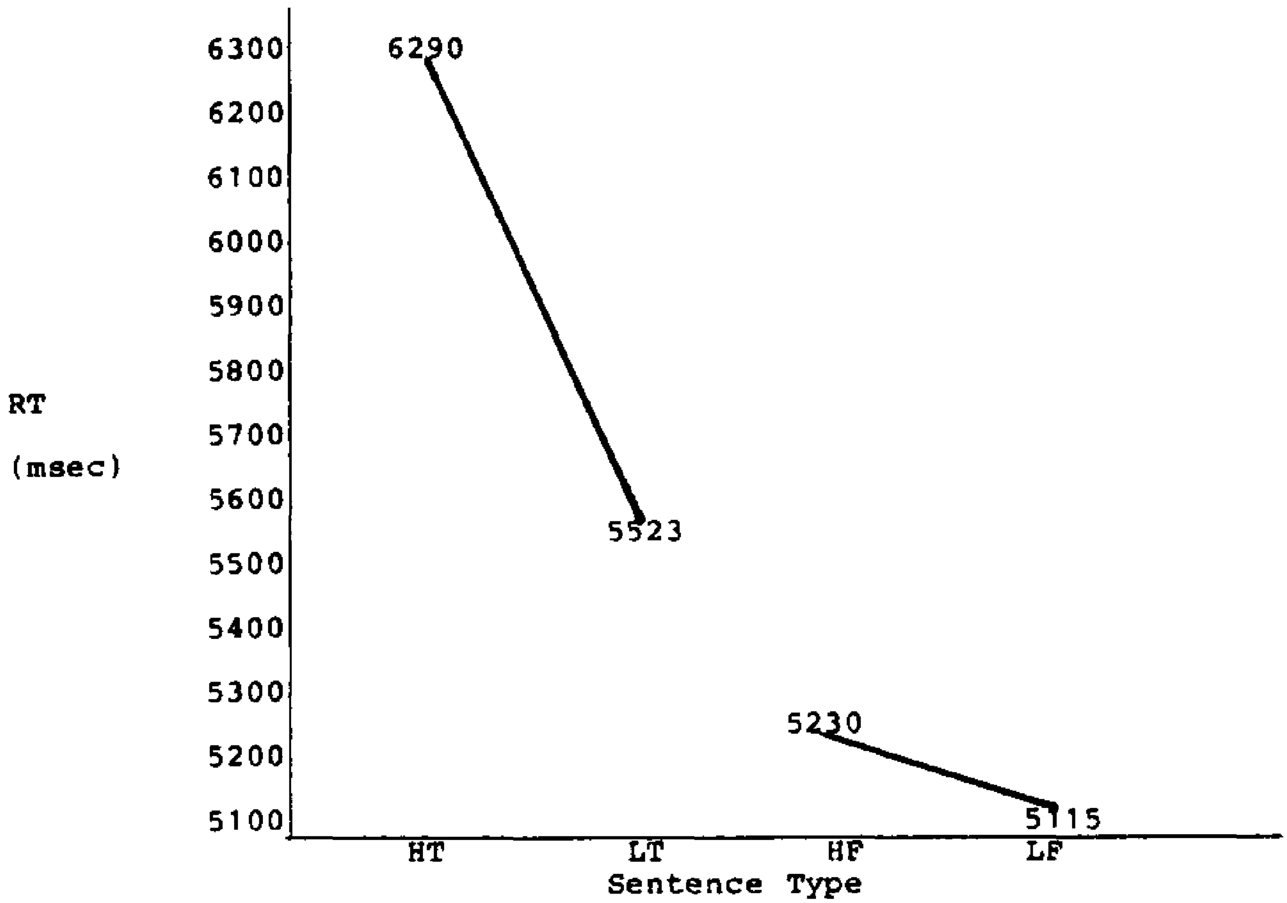
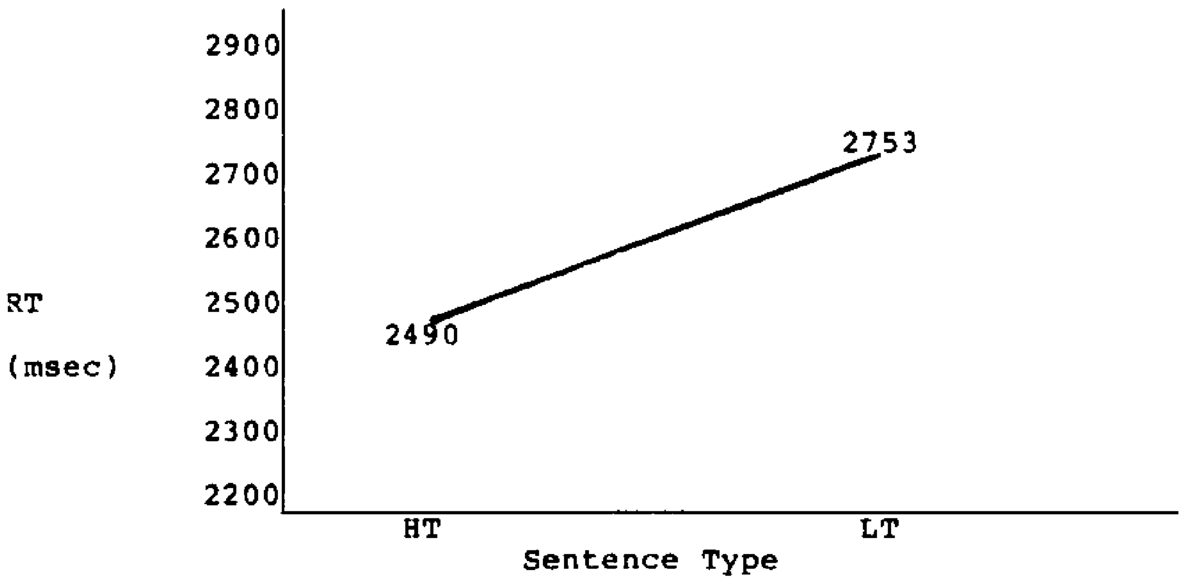


Figure 9

Mean RT By Sentence Type in UF Condition

For Alzheimer Subjects Having The Least Cognitive Impairment



verification signials the initial level of semantic disruption in Alzheimer Type Dementia.

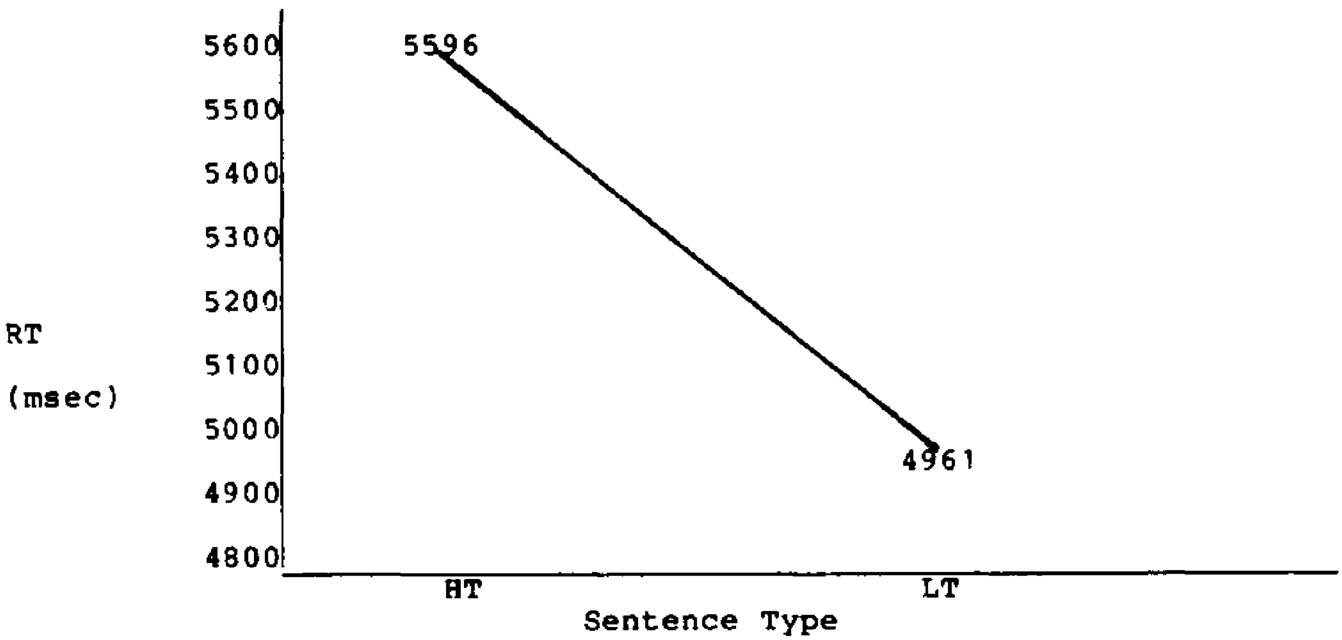
Figure 8 reveals the pattern of sentence verification produced by the Alzheimer subjects who were the most severely impaired. As with the less impaired Alzheimer group, this group also demonstrated more rapid verification of HF sentences as compared with HT sentences. However, the difference is far more striking than that observed in the less impaired group. More importantly, the group having greater impairment no longer produced a typicality effect as illustrated by the complete reversal of HT and LT verification speed. Once again, inspection of the verification patterns in the UF condition confirms the complete loss of this effect (Figure 10).

Division of the total Alzheimer group into two subgroups having different degrees of cognitive impairment made it possible to hypothesize a two-dimensional model of semantic disruption. In the earliest stages, of disruption, HF sentences begin to be verified more rapidly than HT sentences. According to a probabilistic model of semantic verification (McCloskey and Glucksberg, 1979), normal subjects set a specific criterion for the proportion of incoming semantic information that is preserved as true or false, based upon the composition of the test sentences and the demand characteristics of the test situation (speed and accuracy for example). Thus, in the RF condition, the

Figure 10

Mean RT By Sentence Type in UF Condition

For Alzheimer Subjects Having The Greatest Cognitive Impairment



proportion of incoming information that is regarded as true given that the sentence to be verified is false (P_f) is relatively high for HF sentences, since the subject and predicate of these sentences do possess some degree of semantic relationship. In contrast, the P_f for false sentences that have no discernable semantic relationship (UF sentences) is set at a much lower criterion, since the vast majority of information regarding this type of sentence is false. Based on the probabilistic semantic model, a higher criterion setting for P_f normally results in longer latencies when disconfirming HF sentences. If this is the case, then semantic disruption in early Alzheimer Type Dementia may begin with the loss of the ability of these individuals to manipulate the criterion setting for P_f as required by the kind of false sentence that has to disconfirmed. Thus, a spuriously low P_f criterion for HF sentences will result in abnormally fast disconfirmation. It is again noteworthy that the false sentences in both the RF and UF test conditions provided the greatest number of significant discriminators between the Alzheimer group as a whole in comparison to both the spouse and normal aged groups (Table 7). This finding, in addition to the verification patterns produced by the Alzheimer subjects having the least cognitive impairment lend support to the hypothesis that the earliest and most sensitive indicator of semantic disruption resides in the loss of flexibility in adjusting the decision criteria for false sentences.

As semantic disruption becomes more profound, a loss of typicality effect is observed. This is due to the breakdown of both the maintenance of the appropriate decision criteria setting for HT and LT sentences, as well as the loss of meaning of salient semantic information. For example, if the amount of information regarded as true given that the sentence to be verified is true (P_T) is set abnormally high, then one would expect rapid verification of both HT and LT sentences. However, the Alzheimer subjects with the greatest cognitive impairment demonstrated relatively rapid verification of LT sentences, but with abnormally slow verification of HT sentences. Since the latter type of sentence produces the highest degree of semantic relationship between subject and predicate, a high P_t should have resulted in extremely rapid verification. Since this was clearly not the case, it is reasonable to assume that there is a concomitant loss of meaning of critical semantic features. Thus, the loss of typicality effect results from the interaction of an abnormal shift in P_t <u>and</u> a pathological loss of salient semantic features.

In summary, a demonstrable pattern of decline in semantic competence has been delineated, even within the classification of mild impairment. The probabilistic model of semantic memory allows for the detection and subsequent staging of early disruption of semantic memory, and raises many important questions with regard to future investigations of semantic memory and Alzheimer Type Dementia. Are there substantial numbers of individuals with mild impairment who have intact semantic memory, and are they part of a specific subgroup? Can a precise sequential pattern of semantic breakdown be described as the disease progresses? Can early disruptions of semantic memory predict the nature of further decline? It may be possible to answer some of these questions through the use of sentence verification in longitudinal studies of Alzheimer subjects, and especially in studies which seek to isolate predictive factors for the development of Alzheimer Type Dementia in groups of high risk individuals.

One final result concerns the role of oral physostigmine in the performance of the Alzheimer group on sentence verification. While oral physostigmine failed to restore context or typicality effects, it did appear to improve some aspects of the decision process in semantic memory. Specifically, subjects seemed to demonstrate somewhat greater improvement in the verification speed of LF and in particular, UF sentences (Table 13). Perhaps physostigmine acts upon decision making ability in such a way so as to restore flexibility to the probabilistic parameter P_f. This would allow for a differentially lowereD setting of this criterion for UF sentences, thus resulting in more rapid verification. Overall judgement was also observed to improve through an increase in the number of correct responses to sentence verification in every subject who received the drug. Mohs and Davis (1982) reached a similar conclusion in a study which investigated the effect of intravenously administered phosostigmine on recognition memory. Their data was subjected to a signal detection analysis, where D' represented the amount of information stored in memory, and C represented the criterion for making a "yes" or "no" response in item recognition. An increase in both D' and C was discovered during infusion of physostigmine, a finding that was interpreted as indicating a change in the decision criteria due to the subjects' improved ability to discriminate among the recognition items. The change in decision criteria also resulted in the reduction of false alarms, pointing to the need for adequate cholinergic functioning in the production of appropriate responses. The modest but consistent increase in correct responses (Table 14) during the administration of a complex choice reaction time task such as sentence verification may also signal a change in decision criteria for these subjects. That this change was detectable after six weeks of oral ingestion of physostigmine, as compared with 30 minutes of intravenous infusion in the Mohs and Davis study, suggests that chronic enhancement of the cholinergic system may positively affect cognitive mechanisms other than memory. Along these lines, the presence of intrusions, or items verbalized by subjects during recall which were not part of the list of items to be remembered, were shown to decrease as the percentage of cholinesterase inhibition in cerebral fluid increased (Thal, Fuld, Masur, and Sharpless, 1983). This reduction indicates that greater availability of physostigmine facilitates judgement concerning the words that subjects were required to retrieve. Thus, alterations of the capacity for judgement through the administration of physostigmine implies that more global improvement of semantic memory may yet be demonstrated, perhaps in an Alzheimer group having greater homogeneity in task performance.

APPENDIX 1

Test Sentences For Lexical Decision Task

Related False (RF) Condition

Sentence	Type*
1. ALL MOSQUITOES ARE INSECTS	HT
2. ALL SLEDS ARE VEHICLES	LT
3. ALL WEAPONS ARE CANNONS	HF
4. ALL CARROTS ARE VEGETABLES	HT
5. ALL FISH ARE SHAD	LF
6. ALL PENGUINS ARE BIRDS	LT
7. ALL TORPEDOES ARE WEAPONS	LT
8. ALL FISH ARE TUNA	HF
9. ALL GEMS ARE ZIRCONS	LF
10. ALL SCREWDRIVERS ARE TOOLS	HT
11. ALL ELMS ARE TREES	HT
12. ALL BIRDS ARE GEESE	LF
13. ALL TOOLS ARE ANVILS	LF
14. ALL RELATIVES ARE AUNTS	HF
15. ALL SONS ARE RELATIVES	LT
16. ALL FLOWERS ARE CARNATIONS	HF
17. ALL PEACHES ARE FRUITS	HT
18. ALL WEAPONS ARE RIFLES	HF
19. ALL BEGONIAS ARE FLOWERS	LT
20. ALL FRUITS ARE FIGS	LF
21. ALL CRIMES ARE FORGERIES	LF
22. ALL VEGETABLES ARE ONIONS	LF
23. ALL WIGWAMS ARE DWELLINGS	LT
24. ALL HADDOCK ARE FISH	LT
25. ALL MURDERS ARE CRIMES	HT
26. ALL TROUT ARE FISH	HT
27. ALL GEMS ARE SAPPHIRES	HF
28. ALL TURNIPS ARE VEGETABLES	LT
29. ALL CRIMES ARE ROBBERIES	HF
30. ALL DWELLINGS ARE MANSIONS	HF
31. ALL BLOUSES ARE CLOTHES	HT
32. ALL DWELLINGS ARE WIGWAMS	LF

* = HT - High Related True
LT - Low Related True
HF - High Related False
LF - Low Related False

APPENDIX 2

Test Sentences For Lexical Decision Task

Unrelated False (UF) Condition

Sentence	Type*
33. ALL GEMS ARE BANANAS	UF
34. ALL VEGETABLES ARE PRISONS	UF
35. ALL HADDOCK ARE FISH	LT
36. ALL FRUITS ARE WIGWAMS	UF
37. ALL INSECTS ARE CANNONS	UF
38. ALL BEGONIAS ARE FLOWERS	LT
39. ALL CARROTS ARE VEGETABLES	HT
40. ALL TROUT ARE FISH	HT
41. ALL MURDERS ARE CRIMES	HT
42. ALL WIGWAMS ARE DWELLINGS	LT
43. ALL DWELLINGS ARE HAMMERS	UF
44. ALL SONS ARE RELATIVES	LT
45. ALL BLOUSES ARE CLOTHES	HT
46. ALL VEHICLES ARE SONS	UF
47. ALL CRIMES ARE HADDOCK	UF
48. ALL WEAPONS ARE GEESE	UF
49. ALL FLOWERS ARE HARPOONS	UF
50. ALL SLEDS ARE VEHICLES	LT
51. ALL FLOWERS ARE MURDERS	UF
52. ALL MOSQUITOES ARE INSECTS	HT
53. ALL TORPEDOES ARE WEAPONS	LT
54. ALL TREES ARE SHIRTS	UF
55. ALL PENGUINS ARE BIRDS	LT
56. ALL DWELLINGS ARE DAUGHTERS	UF
57. ALL BIRDS ARE DIAMONDS	UF
58. ALL TURNIPS ARE VEGETABLES	LT
59. ALL PEACHES ARE FRUITS	HT
60. ALL FISH ARE TRUCKS	UF
61. ALL SCREWDRIVERS ARE TOOLS	HT
62. ALL GEMS ARE UNCLES	UF
63. ALL ELMS ARE TREES	HT
64. ALL FISH ARE OAKS	UF

* = HT - High Related True
LT - Low Related True
UF - Unrelated False

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