SEMANTIC AGRAPHIA IN ALZHEIMER'S DISEASE

By

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A nonsemantic lexical spelling route may account for some neurologically impaired patients' apparent ability to spell irregular words apart from semantic influence. Alzheimer's disease (AD) has devastating effects upon semantic memory. We hypothesized that the spelling of AD patients may provide evidence of this nonsemantic spelling route.

Oral spelling of homophones, nonhomophones and nonwords was tested in 12 AD and 12 normal control subjects. Homophone pairs of which one member was regularly spelled and the other member was irregularly spelled were presented within semantically distinguishing sentence contexts. Auditory comprehension of these same homophones was tested using two picture matching tasks and a definitions task.

As predicted, the AD group was significantly impaired across experimental tasks as compared to the control group. Also as predicted, the AD group performed better in spelling

nonhomophones than in spelling homophones. However, the AD group performed as poorly in spelling nonwords as in spelling homophones. The AD group produced significantly more alternate homophone spelling errors (i.e., errors in which the target homophone was replaced by the other member of the homophone pair) than did the control group.

The same homophones in the same sentence contexts were presented in the homophone spelling task and in the definitions task (which requires semantic mediation). If lexical spelling also required semantic mediation, we would have expected the occurrence of alternate homophone errors in the definitions task and in the homophone spelling task to be approximately equal. The AD group produced many homophone spelling errors in which they selected the irregularly spelled member of the homophone pair in place of the regularly spelled target. However, the AD group produced very few errors of this type in the definitions task. Thus, we concluded that lexical spelling does not require semantic influence and that the AD subjects were often using a nonsemantic lexical spelling route. We also concluded that the AD subjects often used this nonsemantic lexical spelling route in spite of partial semantic knowledge of both members of a homophone pair.

INTRODUCTION

Current theoretical models of lexical information processing are based upon evidence collected from studies of normal and pathologic populations. These data have forced modifications of former conceptions of lexical processing, but several controversies remain as to how the data can best be explained. One current topic of disagreement is the existence of "direct" lexical nonsemantic processing routes for spelling and for reading. This question of whether spelling to dictation or reading aloud can be performed without semantic influence demands that the characteristics of lexical processing be examined more thoroughly. While it may be virtually impossible to experimentally isolate lexical processing from semantic influence in normal subjects, patients with Alzheimer's disease would seem to provide a source of subjects in whom reduced semantic influence upon lexical processing could be studied. Although the nature of the semantic impairment in Alzheimer's disease is controversial, it is widely believed that this disease has devastating effects upon semantic memory. For this reason, we have chosen to investigate the spelling abilities of Alzheimer's disease patients in our attempt to understand the characteristics of lexical

processing apart from normal semantic influence. This study, therefore, may inform us of some of the clinical implications of Alzheimer's disease, in addition to informing us of the role of semantics in the normal process of spelling. The justification for this study is evident from the controversy outlined in the following review of the literature.

Information Processing Models of Spelling

In 1865, Benedikt first applied the term "agraphia" to disorders of writing resulting from brain damage (Rothi, Roeltgen and Kooistra, 1987). Benedikt suggested separate anatomic localizations for written and spoken language, but did not cite exact locations of brain damage underlying agraphia. Ogle, in 1867, was one of the first to classify the agraphias (Roeltgen, 1985). He proposed two forms of agraphia, suggesting that accurate writing required both linguistic and motoric subsystems (Rothi, Roeltgen and Kooistra, 1987). Ogle suggested that there were distinct cerebral centers for writing and for speaking, but that because agraphia and aphasia usually occurred together, these centers were close together.

In contrast to Ogle, Lichtheim proposed in 1885 that writing disorders were usually the same as disorders of speech (Roeltgen, 1985). Lichtheim accounted for this by arguing that the acquisition of writing (and spelling) utilized previously acquired speech centers. Head (1926)

also stressed that the ability to write was associated with internal speech because writing development was superimposed on speech. Head's classification of the agraphias, therefore, was the same as his classification of the aphasias (Roeltgen, 1985).

Nielson (1946) took a view similar to Ogle's in that he described writing as closely associated with speech, but separable from it. He classified the agraphias as apractic, aphasic, or isolated. "Isolated agraphia" he defined as agraphia without associated neuropsychological signs, and he linked this agraphia to a lesion of the frontal writing center (Exner's area) or of the angular gyrus. Nielson suggested that functional and anatomic associations (e.g. fibers carrying information from the angular gyrus to Exner's area passed close to Broca's speech area) accounted for the frequent co-occurrence of agraphia and aphasia (Roeltgen, 1985). Goldstein (1948) also took the position that agraphia is often but not always associated with aphasia.

These early accounts of writing disorders following brain damage are the basis of the more detailed theories of normal writing and spelling we will review. The theoretical model of normal spelling processing that we will use as a framework for our discussion (Figure 1) is based upon evidence from both normal and pathologic populations, but is by no means absolute (e.g. Campbell, 1983; Hillis, Rapp,

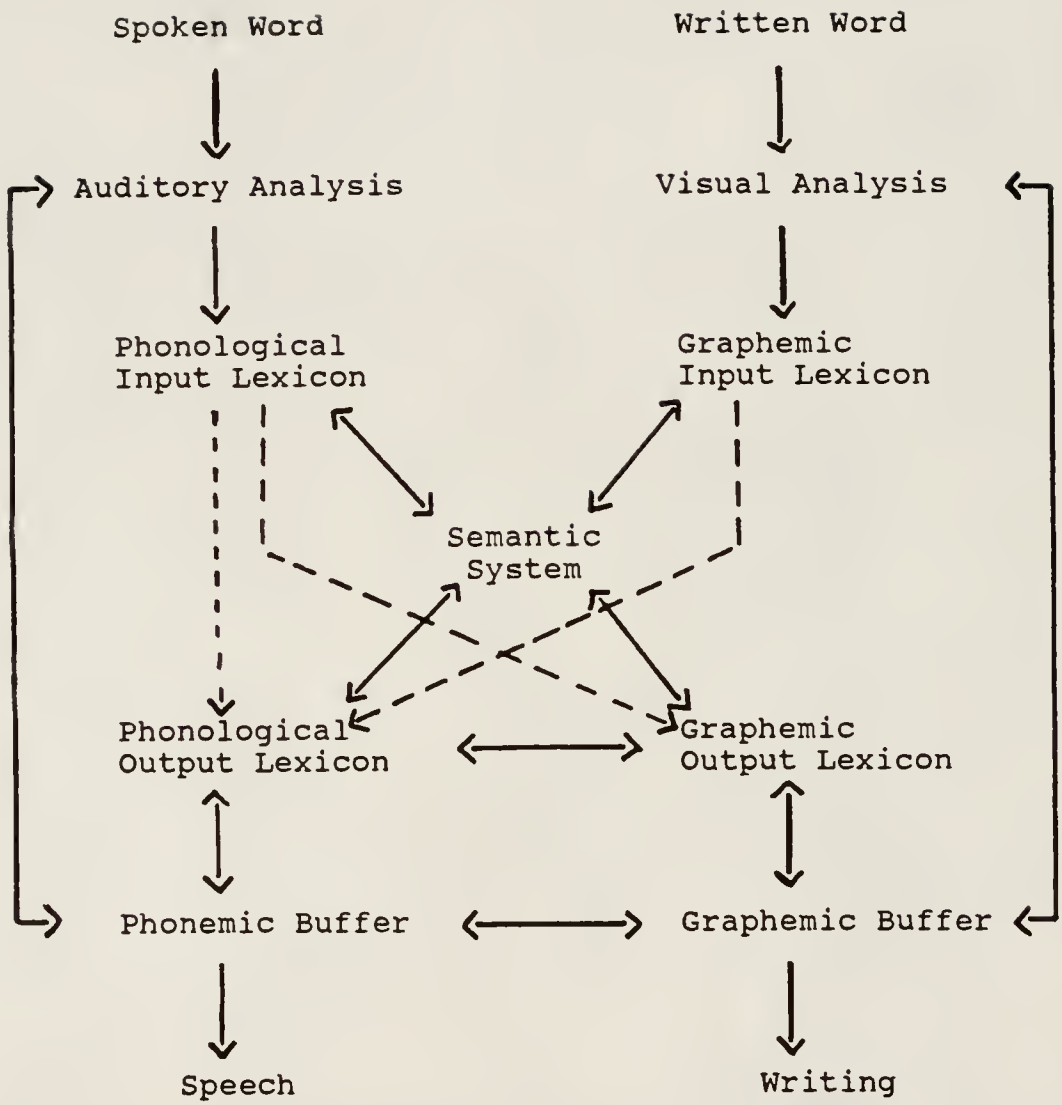

Figure 1. A cognitive neuropsychological model of spelling (a modification of Ellis and Young, 1988).

Romani and Caramazza, 1990; Hillis and Caramazza, 1991). Many aspects of normal spelling are in dispute other than the issue of direct lexical nonsemantic spelling (e.g., single- versus dual-route theories of graphemic recoding; the nature of input to the Graphemic Output Lexicon). The model we describe is probably the most widely accepted characterization of normal spelling in the literature (Morton and Patterson, 1980; Howard and Franklin, 1988), and while we acknowledge alternative views (Campbell, 1983; Hillis et al., 1990), we will elaborate this model for our discussion. It is an adaptation of a series of versions of Morton's "logogen model" (e.g., Morton, 1964, 1970, 1980a).

In this model, three processing routes for spelling are available: the sublexical phonological route, the lexical-semantic route, and the lexical nonsemantic route. The assumption of functionally separate procedures, which is based on the existence of qualitatively different spelling disorders, does not mean that the routes operate with complete independence in the normal system (Bub and Chertkow, 1988, p. 403). However, as Patterson and Morton (1985, p. 337) point out, even if two routes do not normally operate in complete isolation, if they are separable it will be possible for only one of them to be impaired or lost as a result of brain damage.

This model includes a "sublexical phonological route" (or "nonlexical route") which is thought to convert the

phonemic code a person hears into the graphemic code needed to write what was heard (i.e., written spelling to dictation), or into the phonemic code needed to speak what was heard (i.e., oral repetition). This route is thought to be the mechanism for spelling nonwords or regularly spelled words that follow "rules" of sound to letter correspondence. This route operates apart from whole-word lexical knowledge; as a consequence, this route does not support the spelling of irregularly spelled words, for which lexical knowledge is required.

The "lexical-semantic route" for spelling to dictation is represented in this model as a series of processes by which heard words are recognized as real, are comprehended, and are then spelled after the appropriate letter codes are retrieved. The same abstract letter codes are thought to be utilized for oral or written spelling production. The operation of this lexical-semantic route is thought to involve central semantic memory which must mediate between the words the person hears and the spelling response the person produces. This route can support the spelling of real words, whether regularly or irregularly spelled, but it cannot support the spelling of nonwords.

Lexical nonsemantic (i.e., "direct) processing routes for both spelling and for reading are represented by dotted lines in this model. The "direct" spelling route is thought to involve the recognition of heard real words, and the

spelling of these words without the influence of semantic memory. Two theories have been put forth to explain how direct spelling could be accomplished: One theory (e.g., Goodman and Caramazza, 1986) is that abstract letter codes for spelling production can be retrieved once the heard word has been recognized as real (recognized but not comprehended). A second theory is that retrieval of abstract phonological codes (which would normally be used for speech production) must occur before the corresponding letter codes can be retrieved (Hotopf, 1980; Ellis, 1982; Patterson, 1986). Thus, in either of these ways, the theorized direct spelling route can retrieve letter codes for spelling without accessing central semantic memory.

The evidence upon which these spelling theories are based primarily has come from reports of brain-injured patients whose spelling reflected selective impairment to one or more of the proposed spelling routes. Beauvois and Derousne (1981), for example, reported that their patient, RG, could produce plausible spellings for nonwords, but that he also wrote real words as if they were nonwords. They interpreted this as an impairment to the lexical spelling route, with reliance on the sublexical phonological route. Hatfield and Patterson's (1983) patient TP also became a phonological speller after brain injury; however, TP's spelling reflected some knowledge of word-specific spellings as well as phonological knowledge. Roeltgen and Heilman

(1984) reported four patients whose spelling performance reflected disruption to the lexical spelling systems and preservation of the phonological spelling systems. One of their patients was of particular interest in that he spelled correctly all the nonwords presented to him while his lexical spelling was impaired.

On the other hand, Shallice's (1981b) dysgraphic patient, PR, could spell many familiar words but was very poor at generating spellings for nonwords. Thus, he was assumed to have an impairment of the sublexical phonological spelling route. A patient reported by Roeltgen, Rothi and Heilman (1982a) also showed an almost isolated disturbance in spelling nonwords. Roeltgen, Sevush and Heilman (1983) reported four "phonological" dysgraphics for whom the spelling of nonwords or unfamiliar words was much more difficult than the spelling of familiar real words. Reports such as these have been interpreted as evidence that the lexical spelling system and the phonological spelling system are dissociable in operation.

We will describe the components of the theoretical spelling model, as well as the interactions thought to occur within and among these components (Ellis and Young, 1988). In addition, we will address alternative views of how normal spelling may be accomplished.

The model in Figure 1 includes a component labeled the Auditory Analysis System, which represents a stage at which

individual speech sounds can be extracted from what a person hears, and adjustments can be made for variations in voice, accent or rate of speech. Selective impairment of this component of lexical processing may result in "pure word deafness," a disorder in which normal-hearing patients are unable to understand or to repeat heard words while they retain the ability to speak, read and write normally (Ellis and Young, 1988).

The Phonological Input Lexicon represents the stage at which spoken words are thought to be recognized as familiar. The meanings of the words, however, are not thought to be accessed until their subsequent activation in the Semantic System. Ease of activation of representations in the Phonological Input Lexicon seems to be a function of word frequency, with high frequency words more easily accessed than low frequency words. Selective impairment of the Phonological Input Lexicon would result in the inability to recognize spoken words. Even with this impairment, however, accurate repetition of heard words could be achieved via the sublexical phonological routine (i.e., direct transmittal of information from the Auditory Analysis System to the Phonemic Buffer).

The model includes a connection between the Phonological Input Lexicon and the Semantic System which permits the meanings of heard familiar words to be accessed in the Semantic System. A patient with selective impairment

to this connection would be unable to understand heard words, although he would be able to differentiate between heard words and nonwords in an auditory lexical decision task. If the impairment were only partial, the patient may not be able to understand heard words precisely, but may be able to comprehend the general category of the target word, or information specifying some of the semantic features of the target word (e.g., Hillis and Caramazza, 1991).

The Semantic System represented in the model corresponds to the "semantic memory" component of many cognitive models of memory (Ellis and Young, 1988). Impairment of the Semantic System may result from a variety of neuropsychological conditions (e.g., dementia) and yields an inability to attach appropriate meaning to incoming stimuli or to semantically encode output. It is generally thought that the Semantic System may be impaired in three main ways: by a semantic access deficit (Shallice, 1988), by the loss or degradation of semantic representations (Shallice, 1988), or by impaired egress from the Semantic System (Howard and Franklin, 1988; Raymer, Maher, Greenwald, Morris and Rothi, 1991).

It is generally assumed that the imageability of a word influences the ease of its retrieval from the Semantic System. Highly imageable (i.e., "concrete") word meanings seem to be more accessible within the Semantic System than word meanings of low imageability (i.e., "abstract").

Therefore, it is sometimes the case (Howard and Franklin, 1988) that neurological damage may disrupt the retrieval of low imageability words from the Semantic System while high imageability words remain accessible.

Semantic spelling errors may result from impairment of the Semantic System. These are errors in which a word is produced which is not the correct word, but which is semantically related to it. Patients who produce a predominance of semantic errors in spelling and who show a pattern of better performance for high imageability versus low imageability words are said to have "deep dysgraphia" (e.g., Bub and Kertesz, 1982b). For example, patient GR (Newcombe and Marshall, 1980a) wrote "moon" when asked to write "star," two patients of Saffran, Schwartz and Marin (1976b) made errors such as writing "time" for "hours," and a German patient (Peuser, 1978) made similar semantic spelling errors (Ellis and Young, 1988, p. 172).

The component of the model labeled the Phonological Output Lexicon represents the stage at which representations of the spoken forms of words can be accessed. Ease of activation of these representations seems to be a function of word frequency, with high frequency words more easily accessed than low frequency words. For example, anomic aphasics may exhibit word retrieval problems even when they know the meaning of the words, but may have particular difficulty in retrieving low frequency words. For these

less common words, they may be able to retrieve partial information which causes them to generate approximations of words similar to the "tip-of-the-tongue" state in normal speakers (Brown and McNeill, 1966; Ellis and Young, 1988).

A connection in the model between those components labeled the Phonological Input Lexicon and the Phonological Output Lexicon represents the retrieval of output phonological codes directly after the heard word is recognized, without any influence of the semantic system. A hypothetical patient who could repeat real words but not understand them would be evidence to support the existence of this connection, but only if this patient were unable to repeat nonwords (i.e., could not be repeating via the nonlexical phonological route). Apparently, a patient with this pattern of performance has not been reported to date, but this connection in the model has been proposed to explain some patients' apparent ability to spell irregular heard words apart from semantic influence. That is, one theory of how a direct spelling route may operate is that abstract phonological codes can be retrieved without semantic influence and can then cause retrieval of corresponding letter codes. Proponents of this theory of direct route spelling (e.g., Patterson, 1986) suggest that patients who can spell irregular words to dictation but who apparently cannot understand these words provide evidence that the Phonological Output Lexicon can receive lexical

information directly and not only through the Semantic System. However, some researchers view this evidence as weak (Ellis and Young, 1988; Hillis et al, 1990; Hillis and Caramazza, 1991).

The Graphemic Output Lexicon component of the model represents the existence of abstract graphemic representations specifying the spelled forms of familiar whole words (whether regular or irregular). Ellis (1982, p. 117) theorizes that graphemic sequences for words are retrieved according to the specifications of semantic and phonemic processing. These graphemic codes are then thought to be communicated to the level of the Graphemic Buffer as the spelling code for subsequent output.

The same graphemic codes are used for spelling either orally or in writing. Evidence cited (Ellis and Young, 1988, p. 168) for the proposal that the representations retrieved from the Graphemic Output Lexicon are abstract graphemic code rather than a motor program for letter execution comes from reports of patients for whom oral spelling is preserved while written spelling is severely impaired (Rosati and DeBastiani, 1979). Such a pattern of performance implies normal access to spellings in the Graphemic Output Lexicon, but deficient selection, sequencing or execution of letter forms for handwriting.

The Graphemic Output Lexicon may receive input from several sources for spelling tasks: First, from the

Semantic System (Morton, 1980a; Bub and Kertesz, 1982b; Ellis, 1982), secondly, from the Phonological Input Lexicon (Goodman and Caramazza, 1986; Ellis and Young, 1988), thirdly, from the Phonological Output Lexicon (Hotopf, 1980; Wing and Baddeley, 1980; Ellis, 1982, Patterson, 1986), and finally, by a process of interactive activation between the Graphemic Output Lexicon and the Graphemic Buffer (Ellis and Young, 1988, p. 189; cf footnote 4, Hillis and Caramazza, 1991). Additionally, some researchers (Hillis et al., 1990; Hillis and Caramazza, 1991; Smith, Snyder and Meeks, 1990) refer to a model which represents input of the sublexical phonological routine to the Graphemic Output Lexicon, either directly or via the Phonological Output Lexicon.

Selective impairment of the Graphemic Output Lexicon would result in the inability to access the spelling forms for real words, particularly irregularly spelled words. It is generally assumed that regularly spelled words and nonwords could still be spelled by the sublexical phonological routine. Retrievel of spellings from the Graphemic Output Lexicon can be partial, as reflected by spelling errors of normal subjects and dysgraphic patients which include portions of irregularly spelled words (Ellis and Young, 1988). Semantic errors in writing reflect a deficit in incoming information from the Semantic System to the Graphemic Output Lexicon or, according to Caramazza and Hillis (1990), may also result from a deficit within the

Graphemic Output Lexicon itself. Caramazza and Hillis make the assumption that a semantic representation activates in parallel all codes in the Graphemic Output Lexicon in proportion to the amount of semantic similarity there is between the graphemic code and the input code from the Semantic System (1990).

The Graphemic Output Lexicon seems to be organized similarly to the Phonological Output Lexicon in that ease of activation of graphemic representations is frequency-related. High frequency words have lower thresholds of activation than do less frequent words. However, the frequency of a representation in the Graphemic Output Lexicon is related to how commonly the word occurs in spelling, not in spoken speech as with a representation in the Phonological Output Lexicon. There is evidence that the Graphemic Output Lexicon and the Phonological Output Lexicon are organized so that orthographically or phonologically similar items are stored together, and in terms of grammatical word class (i.e., nouns are more easily accessed than verbs which in turn are more easily accessed than words of other grammatical classes). Lesser (1989) seems to suggest that the grammatical word class effect is due to the influence of the Semantic System, since content words carry more semantic information than words of other grammatical classes. In addition, the Graphemic Output Lexicon seems to

be organized such that root morphemes are stored separately from their affixes (Miceli and Caramazza, 1988).

Errors reflecting "partial lexical knowledge" (Ellis, 1982) may result from incomplete retrieval of representations from the Graphemic Output Lexicon. (Ellis does not state that possibility that disruption at a subsequent stage may also account for partial loss of retrieved graphemic forms.) According to Ellis and Young (1988, p. 168), these errors are common and do not seem to be limited to any specific form of aphasia or dysgraphia. Spelling errors demonstrating "partial lexical knowledge" are any misspellings which reflect substantial knowledge of idiosyncratic or otherwise "irregular" spellings of the target words (e.g "physitian" for "physician"). Access at the level of the Graphemic Output Lexicon must take place for these errors to occur.

The model in Figure 1 includes a connection between the Phonological Output Lexicon and the Graphemic Output Lexicon. This connection has been hypothesized to account for normal "slips of the pen" in which words of the same or similar sound are substituted for the target word. These slips cannot be explained by sublexical phonological processing, because the sublexical route would often yield nonword errors (e.g., "surch" for "search"), and the slips often produce irregularly spelled words which could only be accessed in the Graphemic Output Lexicon (Hotopf, 1980).

Errors similar to these normal "slips of the pen" also occur in patients with dysgraphia secondary to brain injury. For example, Shallice's (1981b) phonological agraphic patient PR produced such irregularly spelled errors (e.g., "thumb" for "plum"), and was unable to use the sublexical phonological routine to assemble spellings from sounds. Finally, this connection from the Phonological Output Lexicon to the Graphemic Output Lexicon may account for the fact that normal spellers seem to activate the spoken forms of words (i.e., the "inner voice") as the graphemic forms are being activated (Ellis and Young, 1988).

Although there is evidence for some involvement of phonological codes of words in retrieving spellings from the Graphemic Output Lexicon (Morton, 1980a), there is also evidence that retrieval from the Graphemic Output Lexicon does not only depend on prior activation of phonemic forms in the Phonological Output Lexicon (Ellis and Young, 1988). For example, patient MHY (Bub and Kertesz, 1982a) could correctly write words whose sound forms she did not know.

Bub and Chertkow (1988) address the question of why the Graphemic Output Lexicon would need additional input from the spoken representation of a word when the meaning of the word could already provide direct access to its description in the Graphemic Output Lexicon. They report that the answer most frequently given is that "smooth written production of sentences depends on the temporary storage of words in a

buffer that maintains information while the response is organized and executed" (p. 404). They note that many theorists consider whole-word phonology to be the best code for a storage device of this kind. For example, Hotopf (1983, p. 166) argues that if words that have been accessed have to be held in a buffer store for a few seconds during a writing task, "acoustic, as opposed to visual, coding will, according to the evidence from studies in short-term memory, be the more durable" (also see Patterson, 1986; Caramazza Berndt and Basili, 1983).

Evidence that the spoken form of a word can exert an influence on retrieval of its graphemic code has come from the analysis of writing errors in normal performance, in which there is good reason to assume that the writer knew the correct spelling of the target. Hotopf (1980, 1983) examined a corpus of such normal "slips of the pen" and found examples of homophone confusions (e.g.,"weight" for "wait), word substitutions for phonologically similar items (e.g.,"28" for "2A"), and occasional responses that suggest a reliance on phoneme-grapheme translation (e.g., "ques" for "cues").

Bub and Chertkow (1988) point out that even though many different codes are automatically activated during the recognition or production of words and sentences, information at one level may affect the course of events at another level in the system without being critically

involved in the performance of the task. As an example, they cite evidence (Seidenberg and Tanenhaus, 1979) that normal subjects are slower to carry out rhyme judgements of auditory words when the word pairs have different orthographic endings (e.g., "pie" and "sky") than when the orthographic endings are the same. Bub and Chertkow argue that although this evidence indicates that the spelling of a word can automatically enter into the phonological judgement, it does not mean that the spelling of the word forms an ESSENTIAL part of the rhyme judgement. Similarly, they conclude that the influence of the phonological form of a word upon retrieval of its graphemic form is not essential, and that this is born out by discrepancies among the spelling performances of various patients (p. 406).

The evidence described above for influence of different orthographic endings on normal subjects' ability to make rhyme judgements would seem to support the inclusion of a connection in our model from the Graphemic Output Lexicon to the Phonological Output Lexicon. Therefore, the abstract representations in these lexicons are conceptualized in this model as having mutual influence which is, however, not essential for retrieval of graphemic or phonological representations in normal subjects.

The model includes connections between the output lexicons and their buffers (i.e., Phonological Output Lexicon to Phonemic Buffer; Graphemic Output Lexicon to

Graphemic Buffer) which represent relationships of mutual interactive activation. When this interactive process errs, real word speech or spelling errors may be produced which, for impairment to the phonological system would be similar in sound to the intended target (e.g., saying "late" for "light"), or for impairment to the graphemic system would be similar in spelling to the intended target (e.g., spelling "file" for "film") (Ellis and Young, 1988) (cf footnote 4, Hillis and Caramazza, 1991).

The component of the model labeled as the Graphemic Buffer is thought to allow the abstract graphemic representations of a word to be held during the execution of either oral or written spelling. This level receives input from the Visual Analysis System (which may allow for direct copying from print), from the Phonemic Buffer (i.e., the phoneme-to-grapheme conversion process by which nonwords are spelled to dictation), and from the Graphemic Output Lexicon (Ellis and Young, 1988).

The graphemic representations at the level of the Graphemic Buffer are thought to be abstractions of each of the letters used in English (Ellis, 1982). For example, upper- and lower-case versions of a letter would be represented by a single representation (Ellis and Young, 1988). Particular letter forms are thought to be selected subsequent to the Graphemic Buffer, as are particular modes of spelling output. Impairment of the Graphemic Buffer may

be the cause of frequent errors in some peripheral dysgraphic patients (Ellis and Young, 1988).

Similar to the Graphemic Buffer, the Phonemic Buffer represents a stage at which the phonemic representations of words are thought to be held temporarily during the execution of appropriate output processes. As described above, this level receives input from the Auditory Analysis System and also may be linked to the Phonological Output Lexicon in a relationship of interactive activation (Ellis and Young, 1988).

The model in Figure 1 includes a connection between the Auditory Analysis System and the Phonemic Buffer, which represents the ability of both normal speakers and many aphasic patients to repeat aloud nonwords or unfamiliar words without comprehension or recognition. This connection, together with the connection from the Phonemic Buffer to the Graphemic Buffer, represents the sublexical phonological routine for spelling (i.e., the ability of skilled writers to generate plausible spellings for unfamiliar words or nonwords by a system for converting phonemes into graphemes). The use of this conversion system in English may lead to many errors (e.g., misspelling "biscuit" as "biskit") because of the unreliability of sound-to-spelling correspondences in English (Hatfield and Patterson, 1983).

According to Ellis and Young (1988), activation of phonemes at the level of the Phonemic Buffer can provide feedback to the Auditory Analysis System, providing a mechanism for "inner speech" in which normal subjects seem to hear their own silent speech internally.

Just as we have included an interactive connection in our model between the Phonological Output Lexicon and the Graphemic Output Lexicon, as described above, we have also included an two-way connection in our model between the Phonemic Buffer and the Graphemic Buffer. We have discussed above that input from the Phonemic Buffer to the Graphemic Buffer is thought to allow for the spelling of nonwords to dictation. We suggest that, in turn, input from the Graphemic Buffer to the Phonemic Buffer may allow for oral spelling of irregular and regular words. We also suggest that the oral spelling of nonwords to dictation may be accomplished via this process of interactive activation between the Phonemic Buffer and the Graphemic Buffer. This connection seems to us to be a more parsimonious account of oral spelling than suggestions that subsequent to the Graphemic Buffer there is a separate "Letter Name Conversion" stage that accounts for oral spelling (Goodman and Caramazza, 1986b).

As we have discussed previously, the model in Figure 1 includes separable routes for lexical and nonlexical spelling. However, Campbell (1983, p. 154) maintains that

the skill of phoneme-to-grapheme conversion in adult readers NEVER becomes independent of lexical skill. She points out three main reasons to question the theory of two phonological spelling routes. First, she notes that in developing readers, it is assumed that spelling performance improves as the phoneme-to-grapheme rule system develops, so that as lexical knowledge increases, reliance on lexical analogies in spelling decreases. But, as Campbell points out, "increased LEXICAL knowledge and flexibility in lexical decomposition will have precisely the same effect" (p. 154). She goes on to argue that if the development of a child's ability to spell depended upon a dissociation between lexical and nonlexical spelling systems, that the child's spelling would become more uniform as the child learned the rules (p. 154).

Campbell's (1983, p. 154) second reason for arguing that the nonlexical spelling route is never independent of the lexical routine is that "there are far more ways of spelling a word so that it sounds correct than there are of reading it so that it is correctly pronounced" (Henderson and Chard, 1980; Baker, 1980). Finally, Campbell argues (p. 155) that even in reading, lexical and nonlexical processes cannot be distinguished as clearly as dual-route theory, in its traditional form, predicts (Marcel, 1980; Kay and Marcel, 1981).

The model in Figure 1 includes a connection between the Graphemic Input Lexicon (i.e., the Orthographic Input Lexicon) and the Phonological Output Lexicon which represents a "direct" lexical nonsemantic route for reading. The evidence for this connection comes from brain-injured patients who were reportedly able to read aloud irregular words which they did not appear to understand (Schwartz, Saffran and Marin, 1980a; Coltheart and Byng, 1983). Additionally, there is evidence for this route from normal subjects who were able to read aloud familiar irregular words faster than they could perform any form of semantic categorization of the same words (Ellis and Young, 1988).

A sublexical phonological routine for reading is represented in this model by a connection between the Visual Analysis System and the Phonemic Buffer. This routine would allow nonwords and unfamiliar real words to be read aloud by a process of grapheme-to-phoneme conversion.

Alternative accounts of nonword reading include single-route theories of phonological access in reading aloud, such that the grapheme-phoneme conversion route is merged with the whole-word route (Kay and Marcel, 1981; Campbell, 1983; Henderson, 1985). For example, Schwartz and Chawluk (1990) support the idea that the same inventory of phonological forms is used for nonlexical reading and for lexical reading (Shallice and McCarthy, 1985; Shallice, Warrington and McCarthy, 1983). They attribute their patient's inability

to read either lexically or nonlexically as a deficit in retrieving elements in the same phonological inventory.

Current models of lexical processing in reading include computational models which may have implications for models of spelling as well. For example, Seidenberg and McClelland (1989) describe their distributed, developmental model of word recognition and naming in which they demonstrate that a single computation that converts spelling patterns into phonological codes is sufficient to account for the naming of exception words and novel words. However, they do include an indirect route via semantic meaning by which phonology can be activated. They contend that this semantic route would be responsible for the pronunciation of homographs. Their model also provides an explicit account of quantitative differences between stimulus types in terms of naming difficulty. In their model, "knowledge of spelling-sound correspondences is represented in terms of the weights on connections between units involved in the computation from orthography to phonology" (p. 558).

Summary

Although controversies abound as to which models of lexical processing are most appropriate in conceptualizing normal spelling and reading, we have chosen in this study to adopt a modification of many accepted models which we have included in Figure 1. This model may allow us to account for subject performance on all the tasks we presented in

this study. Depending on the task (e.g., spelling to dictation; comprehension tasks), different combinations of the model's components are used. However, since in normal spellers multiple processes may operate simultaneously and in parallel, the operation of specific components of the model may only be examined after injury to the system or by experimental manipulation.

Evidence For Direct Lexical Spelling

Evidence supporting the existence of a lexical nonsemantic spelling route primarily has come from studies which have tested subjects' ability to spell single irregular words or single word homophones to dictation when given the semantic context for the target word. The argument is that if accurate transcription is shown in the absence of preserved comprehension and the sublexical phonological route cannot account for the transcription, then there must be a route for accessing lexical representations which is dissociable from semantic influence. For example, as evidence for the existence of this spelling route, researchers have cited instances in which brain-damaged patients have spelled irregular homophones (e.g., "suite") that were not correct for the semantic context (i.e., the semantic context called for a regularly spelled homophone, such as "sweet"). In terms of the model we have described in Figure 1, this "direct" spelling route could be represented by a connection between

the Phonological Input Lexicon and the Graphemic Output Lexicon or by a path from the Phonological Input Lexicon to the Phonological Output Lexicon to the Graphemic Output Lexicon.

As early as 1897, Bramwell reported a patient who could write correctly words which he did not seem to understand (Ellis, 1984a). Apparently, although this patient was not able to understand a question presented auditorily to him, the patient was able to write down the question, read it, and then respond appropriately. The performance of such patients who spell accurately to dictation without comprehension does not seem to be explicable by a phoneme-to-grapheme conversion mechanism because they spell many irregular words correctly (Kohn and Friedman, 1986; Patterson, 1986; cf Hillis and Caramazza, 1991).

Patterson (1986) reported that Patient GE could write regular and irregular words to dictation with a high degree of accuracy, but did not write spontaneously and was severely impaired in writing nonwords to dictation (34% accurate). GE's accurate spelling of words was reported to occur in spite of an inability to comprehend some of the words in word-picture matching tasks and in semantic categorization. GE's performance was interpreted as not attributable to sublexical phonological processing because his spelling of nonwords to dictation was impaired. Patterson noted (p. 352) that GE very rarely made

"phonologically plausible" spelling errors, that is, errors that would suggest sub-word conversion from phonology to orthography. No effect of spelling regularity or of imageability was evident in GE's writing to dictation, and there was no word class effect. The pattern of GE's spelling performance was attributed by Patterson (1986) to the operation of a direct nonsemantic spelling route.

The characteristics Patterson described as indicative of direct nonsemantic spelling (1986, p. 359) were 1) ability to spell a word to dictation even when unable to comprehend the word; 2) no influence of imageability or regularity of phoneme-to-grapheme correspondences (however, Lesser, 1989, takes a different view); and 3) general competency in spelling real lexical items, but major difficulty with one particular class of words: homophones which are nonhomographic.

Among the tasks Patterson (1986) administered to GE were three spelling tasks in which the target word lists included homophones and in which the semantic context for each homophone was provided. For a word list containing 18 homophones, GE made several homophone confusions (the exact number was not reported). For another word list containing eight homophones, GE spelled the inappropriate homophone four times. Finally, for a list of 80 homophones (40 pairs), GE made 8% homophone errors compared to 84% correct productions.

Patterson (1986) compared GE's performance on writing to dictation tasks to his comprehension for the same lists of words as measured by word-picture matching tasks and semantic categorization. The comparison was not reported item-by-item, but rather as word-list accuracy scores. For the word-picture matching tasks, Patterson separately analyzed writing of object names (.66 correct, n=62), concrete words (.80 correct, n=25), and abstract words (.60 correct, n=25). For the semantic categorization task, a set of 60 spoken words (half animal names and half names of nonanimal objects) was presented. GE's semantic classification was 84% correct. His spelling of these same 60 words was 90% accurate. Patterson emphasized that the important point in regard to these data is that "fair though these comprehension performances were, his spelling of the same spoken words was better still"(p. 357).

Patterson (1986) describes Patient GE as an important neuropsychological case of evidence for the direct nonsemantic spelling routine because, as Patterson says, "the only neuropsychological evidence prior to GE comes from cases of word meaning deafness, in which a patient fails to understand a spoken word but succeeds in writing it" (p. 364). Patterson (1986) notes that although this phenomenon does suggest the operation of a nonsemantic lexical routine, that there are almost no well-documented cases of word meaning deafness. She describes Kohn and Friedman's (1986)

description of patient HN as the "most satisfactory" report, but notes that, even in this case, occurrences of word meaning deafness were rare: Kohn and Friedman (1986) report instances of word meaning deafness in HN on a total of eight words.

Roeltgen, Rothi and Heilman (1986) reported five brain-damaged patients whose spelling seemed to reflect the dissociation of the lexical spelling system from semantic influence. All five patients were described as having the ability to orally spell irregular words in spite of difficulty incorporating meaning into what they spelled. These patients demonstrated some use of the sublexical phonological spelling routine in that they could spell many nonwords; however, this could not account for their ability to spell irregular words. In a homophone spelling task, these patients spelled irregular words with no apparent semantic mediation, often spelling the incorrect homophone for the semantic context given (e.g. "bare" when the semantic context required "bear," or "plumb" when the sentence context required "plum").

A homophone spelling test consisting of homophones with both orthographically regular spelling and irregular spelling was administered to these five patients (Roeltgen et al., 1986). A homophone was considered irregular if it fulfilled either of two criteria: first, if it had unpronounced consonants (e.g., the "b" in "plumb"); second,

if the correct spelling for a phoneme was not the most common spelling for that phoneme (e.g.,"l-e-d" is regular; "l-e-a-d" is irregular.) Homophones with unique sound-to-letter correspondences (e.g., "colonel") made up a large part of the list of irregularly spelled homophones. The homophones were divided into two general groups: high frequency and low frequency. A homophone was considered frequent if its relative frequency of occurrence was equal to or greater than 40%. As the list of homophones was dictated to each patient, each homophone was followed by a sentence demonstrating the word's meaning, and the patients were asked to orally spell their responses.

Roeltgen et al. (1986) calculated the percentage of each patient's correct responses in each of four categories of homophones: high-frequency regular, low-frequency regular, high-frequency irregular, and low-frequency irregular. They also analyzed the incorrect responses in terms of misspellings or correctly spelled but semantically incorrect responses. The five patients correctly spelled the correct homophone on 43% of trials, and they correctly spelled an incorrect homophone (semantically incorrect) (e.g., "knot" for "not") on 31% of trials. The responses on the remaining 26% of trials were incorrect words or misspellings. High-frequency irregular homophones were spelled correctly on 43% of the trials, better than low-frequency irregular homophones (25%). Low-frequency regular

homophones were spelled correctly on 29% of the trials, and high-frequency regular homophones were spelled correctly on 64% of the trials. Any influences of word class on these patients' writing of homophones was described as minimal (p. 275). However, a regularity effect was present, especially for high-frequency homophones, in that regular homophones were spelled correctly more often than irregular homophones (p. 277).

Special comprehension tests (i.e., more than those provided by the initial aphasia examination) were given to three of the five patients in the Roeltgen et al. (1986) study. Patient 3 was given a modification of the homophone test from the Battery of Adult Reading Function (BARF) (Rothi, Coslett and Heilman, 1984) in which he was asked to write 40 dictated homophones under two conditions. In one condition, a sentence containing the homophone was subsequently dictated to the patient, while under the second condition the patient was shown a picture in order to help him distinguish the homophone. Eight of these homophones were the same as those in the homophone spelling test. The results of this comprehension testing revealed that Patient 3's ability to spell the correct homophone improved when the dictated homophone was accompanied by a picture rather than a dictated sentence.

In the Roeltgen et al. (1986) study, Patient 4 was asked to spell 100 homophones under three conditions:

first, as in the homophone spelling test; second, the dictated homophone was accompanied by a picture illustrating the correct homophone; and third, the dictated homophone was accompanied by a written sentence with a blank space where the homophone belonged. Patient 4 was also asked to choose the correct written homophone either when a sentence containing the homophone was dictated to him or when he was shown a picture of the homophone. Patient 4 was asked to choose the correct pictured homophone either when he was shown the written homophone or when the homophone was spelled to him. Target homophones were the same 100 as in the homophone spelling task. Patient 4 had difficulty spelling homophones in all conditions. In addition, except when asked to choose the correct picture when reading a homophone, he was barely above chance when asked to choose written homophones or pictures.

For Patient 5 of the Roeltgen et al. (1986) study, a subset of the homophones from the homophone spelling test was used in the same way as the BARF (Rothi et al., 1984) was used for Patient 3. In addition, for each of his 28 incorrect responses on the homophone spelling test in which he correctly spelled a semantically incorrect response, he was asked to supply a sentence synonymous with the stimulus sentence, or in some other way demonstrate comprehension of the dictated sentence. Patient 5 demonstrated comprehension of all but three of these sentences. Even so, he produced

semantically incorrect homophones on most trials. Additionally, when Patient 5 spelled homophones, there was no difference in his performance when the semantic stimulus was a picture versus a dictated sentence.

Roeltgen, Rothi and Heilman (1986) interpreted the spelling performances of these five patients as evidence that the spelling of irregular words can be accomplished even when the words are not contextually attached to a meaning (p. 274). They argued that "because irregular words are products of the nonphonological or lexical-semantic spelling system, and because the incorporation of meaning into language is a product of semantics, these results also demonstrate that what has been termed the lexical-semantic system can be dissociated from semantics" (p. 274). They proposed that "this dissociation and loss of semantic influence on writing . . . be termed linguistic semantic agraphia" (p. 274). This supported their previous report in the literature (Roeltgen, Rothi and Heilman, 1982b). However, they noted that "although all five patients showed the same general behavioral disorder (production of semantic errors on the homophone spelling test), the functional disruption differed among the three patients tested in detail" (p. 276). Roeltgen, Rothi and Heilman (1986) noted that semantic agraphia does not seem to have a specific anatomic locus but has a relatively specific functional association in that it is associated with comprehension

disturbance seen in transcortical sensory or mixed aphasias. They described this association as involving lesions in the anatomic substrates important for language comprehension (p. 279).

In another spelling study, which primarily examined the anatomic and behavioral dissociability of lexical and phonological agraphias, Roeltgen and Heilman (1984) noted that three of their patients with lexical agraphia often correctly spelled a homophone that was incorrect for the semantic context. These patients were reportedly able to supply the meaning for the word they were unable to spell. Roeltgen and Heilman (1984) interpreted these findings as evidence that "some words were spelled despite an inability to use their meanings in written output, and preserved knowledge of the words' meanings . . ." suggesting "at least a partial disruption of the semantic influence on spelling ability" (p. 822). These authors had previously suggested that the lexical system can be dissociated from semantic influence by destruction of semantic ability or disruption of the neural pathways by which the semantic area influences spelling ability (Roeltgen, Rothi and Heilman, 1982b).

Further support for the direct lexical nonsemantic spelling routine was presented by Goodman and Caramazza (1986a). They attempted to discriminate between what they termed the "Direct Nonsemantic Access Hypothesis" (i.e., operation of a direct lexical spelling route) and the

"Indirect Access Only Hypothesis" (i.e., lexical spelling representations must be accessed via the Semantic System) by studying the manner in which their patient spelled homophones differentiated by the appropriate sentence context. They concluded that the pattern of spelling errors produced by JG, a closed head injury patient, reflected the use of a direct lexical nonsemantic spelling route.

Goodman and Caramazza (1986a) predicted that because high frequency words are thought to be more easily retrieved from the Graphemic Output Lexicon than low frequency words, that different patterns of performance would result when various combinations of high and low frequency homophones were presented as test items. They tested their patient's spelling performance for 60 homophone pairs: 17 pairs in which both members were high frequency words (HH), 17 pairs in which both members were low frequency words (LL) and 26 pairs in which one member was a high frequency word while the other member was a low frequency word (HL). The examiner auditorily presented a homophonic word immediately followed by a short definition and finally again by the presentation of the homophonic word. The patient was instructed to write only the target word and not the definition.

According to the Direct Nonsemantic Access Hypothesis, Goodman and Caramazza predicted that many homophone

substitutions would occur for the HH conditon because the two homophone spellings would have an approximately equal chance of being activated in the Graphemic Output Lexicon. When both members of the homophone pair were low frequency words (LL), Goodman and Caramazza predicted that neither would be accessible in the Graphemic Output Lexicon and so a response would be assembled by the sublexical phonological routine. Errors which they predicted in this case would be phonologically plausible nonword responses (e.g., "korse" for "course") rather than the alternative homophonic spelling (i.e., "coarse"). Lastly, in the HL condition, the Direct Nonsemantic Access Hypothesis would predict that the high frequency member of the pair would be activated when either of the two semantic contexts was given, resulting in a homophone substitution error.

As the Direct Nonsemantic Access Hypothesis had predicted, Goodman and Caramazza found that their patient did often make homophone substitutions in the HH and the HL conditions. Also as predicted, if both the members of the homophone pair were low frequency words, the patient often produced phonologically plausible nonword errors.

In what Goodman and Caramazza (1986a) called the clearest refutation of the Indirect Access Only Hypothesis, J.G. produced a substantially higher percentage of phonologically plausible errors for the LL pairs than for the low frequency members of the HL pairs. If the Indirect

Access Hypothesis were correct, they had predicted that there should be no difference in the percentage of phonologically plausible errors produced for low frequency members of one type of homophone pair compared to low frequency members of another type of homophone pair. Goodman and Caramazza (1986a) also cited the fact that few errors were produced for high frequency homophones as evidence in support of the Direct Nonsemantic Access Hypothesis.

Goodman and Caramazza (1986a) concluded that JG's pattern of errors was incompatible with the idea that the Graphemic Output Lexicon can only be addressed from the Lexical-Semantic System. Instead, they described JG's performance as support for the theory that graphemic representations can be accessed directly from the Phonological Input Lexicon.

Another patient whose spelling performance seemed to reflect disruption of semantic influence upon lexical processing was Patient TP (Hatfield and Patterson, 1983). TP became a phonological speller after brain damage. However, TP did not always seem to be spelling by sound alone, as evidenced in his ability to spell irregular words, or to produce errors reflecting partial lexical knowledge of irregular spellings. Of interest to this discussion was TP's occasional production of homophone substitutions when he was asked to write a homophone, even when the context

made it perfectly clear which meaning was meant. Of importance (Ellis and Young, 1988, p. 178) is the fact that sometimes the homophonic misspellings were themselves irregular spellings. Ellis and Young (1988) suggest that patient TP's production of homophone errors may reflect input to the Graphemic Output Lexicon from the Phonological Output Lexicon.

Ellis and Young (1988, p. 204) note that further evidence for the existence of direct nonsemantic lexical processing routes is provided by studies of normal subjects. For example, Warren and Morton (1982) have argued that a direct lexical nonsemantic reading route may account for a difference in the way normal people process words versus pictures. In a speeded task by Potter and Faulconer (1975), normal subjects were asked to classify written words or pictures as living or non-living or, alternatively, to name the words or pictures. Normal subjects responded to pictures faster than written words in the classification task, but, in the naming task, written words were named faster than pictures. Warren and Morton (1982) proposed that pictures access the Semantic System faster than do words. They accounted for the difference in performance for the naming and the classification tasks by the presence of a direct route between the Orthographic Input Lexicon and the Phonological Output Lexicon which allows words to be named

rapidly, whereas the naming of pictures must proceed via a slower route through the Semantic System.

Lesser (1989) reported the case of a mild multi-infarct dementia patient, TF, who was able to spell single words very well orally, but was impaired in all other language functions except repetition. Lesser proposed that TF's performance suggests a dissociation of his "orthographic system" and his Semantic System because he showed several examples of a disparity between his definition of a homophone and his spelling of it (i.e., relatively good oral spelling in the presence of a severe semantic impairment)(p. 247). Lesser also interpreted his performance as suggesting that oral and written spelling are derived independently from orthographic representations more central than the Graphemic Buffer.

For a list of 22 homophones, TF was asked to spell the homophone and then to give the homophone's definition. Among his errors were examples in which he spelled a homophone one way but then defined it the alternate way. He also produced spelling errors which were nonwords. He gave as many less frequent spellings of the homophone as more frequent (Francis and Kucera, 1982).

Lesser (1989) points to several examples in TF's performance of apparent activation of the Graphemic Output Lexicon. First, TF demonstrated partial lexical knowledge in some of his misspellings of irregular words. Second, TF

did succeed in spelling 8/20 irregular words correctly. Third, assuming that severe impairment of the Graphemic Output Lexicon would affect low frequency items more than high frequency items, Lesser cites the lack of a frequency effect in TF's spellings of homophones as evidence that the Graphemic Output Lexicon is not severely damaged. (We will assume that Lesser's conclusion here must be based on a high accuracy of spelling performance by TF for both high and low frequency words, not on a low accuracy of spelling performance for both high and low frequency words. The latter pattern of performance would indicate damage to the Graphemic Output Lexicon.)

Further evidence cited by Lesser (1989) for TF's use of the Graphemic Output Lexicon was that TF was able to give the names of 6/11 irregularly spelled words when they were presented to him auditorally letter-by-letter. When TF was given letter sounds instead of letter names, he was only able to name short regular words, and used a strategy of converting the letter sounds into letter names. Lesser interpreted this as evidence for only minimal reliance on a phoneme-to-grapheme conversion process for spelling regular words. Additionally, Lesser reported that TF was able to name some items of the Boston Naming Test (Goodglass, Kaplan and Weintraub, 1983), which he had previously been unable to name, if he was simultaneously presented with the letter names for the items and the test picture. Lesser concluded,

therefore, that there did appear to be some facilitation of semantic retrieval through prompting of the Graphemic Output Lexicon by presentation of letter names (but not by presentation of letter sounds).

TF did show an imageability effect and a regularity effect in his spelling. He showed an effect of regularity with 15/20 regular words spelled correctly compared with 8/20 correct irregular words, on a list matched for frequency. He showed an effect of imageability with 16/20 correct spellings of high imageability words compared to 7/20 accurate spellings of low imageability words, when word frequency was controlled. Lesser interpreted this as evidence that retrieval from TF's impaired Semantic System was easier for highly imageable meanings. TF reportedly showed no evidence of a grammatical class effect in his oral spelling. Lesser interpreted this as further evidence for the reduction of semantic influences on TF's spelling, reasoning that content words carry more semantic information than words of other grammatical classes. It should be noted that Lesser (1989) and Patterson (1986) express different views in regard to imageability and regularity effects. Patterson (1986) describes one characteristic of direct nonsemantic spelling as the absence of an imageability or regularity effect in spelling. Lesser (1989), on the other hand, describes TF as demonstrating the use of a direct

nonsemantic spelling route, but reports that TF did show an imageability effect and a regularity effect in his spelling.

The integrity of TF's Semantic System was tested through use of an auditory word-selection task, an auditory sentence judgement task and a task in which he was required to give definitions for homophones. In the auditory word-picture selection task, TF selected the correct picture for the target word 12/40 times from an array including four distractor pictures. Lesser described this pattern as an indication of a severe disturbance in making semantic discriminations. In a semantic categorization task, TF showed some retention of category information and scored above chance (15/20 correct). In order to examine TF's semantic abilities further, Lesser administered an auditory sentence judgement task. Although the total number of items in this task was not reported, Lesser did report that TF judged eight semantically anomalous sentences as correct. TF was further asked to give definitions to 22 homophones. He was asked to spell them first so that the examiner could establish which meaning TF should be expected to access in his Semantic System. In this task, TF gave as many less frequent spellings of the homophones as more frequent. For at least three test items, TF gave a definition for the alternative meaning of the word he had spelled (e.g. "s-t-a-k-e": "a steak of a dinner"). Lesser stated that the route TF was using for oral spelling of homophones "was not

necessarily through semantics" (p. 243), even though she interpreted 12 of his definitions as reflecting "at least some diffuse awareness of the meaning of the word" (p. 243).

Lesser (1989) also notes that another patient, briefly described by Wapner and Gardner (1979), demonstrated a spelling pattern similar to TF. This patient, a transcortical sensory aphasic, was reportedly able to spell effortlessly despite a severe loss of language comprehension.

Schwartz and Chawluk (1990, p. 256) note that single-word oral reading is often preserved in degenerative dementia patients who demonstrate word retrieval problems (Nelson and O'Connell, 1978; Schwartz, Saffran and Marin, 1980). They suggest that this is evidence of well-retained access to output phonology while the word retrieval deficit is located more centrally (i.e., in semantic access to the output lexicon or within semantics).

Summary

These reports of performance on a variety of lexical processing tasks by normal and pathologic populations seem to suggest that the spelling of irregular words can sometimes be accomplished without semantic mediation. This pattern would support the existence of a direct nonsemantic lexical processing routine for spelling. However, there are other researchers who are critical of this theory and find other ways to explain the spelling performances of the

subjects described above. We turn, in the next section, to a consideration of these alternative views.

Evidence Against Direct Lexical Spelling

The conclusion that a direct nonsemantic lexical routine for spelling must exist has been described as "weak" by several authors (Howard and Franklin, 1988; Ellis and Young, 1988; Hillis, Rapp, Romani and Caramazza, 1990; Hillis and Caramazza, 1991). It has been challenged in particular by Hillis et al. (1990) and Hillis and Caramazza (1991). They argue that the evidence for the lexical asemantic route is weak for two main reasons: First, the researchers in studies purporting to give evidence for the direct nonsemantic route have failed to establish the complete abolishment of semantics in their patients. Item-specific comprehension was not demonstrated for those irregular words that were spelled correctly. Second, a combination of partial cues from the semantic system and from the nonlexical phonological route could explain the performance of these patients.

Hillis, Rapp, Romani and Caramazza (1990) argue that they are not convinced by the evidence provided in support of theories of direct lexical reading and writing. They propose an alternative account of the existing data. Hillis et al. (1990) challenge the interpretations of the data from several reading studies which supported a direct lexical nonsemantic reading route (Schwartz, Saffran and Marin,

1980; Shallice, Warrington and McCarthy, 1983; Bub, Cancelliere and Kertesz, 1985; McCarthy and Warrington, 1986). In these studies, patients were reported to be able to read some irregular words correctly despite very impaired comprehension. Hillis et al. (1990) argue that these patients may have been able to obtain partial semantic cues in addition to partial phonological cues from the sublexical reading route. They argue that the combination of these two sources of information could "block" semantic paralexias. They cite patient KE as an example of a patient who had the general pattern of performance reported for "nonsemantic" readers, but who was able to read all words for which he demonstrated <u>some</u> comprehension. Hillis et al. (1990) suggested that this patient's performance, and those of the patients who had previously been described as "nonsemantic" readers, could be attributed to the combination of partial cues from a partially preserved Semantic System and the nonlexical phonological route.

The explanation Hillis et al. (1990) put forth for "nonsemantic" reading is similar to their explanation for "nonsemantic" spelling. They describe case reports in support of the direct lexical nonsemantic spelling route (Baxter and Warrington, 1987; Goodman and Caramazza, 1986b; Patterson and Shewell, 1987) as instances in which the patients demonstrated high reliance on phonology-to-orthography conversion procedures, as well as some (if not

perfect) understanding of spoken words. Hillis et al. (1990) maintain that even in cases where the nonlexical spelling route was impaired (e.g., Kremin, 1987), the nonlexical spelling procedures were sufficient to "block", at the level of the Graphemic Output Lexicon, semantically related words activated by a partial semantic representation. Hillis et al. (1990) cite as further evidence for their theory the fact that nearly all of the words spelled correctly by Kremin's patient were reportedly understood perfectly or at least partially. Thus, Hillis et al. (1990) argue that the data and the arguments which support the existence of lexical nonsemantic procedures for reading and spelling are not compelling.

Underlying the arguments of Hillis et al. (1990) are assumptions about the representation and processing structure of the Semantic System. They make the assumption that the Semantic System represents information in terms of sets of predicates referring to perceptual, functional, and relational attributes of a term. According to Hillis et al. (1990), they make the further assumption that the Semantic System may be selectively impaired so that only <u>some</u> of the predicates are affected, resulting in an incompletely specified semantic representation for a term.

Hillis and Caramazza (1991) reported the performance of a left hemisphere stroke patient, JJ, whose oral reading of words exceeded his naming and comprehension performance for

the same words. Rather than presenting this case as evidence for a direct lexical nonsemantic reading route, Hillis and Caramazza (1991) reported two results that they argue provide evidence against the existence of a direct route. First, although Patient JJ accurately read aloud all orthophonologically regular words, JJ was able to read only those irregular words for which he demonstrated <u>some</u> comprehension (as indicated by correct responses OR within-category semantic errors in naming and comprehension tasks). Secondly, for words that JJ did not understand at all (but did recognize as words), his reading errors were phonologically plausible (e.g., "soot" read as "suit"). Hillis and Caramazza (1991) proposed that JJ's performance was the result of the combination at the level of the Phonological Output Lexicon of partially preserved semantic information and information from the nonlexical grapheme-to-phoneme conversion process. They presented similar arguments for the interaction of nonlexical procedures with the Graphemic Output Lexicon during the process of spelling.

The argument of Hillis et al. (1990) and Hillis and Caramazza (1991) seems in part based upon the ideas of Howard and Franklin (1988, p. 124). Howard and Franklin say that the notion of combining information from the two processing routines can explain why their patient MK does not make semantic errors in reading. They describe the output of a degraded Semantic System as resulting in the

activation of a range of semantically related word forms in the output lexicon, including the correct word (cf Howard and Orchard-Lisle, 1984). They describe the nonlexical phonological route as providing, for regularly spelled words, information that is consistent with the correct response. With this combined activation, Howard and Franklin (1988) maintain that it is likely that the correct word form will be produced. They propose that the nonlexical route will never support the production of semantic errors, so there would not be sufficient activation for them to be produced. Howard and Franklin (1988) note that as words become more and more irregular in terms of spelling to sound correspondence, there will be less and less support from the nonlexical route for their production. Thus, Howard and Franklin (1988, p. 125) have proposed that any evidence for the direct nonsemantic route would have to take into account how different sources of PARTIAL information could interact in producing a response.

Ellis and Young (1988) proposed that an impairment to the phoneme-to-grapheme conversion mechanism is necessary for the production of semantic spelling errors. They reason that one patient, JC, would not have written CLOCK for TIME or CHAIR for DESK if intact phoneme-grapheme conversion procedures could have treated TIME and DESK as nonwords and at least generated 't' as the only likely initial letter for TIME and 'd' as the only likely initial letter for DESK" (p.

176). Ellis and Young (1988) write that they are not arguing that this route prevents semantic errors in normals, but that an impairment to the phoneme-to-grapheme translation process must be present AS WELL as an impairment in the transmission of information from the Semantic System to the Graphemic Output Lexicon before semantic spelling errors will occur.

Ellis and Young (1988, p. 202) noted alternative explanations to the combination of partial cues theory in the instance of reported intact writing to dictation without comprehension in "word meaning deafness". One alternative possibility they described is that semantic units do mediate the transfer from input to output even though the patient cannot act upon the products of semantic processing to indicate comprehension in a task such as category-sorting. They cited a study of reading in Alzheimer's patients by Nebes, Martin and Horn (1984) in which patients who showed little conscious understanding of written words could read words like BREAD aloud more quickly if they had just read BUTTER rather than an unrelated word. Ellis and Young (1988) concluded that if it is established that demented patients are able to access semantic representations for which they have no conscious awareness, then cases of apparent reading aloud without comprehension (e.g., Patient WLP from Schwartz, Saffran and Marin, 1980), could not

provide evidence for a direct nonsemantic route for reading aloud.

Summary

The existence of a direct nonsemantic lexical spelling route is, then, currently a controversial theory in the literature. Researchers on both sides of the issue have cited evidence from normal and pathologic populations, including patients with dementing disease (Lesser, 1989; Nebes et al., 1984). Further studies of the spelling abilities of one subgroup of dementia patients, those with Alzheimer's disease, will be discussed in the next sections.

Alzheimer's Disease

Neuropathologic and clinical features

Alzheimer's disease (AD) is the most common type of dementia in the elderly and the fourth leading cause of death among the elderly in the United States (Cummings, 1990). AD is heterogeneous in its clinical presentation and course (Boller, Becker, Holland, Forbes, Hood and McGonigle-Gibson, 1991). This diversity is thought to reflect the differential involvement of neural systems that support cognition (Damasio, Van Hoesen, and Hyman, 1990; Chawluk, Grossman, Calcano-Perez, Alavi, Hurtig and Reivich, 1990). The cause of AD is unkown, but research suggests that AD may be inherited in an autosomal dominant pattern (Kertesz, 1990). Although a particular genetic or molecular cause of the disease has not been identified, genetic linkages have

been found to chromosome 21 (St. George-Hyslop, Tanzi and Polinsky, 1987).

Progressive decline in two or more major areas of cognition that cannot be attributed to other known diseases is the basis for identification of AD clinically. Histopathologic evidence of neurofibrillary tangles and neuritic plaques in concentrations that exceed age-graded thresholds (Damasio, Van Hoesen, and Hyman, 1990) confirms the diagnosis from biopsy or autopsy (Schwartz, 1990). Connectivity among cortical regions is disrupted in AD due to the development of neurofibrillary tangles and the consequent neuronal loss and disruption of normal cellular anatomy. The role of neuritic plaques in the disruption of normal anatomy is less clear. Even less understood changes in AD include Hirano bodies, granulovacuolar degeneration, and cell loss (Damasio, Van Hoesen and Hyman, 1990).

Damage to cerebral cortices in AD is most pronounced in the higher-order association cortices (e.g., Lewis, Campbell, Terry and Morrison, 1987; Pearson, Esiri, Hiorns, Wilcock and Powell, 1985). Pathology in layers III and IV of association cortices is thought to disrupt the feedforward and feedback projections among cortical areas of different hierarchies (Damasio, Van Hoesen and Hyman, 1990).

The neuropathological defects in AD occur gradually, selectively affecting neural structures in terms of brain regions, the laminae within the regions, and even the cell

types within the laminae (Damasio, Van Hoesen and Hyman, 1990). Neuritic plaques (NP) in AD appear earliest and in the greatest densities in the mesial temporal lobe, especially in the subicular region (Davies, Wolska, Simms, Kakulas, Masters, Hilbich, Multhaup and Beyreuther, 1988; Kalus, Braak, Braak, and Bohl, 1989).

The profile of impaired and intact functions in AD varies across AD patients, with the relatively selective involvement of some cognitive processes compared to others. However, in the most typical cases of AD, the patients show an initial impairment of learning and recall of newly presented information in verbal and nonverbal domains. This difficulty is closely followed by the development of lexical/semantic, visuoperceptual, and visuospatial dysfunctions. Problem solving is eventually impaired, as are emotion and affect. Nearly all cognitive systems are impaired in the advanced stages of AD (Damasio, Van Hoesen and Hyman, 1990). Most commonly, patients with AD continue to be able to learn new perceptualmotor skills until the very late stages of the disease (Eslinger and Damasio, 1986).

Impairments in lexical retrieval and naming have been consistently associated with AD (Bayles and Tomoeda, 1983; Critchley, 1964). Many researchers maintain that linguistic changes are critical to the diagnosis of AD (Huff, 1990; Appell, Kertesz and Fisman, 1982; Obler and Albert, 1981;

Faber-Langendoen, Morris, Knesevich, LaBarge, Miller and Berg, 1988).

In the early stages of AD, language deficits may be noted in word-finding ability, discourse analysis, vocabulary, descriptive power, and reading comprehension. Speech may become slow and perseverative (Huff, Corkin and Growdon, 1986). Moderately impaired AD patients show extensive perseveration and decreased precision in speech content (e.g., increased circumlocutions) (Hier, Hagenlocker and Shindler, 1985). At this stage, deficits occur in writing, and in auditory and visual-orthographic comprehension (Schwartz, Marin and Saffran, 1979), but syntax and use of phonological information are well-preserved. In the severe stages of AD, patients show profound impairment of language comprehension and production. They may become mute or echolalic; others show relatively good production with meaningless content (Cummings, 1990). Impairments of memory or attention may underly some language errors in AD (Hartman, 1989).

A deficit in semantic memory is regarded as central to the communication problems of AD patients (Bayles and Kaszniak, 1987), but the nature of the disturbance is not entirely clear. AD patients perform poorly on many tests of explicit memory (e.g., story recall) but they may perform normally on some tests of implicit memory (e.g., motor or perceptual skill learning or repetition priming) (Cronin-

Golomb, Corkin and Rosen, 1991). Some studies have suggested deterioration of conceptual representations in semantic memory, while reports of intact semantic associative priming in AD (Nebes, Martin and Horn, 1984; Nebes, Boller and Holland, 1986) have been interpreted as proof that task impairments reflect only a deficit in accessing intact representations. Diesdfeldt (1989) concluded that AD patients have both degradation of semantic representations and difficulty in access, which is not item-specific. Chertkow, Bub and Seidenberg (1989), on the other hand, found that there was pathologically increased semantic priming specific to items whose representations were degraded, as shown by difficulty in naming and semantic recognition tasks.

The semantic memory disturbance in AD may be characterized by disrupted organization of or access to specific attributes that distinguish different lexical concepts within broad semantic categories (Grober, Buschke, Kawas and Fuld, 1985; Huff, Corkin and Growdon, 1986; Martin and Fedio, 1983; Warrington, 1975). Such a change in semantic organization could affect the encoding of new information into both semantic memory and episodic memory (Grober, Buschke, Kawas and Fuld, 1985). Hartman (1989) reported that attentional deficits in AD patients seem to interfere with the normal use of semantic knowledge as an

organizational retrieval strategy (e.g., Weingartner, Kaye, Smallberg, Ebert, Gillin and Sitaram, 1981).

Damasio et al. (1990) emphasize that the semantic memory processing deficit in AD assumes proportions never seen with other amnesic syndromes. They also note that the impaired performance of AD patients in retrieval of semantic memory is far more erratic than those of patients with other kinds of amnesia, in that a response to a given stimulus is more likely to be "an unrelated derailment across semantic fields" (p. 93). Cummings (1990) and Kertesz (1990) note that the increasing sophistication of memory testing in recent years has led many researchers to the conclusion that the principal problems in semantic memory processing in AD are impaired storage and rapid forgetting of learned information rather than an encoding deficit.

Spelling in Alzheimer's Disease

The spelling and writing abilities of AD patients have become a topic of greater research interest in recent years (Smith, Green and Tardelli, 1988; Glosser and Kaplan, 1989; Neils, Gerdeman, Boller and Cole, 1989; Rapcsak, Arthur, Bliklen, and Rubens, 1989; Smith, Snyder and Meeks, 1990). This research is of interest not only for what it may reveal about language deterioration in Alzheimer's disease but also for what it may reveal about normal spelling and writing.

Bayles and Kazniak (1987) documented the deterioration of writing abilities in the early stages of Alzheimer's

disease. Folstein and Breitner (1981) found a significant relationship between agraphia (i.e., "failure to write a sentence") and family history of AD. Cummings, Benson, Hill and Read (1985), found that narrative writing had the most abnormal mean score of the 37 language subscales they administered to 30 AD patients.

Rapcsak, Arthur, Bliklen and Rubens (1989) studied the ability of 11 AD patients to 10 normal subjects in writing single words to dictation. Subjects in this study were asked to write 30 words in each of four categories (i.e., regular words, irregular words, pronouncable nonwords and functors). The regular and irregular word lists were matched for length and frequency of occurrence. Five of the AD patients were apraxic agraphics and were asked to spell the words orally.

The AD patients in the Rapcsak et al. (1989) study demonstrated a selective impairment of the lexical spelling system and a reliance on the phonological system (i.e., "lexical agraphia"). The AD patients spelled regular words and nonwords very well, but they were poor at spelling irregular words, and produced primarily phonologically plausible errors. Oral and written spelling performances were similar, suggesting core linguistic processes underlying both output modes. Rapcsak et al. (1989) interpreted these results as reflecting a loss of and/or an inability to access word representations from the Graphemic

Output Lexicon. They concluded that their study supported the view that language deterioration in AD predominantly affects lexical, semantic, and pragmatic abilities, while sparing phonological and syntactic processes.

In contrast to Rapcsak et al., (1989), Smith, Green and Tardelli (1988), in a study of spelling ability in AD, found many spelling errors which showed evidence of lexical influence, suggesting at least partial use of the lexical route. In a follow-up study, Smith, Snyder and Meeks (1990) tested the single word spelling abilities of 25 mildly to moderately impaired AD patients and 22 normal control subjects. Test stimuli consisted of short, medium and long words balanced for regularity and frequency of occurrence. The number of words in each category was similar except when there were not sufficient items in the language (e.g., long high-frequency items). A group of nonwords matched in length to the short words was also tested.

Smith et al., (1990) administered a three-choice recognition test to their subjects. The correct spelling of the target was presented along with a phonetic foil and a foil that had an omission error. The comprehension test was a "cloze" test in which a sentence was presented with a choice of three items to complete the sentence. The choices were made up of the target word and two items from the spelling list matched in length.

Smith et al., (1990) reported that both the AD and control groups performed significantly better on the recognition and comprehension tests as compared to the spelling test. Analysis of spelling errors involved scoring number of words correct and the number of errors within each incorrectly spelled word. Substitutions and omissions were the most prevalent error types. Of the substitutions by AD patients, 81% were phonetic; for controls, 79% were phonetic substitutions. All the AD patients in the study were able to spell many irregular words correctly. They also produced examples of intact lexical orthographic knowledge (e.g., "physiction" for "physician").

Smith et al. (1990) proposed that the spelling impairment in their patients was not at the level of the Graphemic Buffer as they might have expected in view of AD patients' memory problems. They reasoned that if the AD patients' primary deficit lay in the Graphemic Buffer, one would not expect them to show major effects of lexical factors such as frequency and regularity, nor a prevalence of phonetic substitutions. Further, they reasoned that a Graphemic Buffer deficit would predict a prevalence of memory-related errors such as transpositions and non-phonetic omissions. These error types were not prominent in their patients' spelling.

Smith et al. (1990) proposed a deficit in the interface between the Graphemic Output Lexicon and the Graphemic

Buffer as the locus of their AD patients spelling errors. They described the Graphemic Output Lexicon as receiving information from the Lexical-Semantic System and from the Phonological Input Lexicon (the direct nonsemantic spelling route). They accounted for their patients' good performances in the recognition and comprehension tasks by the operation of an intact Graphemic Output Lexicon. Thus, Smith et al. (1990) did find evidence for a deficit in the use of lexical orthographic information, but they suggested that this could be accounted for by the impairment in the connection between the Graphemic Output Lexicon and the Graphemic Buffer. They interpreted their AD patients' performances as consistent with mixed reliance upon lexical and phonological information. In addition to the deficit they have proposed, Smith et al. (1990) suggest that additional points within the spelling system may also be impaired in AD patients.

Glosser and Kaplan (1989) compared the writing performances of patients with focal and multifocal central nervous system disorders. Their study addressed three theoretical hypotheses that had been proposed to account for the linguistic disturbance in AD. The first of these hypotheses was that the language disorder in AD depends on degenerative changes in the classical language zones of the left hemisphere. They noted that implicit in this account is the notion that each of the cognitive/behavioral deficits

in AD reflects dysfunction in a focal neurological system. The second hypothesis described the language disorder in AD as a product of the multifocal nature of the underlying neuropathological changes in AD. This hypothesis suggests that the semantic disturbance and impairment in referential operations characteristic of AD reflects disruption of a diffusely organized neurolinguistic system. According to this hypothesis, unlike fluent aphasics, AD patients would not evidence impairment in modularized, syntactic-phonological operations. The third hypothesis states that the language disturbance in AD represents an exaggeration or quantitative extension of the linguistic changes observed with normal aging.

Glosser and Kaplan (1989) presented the same writing tasks (i.e., written confrontation naming, word dictation, word copying, written sentence completion, written sentence completion, sentence dictation and sentence copying) to 12 AD patients, ten fluent aphasic patients, and 32 normal control subjects. On several tasks that did not require volitional, organized, and contextually bound semantic processing and lexical search, the AD patients' performances were surprisingly intact. Paralinguistic problems in AD (e.g., "parasyntactic" errors in spontaneous writing) suggested that Hypothesis Two was correct. Hypothesis Three was not contradicted by the test results, but it was not conclusively supported (p. 376). Glosser and Kaplan (1989)

stated that the identification of these other neurologic systems (i.e., systems other than those localized in the classical language zones) deserves further investigation, as well as examination of their functional properties and further specification of their contribution to language processing.

Neils, Gerdeman, Boller and Cole (1989) studied the descriptive writing abilities of Alzheimer's disease patients in order to determine which characteristics occured more frequently in patients with AD than in age-matched controls. They analyzed 16 features of written linguistic ability. The presence of errors in writing in the elderly is not indicative of a pathological state (Chedru and Geschwind, 1972); however, it appears that certain errors are more characteristic of AD subjects than normal elderly subjects. Test results demonstrated that the AD subjects wrote shorter descriptive paragraphs than normal elderly subjects. Features related to letter or spelling errors and content words were found to be significantly different between the two groups, whereas functor word errors and the number of attempted corrections did not significantly differ between the two groups. Only the AD subjects repeated the content of the story.

Neils et al. (1989) suggested that further research on the writing abilities of AD patients is warranted because writing analysis could contribute to the early diagnosis of

AD, and because repeated measures during the progression of the disease would be a useful measure of deterioration in linguistic abilities (Holland, McBurney, Moossy and Reinmuth, 1985).

Summary

Spelling has been studied in Alzheimer's disease patients at the sentence, narrative and single-word levels. The spelling abilities of Alzheimer's disease patients may inform us as to the operation of spelling routines apart from normal semantic influence, as well as informing us as to characteristics of language deterioration in Alzheimer's disease. Some of the questions which remain in regard to spelling in Alzheimer's disease, and the rationale for this study, will be elaborated in the following section.

Statement of the Problem

Lexical processing routes for spelling have been proposed based upon evidence of spelling performance in patients suffering from dementing disease (Nebes et al., 1984; Lesser, 1989; Rapcsak et al., 1989; Smith, Snyder and Meeks, 1990; Glosser and Kaplan, 1989), as well as in other pathologic populations (Patterson, 1986; Roeltgen, Rothi and Heilman, 1986; Hatfield and Patterson, 1983; Goodman and Caramazza, 1986a), and in normal subjects (Hotopf, 1980; Ellis, 1982). It is generally accepted that normal spelling can proceed in either of two ways: 1) in an assembled, nonlexical routine which converts phonemes to graphemes

based upon "rules" of phoneme-to-grapheme correspondences in the English language, and therefore is able to compute unfamiliar words, regular words or nonwords, or 2) in an addressed, lexical-semantic routine which can compute familiar regular and irregular words and which calls upon stored memories of familiar words and their meanings in order to access representations of spelling (for an alternative view, see Campbell, 1983). The conceptualization of spelling procedures originally mimicked that of reading; however, important differences between the processes of spelling and reading (Henderson and Chard, 1980; Hatfield and Patterson, 1983) preclude wholesale borrowing of reading theories for spelling research. Still, several issues important to the current understanding of spelling do parallel similar issues in reading research. One of these issues is the question of the existence of a direct, lexical nonsemantic processing routine for spelling or reading. A small body of literature has developed which argues for the existence of such a direct routine in spelling (Lesser, 1989; Goodman and Caramazza, 1986a; Roeltgen, Rothi and Heilman, 1986; Patterson, 1986) and in reading (Coltheart and Byng, 1983; Schwartz, Saffran and Marin, 1980a; Shallice et al., 1983; Bub, Cancelliere and Kertesz, 1985; McCarthy and Warrington, 1986; Funnell, 1983; Coltheart, 1985). However, the evidence supporting such a view is not strong (see Howard and Franklin, 1988, p. 124

for a discussion) and has been criticized particularly by Hillis et al. (1990) and Hillis and Caramazza (1990).

The specific intent of this study was to examine the spelling abilities of Alzheimer's disease patients in light of the described controversy about normal spelling routines. Because the general consensus is that AD results in impairment of the Semantic System, patients with Alzheimer's disease are a good population in which to study the possibility of a lexical processing routine for spelling which operates apart from normal semantic influence. Also, Alzheimer's disease patients would seem to be more numerous clinically than patients with particular discrete brain lesions, thereby providing us the opportunity to study spelling performance within and across individual Alzheimer's patients. Spelling performance for carefully chosen stimuli was studied in several conditions as the production measure; the same stimuli were presented in comprehension tasks in an attempt to establish item-by-item comparisons of spelling performance and comprehension.

To date, studies of the spelling and writing abilities of AD patients have included such tasks as written discourse, written naming, writing single words to dictation, writing single words to dictation when a sentence context or definition is provided, and written naming of single irregular words, regular words and nonwords. The results of the few studies of this kind which have been

reported have not always been consistent (e.g., Rapcsak et al., 1989; Smith et al., 1990). The present study provides further information about the spelling abilities of AD patients, and thus contributes to current understandings of normal spelling and of Alzheimer's disease.

Hillis and Caramazza (1991) have claimed that the theory of the combination of partial semantic and nonlexical cues effectively weakens all of the arguments supporting the existence of a direct nonsemantic spelling route which have been reported in the literature. They propose that any evidence that a patient is able to spell irregular words that he cannot fully comprehend does not necessarily indicate the operation of a direct nonsemantic spelling route. The usefulness of theory of the combination of partial cues as an explanation for "direct" route spelling may be evaluated experimentally. The spelling of AD patients in this study may provide clues about the mechanisms underlying normal spelling, and may also provide interesting information about language deterioration in AD.

Given the body of information described above, and the theories of spelling breakdown in AD, we have made several predictions. First, we predicted that normal control subjects and AD patients would differ in their performance on the experimental tasks in this study. That is, we predicted that control subjects would perform well on all tasks requiring semantic mediation in spelling and in

auditory comprehension, while AD patients would perform poorly on some or all tasks requiring semantic processing of stimuli. Based upon this prediction, we asked the following research question:

1) Do AD subjects demonstrate an impairment of spelling or auditory comprehension when compared to normal control subjects? The null hypothesis can be stated: AD subjects do not demonstrate an impairment of spelling or auditory comprehension when compared to normal control subjects.

Given the information that has been reported to date regarding spelling and comprehension abilities in AD, we made our second prediction. We predicted that AD patients would demonstrate particular difficulty in performing spelling tasks which demand semantic mediation. Based upon this prediction, we asked the following research question:

2) Do AD patients demonstrate greater difficulty in performing spelling tasks which require semantic influence than in performing spelling tasks which do not require semantic influence? In turn, the null hypothesis can be stated: AD patients do not demonstrate greater difficulty in performing spelling tasks which require semantic influence than in performing spelling tasks which do not require semantic influence.

The characteristics of AD, and the controversy we have discussed regarding the existence of a direct nonsemantic spelling route, led to our third prediction. We predicted that AD patients might demonstrate lexical spelling apart from semantic influence. Based upon this prediction, we asked the following research question:

3) Do AD subjects demonstrate lexical spelling apart from semantic influence? Therefore, the final null hypothesis can be stated: AD subjects do not

demonstrate lexical spelling apart from semantic influence.

METHODS

The purpose of this study was to examine the nature of semantic influence on spelling. Comparisons were drawn within and across Alzheimer's disease patients, a population in which semantic memory is impaired, and normal control subjects on a variety of spelling and comprehension tasks.

Subject Description and Selection

The experimental group consisted of 12 men and women with a clinical diagnosis of probable Alzheimer's disease (AD). Subject selection was made based upon diagnosis by a physician as documented in medical records and in accordance with NINCDS criteria (McKhann, Drachman, Golstein, Katzman, Price and Stadlan 1984) (see Appendix A). The 12 experimental subjects were selected from the following sources in Florida: Shands Teaching Hospital, University of Florida, Gainesville (4 subjects); Upreach/Vista Pavilion, Gainesville (1 subject); and the Alzheimer's Resource Center, Winter Park (7 subjects). Descriptive information regarding each of the experimental subjects is provided in Table 2-1.

The control subject group was comprised of 12 healthy, neurologically-intact volunteers in the community. These subjects were matched as closely as possible to the

experimental subjects for age, sex and educational level. Descriptive information regarding each of the control subjects also is provided in Table 2-1.

Table 2-1: Experimental and Control Subject Identification

AD Subjects	Sex	Age	Edc.*	MDRS**	Control Subjects	Sex	Age	Edc.	MDRS
01	M	64	22	129	01	M	68	19	144
02	M	74	16	122	02	M	67	16	144
03	M	73	11	118	03	M	74	13	143
04	M	60	12	115	04	M	62	14	144
05	M	78	19	104	05	M	78	22	144
06	M	66	18	101	06	M	62	17	144
07	F	69	18	82	07	F	64	12	143
08	F	71	11	81	08	F	75	12	142
09	F	69	12	73	09	F	71	13	141
10	M	69	12	67	10	M	72	12	143
11	M	76	12	66	11	M	76	12	141
12	M	78	16	41	12	M	75	16	143

*Educational level in years
**Mattis Dementia Rating Scale (Mattis, 1973, 1988)

Both experimental and control group subjects were right-handed native English-speakers with no history of developmental reading or spelling impairment. All subjects had hearing and vision within normal limits, with or without correction (i.e., all subjects requiring hearing aids or

eyeglasses wore them during all test procedures). Individuals who had a history of prior neurological or psychiatric disease, or who were taking any psychoactive medications at the time of evaluation, were excluded from the study.

Screening Measures

All screening and experimental procedures were conducted for each subject individually by the same examiner. All procedures were conducted in a quiet room, with only the examiner and the subject present. The AD subjects were tested in one or two sessions, depending upon the distractibility and fatigue of the individual AD subject.

The first of the screening measures was the Mattis Dementia Rating Scale (MDRS) (Mattis, 1973, 1988), a mental status examination which covers five areas that are particularly sensitive to the behavioral changes that characterize AD. These areas are 1) Attention (digits forward and backward up to four; follow two successive commands); 2) Initiation and perseveration (e.g., name articles in supermarket); 3) Construction (e.g., copy a diamond in a square); 4) Conceptualization (e.g., identify which of three items is different); and 5) Memory (e.g., delayed recall of a five-word sentence). In this examination, the items in each subtest are presented in descending order of difficulty. This scale has high

internal reliability as indicated by "split-half" scoring of responses given by a group of elderly deteriorated patients (Gardner, Oliver-Munoz, Fisher and Empting, 1981). The Mattis Dementia Rating Scale scores for the experimental and control group subjects are listed in Table 2-1. Further information about AD group performance on the individual subtests of the Mattis Dementia Rating Scale (Mattis, 1973, 1988) is listed in Appendix B.

The short form of the Geriatric Depression Scale(GDS) (Yesavage, Brink, Rose, Lum, Huang, Adey and Leirer, 1983) was administered as a screening measure to all subjects. The original GDS is a 30-item instrument in a yes/no format developed from 100 popular questions commonly used to diagnose depression. The 15-item short version has also been validated. Because the test performance of a subject may be negatively affected by the presence of emotional depression, the two potential subjects classified as probably emotionally depressed by the GDS (i.e., scores of greater than 5) were excluded from the study.

Portions of the Western Aphasia Battery (WAB)(Kertesz, 1982) were administered to all AD subjects. The Auditory Comprehension subtest (i.e., yes/no questions, auditory word recognition and sequential commands) and portions of the Reading subtest were administered. Descriptive information regarding AD subject performance on these portions of the WAB is listed in Table 2-2.

Table 2-2: Western Aphasia Battery Subscores for AD Subjects

Subject	Auditory Comprehension Yes/No*	Wd Recog.*	Commands**	Total***	Reading Total*
01	57	59	80	9.80	52
02	60	60	80	10.00	60
03	60	59	72	9.55	46
04	60	58	80	9.90	57
05	60	60	80	10.00	60
06	60	59	80	9.95	60
07	60	53	28	7.05	60
08	57	58	45	8.00	45
09	51	60	63	8.70	60
10	57	60	33	7.50	52
11	60	59	28	7.35	60
12	42	41	6	4.45	13

* 60 points possible
** 80 points possible
*** 10 points possible

An informal hearing screening to test speech discrimination was conducted for all subjects as follows: the examiner verbally presented single words to each subject with no visual or tactile cues and at normal speaking volume, and the subject was instructed to repeat each word after the examiner. The word list presented by the examiner in this oral repetition task was comprised of 25 monosyllabic single words made up of phonemes which range

from the lowest to the highest in speech sound frequency (Causey, Hood, Hermanson and Bowling, 1984). Three potential subjects who were not able to repeat all of these words after the examiner were excluded from the study.

Experimental Procedures

The experimental procedures consisted of spelling to dictation and auditory comprehension tasks. The order of task presentation followed one of two sequences (i.e., Form A and Form B), and half of the subjects (i.e., six AD subjects and six control subjects) received each test form. Both Form A and Form B presented the spelling tasks before the comprehension tasks, so that spelling performance could not be influenced by the information provided in the comprehension tasks. Also, the definition task was provided before the other comprehension tasks, so that performance on the definition task could not be influenced by the picture information provided in the other comprehension tasks. The test sequences for Form A and Form B were as follows:

Form A	Form B
1. spell nonwords	1. spell homophones
2. spell homophones	2. spell nonwords
3. definitions	3. definitions
4. picture comprehension	4. semantic associate comprehension
5. semantic associate comprehension	5. picture comprehension

Training items were given to familiarize the subjects to the tasks. None of the stimuli used in the training set were repeated within the experimental set.

For all experimental tasks, subjects were required to repeat the target word before performing the spelling or comprehension portion of the tasks. If the subject incorrectly repeated the target word, the examiner repeated the item and had the subject attempt to repeat the word again. If, after three presentations of the item, the subject continued to repeat the word incorrectly, the examiner allowed the subject to complete the spelling or comprehension portion of the response and then proceeded to the next test item.

Spelling Tasks

The following spelling tasks were administered to the experimental and control group subjects (total spelling items = 131). Spelling items within the nonword and homophone spelling lists were administered in random order to each individual subject.

Nonword spelling. Stimuli consisted of 30 nonwords which the subjects was required to repeat and then to spell to dictation. The subjects were instructed that the words dictated may or may not be real words. The stimuli for the nonword spelling task are listed in Appendix C.

Homophone spelling. Stimuli consisted of 30 pictureable homophone pairs (n=60) of which one member is regularly spelled and one is irregularly spelled, and for which there are only two possible spellings in English. The two members of each homophone pair were matched as closely

as possible for length. The homophone pairs used were of three types: those in which the regularly spelled word is higher in frequency than the irregularly spelled word (n=20), those in which the irregularly spelled word is higher in frequency than the regularly spelled word (n=20), and those in which the regularly and irregularly spelled words are of comparable frequency (n=20). The homophone stimuli for this task are listed in Appendix D.

Subjects were asked to repeat and to spell to dictation these homophones when a sentence context was provided. Each subject was presented with the target homophone, then with a short sentence containing the target homophone, and again with the homophone. The subjects were required to wait until this sequence has been completed before repeating and then spelling the homophone.

Fifteen (25%) of the homophones from the original list were presented a second time in the original sentence context. These additional 15 items were presented after all the homophone sentences had been presented once each, so that the 15 items served as a measure of a possible fatigue effect during the spelling task.

Nonhomophone spelling. Twenty-six nonhomophonic words were presented in sentence context as distractor items (13 regular and 13 irregular, balanced for length and frequency). The order of presentation of these additional 30 items was randomized throughout the list of homophone

spelling items. Identical items or two members of a homophone pair were not presented consecutively in the spelling list. These nonhomophonic spelling stimuli are listed in Appendix E.

Auditory Comprehension Tasks

The following three comprehension tasks were administered to all subjects. The comprehension tasks targeted the same 30 homophone pairs used in the spelling task (n=60; total comprehension items=180). The same sentence contexts used in the spelling task were used in all comprehension tasks. The sentence stimuli for the comprehension tasks are listed in Appendix D.

Word-picture matching task. Each target word was presented auditorily, then used in the sentence context, and then repeated alone. The subject was required to wait until this sequence has been completed, then to repeat the word and to select from an array of four pictures the one picture which most closely represented the target word.

The four pictures presented for each item in this task included: a) the correct homophone (e.g., him), b) the incorrect homophone (e.g., hymn), c) a semantic distractor to the correct homophone (e.g., woman), and d) one of the following: a phonemic distractor to the correct homophone, a visual distractor to the correct homophone, or an unrelated distractor. Therefore, it always was possible to choose the incorrect homophone or a semantic distractor, and

it was possible on 20/60 items to make either a phonemic error, a visual error or an unrelated error.

Semantic associates task. Each target word was presented auditorily, then used in the sentence context, and then repeated alone. The subject was required to wait until this sequence had been completed, then to repeat the word and to select from an array of four pictures the one picture which is most closely semantically associated with the target word.

The four pictures presented for each item in this task included: a) a semantic associate of the correct homophone (e.g., a tie for "him"), b) a semantic associate of the incorrect homophone (e.g., church for "hymn"), c) a semantic distractor of the correct semantic associate (e.g., a dress), and d) one of the following: a visual distractor to the correct semantic associate or an unrelated distractor. Therefore, it always was possible to choose a semantic associate of the incorrect homophone or a semantic distractor of the correct semantic associate, and it was possible on 30/60 items to make either a visual error or an unrelated error.

Definitions task. Each target word was presented auditorily, then used in the sentence context, and then repeated alone. The subjects were required to wait until this sequence had been completed, then to repeat the word and to explain the meaning of the target word.

Scoring

Subject responses on the experimental auditory comprehension tasks were scored on-line by the examiner. Responses on the definition task were scored as correct if they reflected at least partial semantic knowledge of the correct homophone. For example, responses including information about semantic associates or superordinate semantic category were scored as correct; responses including information about the alternate homophone or unrelated words were scored as incorrect. This manner of scoring auditory comprehension tasks reflected the purpose of their inclusion in the study: to determine if at least partial semantic information about a homophone is available to the subject during any one of the three comprehension tasks in which it is presented.

Subject responses on the spelling tasks were audiotaped for later transcription and scoring by the examiner. Spelling responses were scored using a system developed by the examiner which characterized performance both in terms of homophone selection and of misspellings within the homophone selected (see Appendix F). This manner of scoring spelling responses reflected the research goal of characterizing the spelling error types produced by AD subjects as they compared to control subjects, and particularly those errors of homophone selection.

Thirty-three percent of subjects were randomly selected by the examiner and transcriptions of their spelling responses were scored independently by the examiner and by a second judge (interjudge reliability = 89.5%). The second scoring judge was trained by the examiner in the use of the scoring system during a four-hour training session. None of the spelling responses to be scored by the second judge were used as practice items during the training session.

RESULTS

This investigation had two general areas of interest: it was a study of Alzheimer's disease (AD), and how AD may affect auditory comprehension and spelling abilities; also, it was a study of spelling, and whether spelling can occur apart from semantic influence. Comparisons were drawn between control subjects and AD subjects, a population in which a possible dissociation between lexical spelling and semantic influence could be examined. To address the research questions and predictions stated in Chapter One, the data obtained in this study were evaluated with respect to the following comparisons: (1) differences in overall accuracy by group; (2) differences in error pattern by group; (3) differences across tasks within the experimental group; and (4) differences across tasks within individual experimental subjects. Experimental and control groups did not differ significantly in sex (each group had nine males and three females), age (AD group $x=70.6$, range 60-78; control group $x=70.3$, range 62-78; $F(1,22)=0.01, p<.92$) or educational level (AD group $x=14.3$, range 10-22; control group $x=14.8$, range 12-22; $F(1,22)=0.16, p<.69$).

Research Questions

Based upon a review of the literature suggesting progressively impaired semantic memory as the central neuropsychological disorder of early AD, and because auditory comprehension and correct homophone spelling require semantic processing, a disruption of these skills was predicted to occur in AD subjects. As described in Chapter One, the spelling and auditory comprehension tasks in this study were designed to assess the effect of this proposed semantic memory disruption on specific spelling and auditory comprehension abilities. We have examined AD and control subject performance on these tasks in light of the three research questions outlined in Chapter One.

Research Question 1: Do Alzheimer's disease patients demonstrate an impairment of spelling or auditory comprehension when compared to normal control subjects? The null hypothesis was stated: AD subjects do not demonstrate an impairment of spelling or auditory comprehension when compared to normal control subjects.

Three measures of spelling performance were used to detect spelling impairment: homophone spelling, nonhomophone spelling and nonword spelling. The mean accuracy scores of the AD group and the control group for each spelling task are listed in Table 3-1. Mean spelling accuracy scores when stimuli are grouped by word frequency and spelling regularity are also listed in Table 3-1.

In order to detect auditory comprehension impairment for the specific items in the homophone spelling task, three measures of auditory comprehension were administered:

auditory sentence-picture matching (hereafter referred to as "picture matching"), auditory sentence-semantic associate picture matching (hereafter referred to as "semantic associates"), and auditory sentence-definitions (hereafter referred to as "definitions"). The mean accuracy scores of the AD group and the control group for each auditory comprehension task are listed in Table 3-2.

Table 3-1: Mean Accuracy Scores by Group--Spelling

Task	Subject Group AD	Control
Homophone Spelling:		
Total	36/60***	56.3/60
Regular* High**	7.8/10	10/10
Regular Low**	6.3/10	9.8/10
Regular Close**	5.7/10	9.3/10
Irregular* High	6.6/10	9.3/10
Irregular Low	4.8/10	9/10
Irregular Close	4.8/10	8.9/10
Nonhomophone Spelling:		
Total	22.3/26	25.8/26
Regular High	6/7	6.9/7
Regular Low	5.5/6	5.9/6
Irregular High	6/7	7/7
Irregular Low	4.8/6	6/6
Nonword Spelling:		
Total	18/30	28.9/30

*Regular/Irregular refers to regularity of spelling
**High/Low/Close refers to frequency of word in the English language (for homophones, in relation to other member of homophone pair)
***Number attained out of number possible

Table 3-2: Mean Accuracy Scores by Group--Comprehension

Task	Subject Group AD	Control
Picture Matching	48.8/60*	59.4/60
Semantic Associates	37.9/60	55.9/60
Definitions	56.5/60	59.8/60

*Number attained out of number possible

An analysis of variance procedure was performed for each experimental task with accuracy scores the dependent variable and group the between subject factor. For each experimental task, there was a significant difference in overall accuracy between the two groups. The results of the two-group comparison using analysis of variance (ANOVA) procedures are listed in Table 3-3. Further information about the performance of individual AD group subjects for each experimental task is listed in Appendix G.

Research Question 2: Do Alzheimer's disease patients demonstrate particular difficulty in performing spelling tasks which demand semantic mediation as compared to spelling tasks which do not demand semantic mediation? The null hypothesis was stated: AD patients do not demonstrate particular difficulty in performing spelling tasks which demand semantic mediation as compared to spelling tasks which do not demand semantic mediation.

Semantic mediation was required in the homophone spelling task for correct selection of the appropriate homophone. Semantic mediation was not required in the nonword spelling task and may or may not have been required for the nonhomophone spelling task, depending upon whether

irregularly spelled nonhomophones can be spelled by a direct lexical route or must be processed by the semantic system.

Table 3-3: Means (and Standard Deviations) for Experimental Tasks by Group

Task	Group Means AD	Control	F Value (df=1,22)	p Value
Homophone Spelling	36.0* (12.3)	56.3* (4.2)	29.35	.0000**
Nonhomophone Spelling	22.3 (2.9)	25.8 (0.4)	17.51	.0004**
Nonword Spelling	18.0 (7.2)	28.9 (1.7)	25.92	.0000**
Picture Matching	48.8 (12.8)	59.4 (0.8)	8.15	.0092**
Semantic Associates	37.9 (13.2)	55.9 (1.4)	22.14	.0001**
Definitions	56.5 (2.7)	59.8 (0.4)	17.32	.0004**

*Based on raw scores
**Statistically significant

Percentages of difference from the control group performance were obtained for the AD group on each spelling task. For the homophone spelling task, the percentage of decrement in AD group performance as compared to control group performance was 36%; for the nonhomophone spelling task, the percentage of decrement was 13.6%; and for the nonword spelling task, the percentage of decrement was 37.8%. Thus, the AD group performed better in nonhomophone spelling (which may or may not require semantic mediation)

than in homophone spelling. However, the AD group performed as poorly in nonword spelling (which does not require semantic mediation) as in homophone spelling (which requires semantic mediation).

Therefore, there are two aspects to the results for Research Question 2. Overall, we can state that the null hypothesis was not supported, since AD subjects did have particular difficulty with homophone spelling as compared to nonhomophone spelling. However, nonword spelling was performed as poorly as homophone spelling, a finding that supports the null hypothesis.

Research Question 3: Do AD subjects demonstrate lexical spelling apart from semantic influence? The null hypothesis was stated: AD subjects do not demonstrate lexical spelling apart from semantic influence.

We predicted that Alzheimer's disease patients might demonstrate lexical spelling apart from semantic influence. To obtain evidence about the presence of partial semantic knowledge for specific spelling productions, we made within-subject comparisons of AD subject performance across auditory comprehension and homophone spelling tasks in an item-specific manner. We reasoned that the homophone spelling task could provide evidence supporting lexical nonsemantic spelling if an irregularly spelled homophone were produced in place of its regularly spelled homophone partner, and the subject did not show partial semantic knowledge of the meanings of the homophones during one of the auditory comprehension tasks. Evidence supporting the

lexical nonsemantic spelling route might also be provided even if partial semantic knowledge were not demonstrated in auditory comprehension tasks. However, information about partial semantic knowledge for these spelling productions was obtained in order to address one criticism (Hillis et al., 1990) of the theory of a direct lexical spelling route; that is, the criticism that spelling without semantic influence can be proven only if the abolishment of semantic knowledge for specific spelling productions has been established.

For the homophone spelling task, in 44/360 possible instances (12.2%), the AD group retrieved an irregularly spelled alternate homophone instead of the correct regularly spelled homophone (i.e., an irregular alternate homophone error). Of these errors, 34 were perfectly spelled and 10 contained minor misspellings, but each of the 44 errors reflected access of irregular spelling in the Graphemic Output Lexicon. Of these 44 irregularly spelled responses, there were no instances in which a subject was unable to demonstrate at least partial semantic knowledge for that irregularly spelled response in one or more of the auditory comprehension tasks. In contrast to the AD group, the control group produced irregular alternate homophone spelling errors in only 1/360 possible instances (.28%).

We reasoned that if homophone spelling must proceed via the Semantic System as the definitions task must, then

similar percentages of homophone misselection would be observed in the homophone spelling task and in the definitions task. While the AD group made 44/360 (12.2%) irregular alternate homophone errors in the spelling task, the AD group made only 6/360 (1.7%) irregular alternate homophone errors in the definitions task. This is evidence against the argument that homophone spelling must be accomplished via the Semantic System. That is, the AD patients often chose the incorrect spelling of the homophone in spite of the fact that they had partial semantic knowledge of both members of the homophone pair. In these instances, they did not seem to make use of that partial semantic knowledge in spelling; therefore, it seems they were using an alternative nonsemantic route for spelling.

It is interesting to note that when the regularly spelled and irregularly spelled alternate homophone errors were summed, the AD group made 111/720 (15.4%) alternate homophone selections in the homophone spelling task as compared to 13/720 (1.8%) in the definitions task. However, this comparison is not as informative as the comparison described above since some of the regularly spelled alternate homophone errors could have been processed via the nonlexical route.

Therefore, even though the AD subjects did demonstrate partial semantic knowledge of every irregularly spelled homophone produced as an alternate homophone error, we can

still argue that, in spite of this partial semantic knowledge, these irregularly spelled homophones may have been produced apart from semantic influence. This conclusion is in part based on the fact that alternate homophone errors occurred more frequently in the homophone spelling task as compared to the definitions task. Thus, the null hypothesis was not supported.

Additional Comparisons

In addition to the three research questions outlined above, we asked further questions about the nature of AD and control group performance:

1) How does severity of dementia relate to AD subject performance in experimental tasks?

Within the AD group, there was a significant correlation between dementia severity (as measured by the Mattis Dementia Rating Scale; Mattis, 1973, 1988) and performance on each of the experimental tasks. That is, for each of the experimental tasks listed in Table 3-3, as dementia severity increased, accuracy decreased. This was true for the homophone spelling task ($r=.7286$, $p<.005$), the nonhomophone spelling task ($r=.6167$, $p<.025$) and the nonword spelling task ($r=.6274$, $p<.025$). This significant correlation was also found for AD group performance in the picture matching task ($r=.8230$, $p<.0005$), the semantic associates task ($r=.6905$, $p<.01$) and the definitions task ($r=.7746$, $p<.005$).

2) Was a fatigue effect apparent in subject performance?

Of the three spelling tasks, we predicted that the homophone spelling task would be particularly difficult for the AD subjects. Therefore, we reasoned that AD subject performance in the homophone spelling task may reflect a fatigue effect.

We found that the AD group did demonstrate a relative fatigue effect in the homophone spelling task. Twenty-five percent of the homophone stimuli were administered a second time after the original homophone and nonhomophone stimuli had been administered. When the number of homophones spelled correctly in Time 1 but spelled incorrectly in Time 2 was calculated for each subject, the AD group had a significantly greater number of these responses than did the control group (AD group $x=-0.75$; control group $x=.000$, $F(1,22)=17.47$, $p<.0004$). The control group showed no evidence of a fatigue effect (i.e., only two control subjects made any errors in Time 2, and these errors were for words misspelled in Time 1). The statistically significant difference across groups in fatigue effect ($X^2=12.00$, $p<.0005$) is depicted in Table 3-4.

Although subjects in both groups produced incorrect responses in Time 2 that were different spellings than the incorrect responses in Time 1, in no instance did any AD or control subject spell a homophone correctly in Time 2 after

Table 3-4: Number of Subjects Showing Fatigue Effect by Group--Homophone Spelling

Performance Time 1 to Time 2	Subject Group AD	Control	TOTAL
Decreased	8	0	8
No Change	4	12	16
TOTAL	12	12	24

spelling it incorrectly in Time 1. Therefore, the AD group did demonstrate a relative fatigue effect in homophone spelling.

3) What error types characterized subject performance in the homophone spelling task?

In addition to determining group accuracy scores in the homophone spelling task, we wanted to know how the two groups compared in terms of specific error types. The frequency of occurrence of spelling error types by the AD and control groups in the homophone spelling task is listed in Table 3-5.

The error types most frequently produced by the AD group in the homophone spelling task are listed in Table 3-6, along with the results of analysis of variance procedures used to compare the frequency of occurrence of these error types by group. In each ANOVA procedure, error scores were the dependent variable and group was the between subject factor.

Table 3-5: Frequency of Spelling Error Types by Group--Homophone Spelling Task

Error Type	Subject Group AD	Control
Alternate Homophone	87	12
Alternate Homophone Misspelled:		
Total	24	5
Phonologically Plausible with Partial Lexical Knowledge	9	3
Omission	5	1
Addition	3	0
Unrelated Substitution	1	0
Transposition	2	1
Related Word	1	0
Silent Letter Substitution	1	0
Morphological Omission	1	0
Related Word for Letter	1	0
Correct Homophone	432	675
Correct Homophone Misspelled:		
Total	85*	13*
Phonologically Plausible with Partial Lexical Knowledge	12	3
Letter Omission	31	5
Letter Addition	9	3
Letter Transposition	14	1
Syllable Omission	1	0
Morphological Omission	8	0
Morphological Addition	3	0
Word Ending Omission	4	0
Unrelated Letter Substitution	9	1
Silent Letter Substitution	0	1
Related Word for Letter	1	0
Undetermined Homophone Selection:		
Phonologically Plausible	38	7
with Part Semantically Related	3	1
Part is Phonologically Plausible	4	0
Word Substitution:		
Related (Sem., phon., vis.)**	4	4
Phonologically Related	18	2
Word Ending Omission	11	0
Unrelated Spelling	1	0
Perseveration	2	0
No Response	7	0
Hearing Problems	3	1

*Some responses included more than one error type
**Semantically, phonologically and visually related

Table 3-6: Results of Analysis of Variance (ANOVA) for Frequency of Specific Error Types

Error Type	Group Means AD	Control	F Value (df=1,22)	p Value
Alternate Homophone*	7.3**	1.0	31.02	.0000***
Letter Omission	2.6	0.4	18.32	.0003***
Transposition	1.2	0.1	14.64	.0009***
Phonologically Plausible	3.2	0.6	5.70	.0260***
Phonologically Related Word	1.5	0.2	8.19	.0091***

*Correctly spelled
**Mean number of errors
***Statistically significant

For each individual error type listed in Table 3-6, a comparison was performed of the number of subjects in each group who produced each error type at least once. There was no statistically significant difference in the number of AD subjects who produced the Alternate Homophone error type (with no misspellings) as compared to the number of control group subjects (11 AD subjects; 7 control subjects, $X^2=3.556, p<.0593$). However, there was a statistically significant difference in the number of AD subjects as compared to the number of control subjects who produced the remaining error types listed in Table 3-6: Omission (11 AD subjects; 4 control subjects, $X^2=8.711, p<.0032$); Transposition (9 AD subjects; 1 control subject, $X^2=10.971$, $p<.0009$); Phonologically Plausible (9 AD subjects, 3 control

subjects, X^2=6.000,p<.0143); Phonologically Related Word (8 AD subjects, 2 control subjects, X^2=6.171,p<.013). These analyses were performed only for the AD group's most common error types; additional tests of group differences for the frequency of occurrence of error types were not conducted. However, the control group did not produce any error types significantly more often than did the AD group.

Therefore, the AD group performance in homophone spelling was characterized by a variety of error types that occurred with greater frequency and in more individual subjects within the AD group as compared to the control group.

4) What pattern of homophone selection characterized subject performance in homophone spelling?

In predicting that the AD group would demonstrate particular difficulty in the homophone spelling task as compared to the other spelling tasks, we presumed that the basis of their difficulty in this task would be impaired ability to use sentence context to select the proper spelling of the homophone. Therefore, we anticipated that the AD group would select the alternate homophone more often than did the control group.

The control group made significantly more responses that could be classified as either the correct homophone or the alternate homophone than did the AD group (control group x=.98; AD group x=.87, F(1,22)=11.89, p<.0023).

Although within each group, the percentage of homophone selections that were correct homophone selections was significantly greater than the percentage of homophone selections that were alternate homophone selections (i.e., within the AD group, means=.82 and .18, $F(1,22)=96.23$, $p<.0000$; within the control group, means=.98 and .02, $F(1,22)=3680.43$, $p<.000$), the AD group made significantly more alternate homophone selections (as a percentage of total homophone selections) than did the control group (AD group x=.18; control group x=.02, $F(1,22)=22.87$,$p<.0001$).

Therefore, the AD group produced a higher proportion of alternate homophone selections than did the control group.

5) Were subjects more likely to misspell alternate homophone selections than correct homophone selections?

Since alternate homophone selections represent error performance, we wondered if the lack of knowledge that led to the alternate homophone error would also be reflected in a greater proportion of misspellings for alternate homophones as compared to correct homophones.

There were no significant differences across groups in either the proportion of correct homophones that were misspelled (AD group x=.164; control group x=.019, $Z=1.232$,ns) or in the proportion of alternate homophones that were misspelled (AD group x=.216; control group x=.294, $Z=.388$,ns).

Neither the AD group nor the control group misspelled alternate homophone selections significantly more often than they misspelled correct homophone selections. Thus, within the control group, there was no significant difference in the proportion of misspellings for correct homophones (x=.019) versus the proportion of misspellings for alternate homophones (x=.294) (Z=1.797,ns). Within the AD group, there was no significant difference in the proportion of misspellings for correct homophones (x=.164) versus the proportion of mispellings for alternate homophones (x=.216) (Z=.318,ns).

Within each group, correct homophone selections were spelled correctly significantly more often than they were misspelled (AD group means=.836 and .164, Z=3.292,p<.01; control group means=.981 and .019, Z=4.71,p<.01).

Within the AD group, alternate homophone selections were spelled correctly (x=.784) significantly more often than they were misspelled (.216)(Z=2.66,p<.01). However, within the control group, there was no significant difference in the proportion of alternate homophones that were spelled correctly (x=.706) versus those that were misspelled (x=.294) (Z=1.648,ns).

Therefore, within each group the proportion of alternate homophones that were misspelled did not differ significantly from the proportion of correct homophones that were misspelled. Also, neither the proportion of correct

homophones that were misspelled nor the proportion of alternate homophones that were misspelled differed significantly across groups.

6) Was there an effect of spelling regularity or word frequency in alternate homophone selections?

Within the alternate homophone selections by each group, we were interested to know whether the regularly spelled homophone (which could be spelled by the nonlexical route) was selected more often than the irregularly spelled homophone (which must be spelled by the lexical route). We also were interested to know if alternate homophone selections reflected a tendency to select high frequency words more than low frequency words (since high frequency words are thought to be more readily available within the Graphemic Output Lexicon than low frequency words). Group comparisons of alternate homophone selections with regularity and frequency characteristics are listed in Table 3-7.

Within the control group's alternate homophone errors, the regular homophone was selected for the irregular homophone target ($x=.941$) significantly more often than the irregular homophone was selected for the regular homophone target ($x=.059$) ($Z=3.528, p<.01$). However, within the AD group, there was no significant difference in the proportion of alternate homophone selections in which the regular homophone was selected over the irregular homophone ($x=.604$)

compared to those in which the irregular homophone was selected over the regular homophone (x=.396) (Z=.976, ns).

Table 3-7: Percentages of Error in Homophone Selection by Group--Regularity and Frequency Features

Error Selections	Subject Group AD	Control	Difference in Proportions*
Regular for Irregular Target**	.604	.941	1.67
Regular High	.552	.625	<1.00
Regular Low	.149	.000	1.14
Regular Close	.298	.375	<1.00
Irregular for Regular Target	.396	.059	1.67
Irregular High	.409	1.000	1.12
Irregular Low	.295	.000	<1.00
Irregular Close	.295	.000	<1.00
High for Low Target***	.495	.647	<1.00
Low for High Target	.207	.000	1.37

*None were statistically significant
**Refers to spelling regularity
***High/Low/Close refers to word frequency of one member of homophone pair in relation to the other member of the pair

Within the control group's alternate homophone errors, the high frequency homophone was selected for a low frequency homophone target (x=.647) significantly more often than the low frequency homophone was selected for the high frequency homophone target (x=.00) (Z=2.766, p<.01). However, within the AD group, there was no significant difference in the proportion of alternate homophone selections in which a high frequency homophone was selected over a low frequency homophone (x=.495) versus those in

which a low frequency homophone was selected over a high frequency homophone (x=.207) (Z=1.415, ns).

Of subjects' regular homophone selections, we were interested to know if the regular high frequency homophones were selected more often than the regular low frequency homophones. Within each group, there was a significant difference in the proportion of alternate homophones in which a regular high frequency homophone was selected versus those in which a regular low frequency homophone was selected (control group means=.625 and .00)(Z=2.697, p<.01); (AD group means=.552 and .149) (Z=1.981,p<.05).

Within irregular homophone selections, we were also interested to know if the irregular high frequency homophones were selected more often than the irregular low frequency homophones. Within each group, there was no significant difference in the proportion of alternate homophones in which an irregular high frequency homophone was selected versus those in which an irregular low frequency homophone was selected (control group means=1.0 and .00, Z=1.414,ns; AD group means=.409 and .295, Z=.506,ns).

Therefore, there were no significant differences across groups in regularity and frequency characteristics of responses. Within groups, the control group was more likely to select a regularly spelled homophone over an irregularly spelled target than to select an irregularly spelled

homophone over a regularly spelled target, but the AD group was not. The control group was more likely to select a high frequency homophone over a low frequency target than to select a low frequency homophone over a high frequency target, but the AD group was not. Within each group, regular high frequency homophones were selected more often than regular low frequency homophones, but irregular high frequency homophones were not selected significantly more often than irregular low frequency homophones.

7) Was there an effect of spelling regularity or word frequency in nonhomophone spelling?

Within subjects' nonhomophone spelling responses, we were interested to know if regularly spelled nonhomophones were spelled correctly more often than irregularly spelled nonhomophones (which would suggest an impaired lexical route and a greater reliance on the nonlexical spelling route). Within the AD group, of the total errors in nonhomophone spelling, there was no significant difference in the proportion of irregular word errors (x=.591) as compared to the proportion of regular word errors (x=.409) (Z=.854, ns).

We were also interested to know if there was a frequency effect within irregularly spelled nonhomophone responses or within regularly spelled nonhomophone responses. Of errors for irregular nonhomophones, there was no significant difference in the proportion of errors for irregular high frequency words (x=.462) versus errors for irregular low frequency words (x=.538) (Z=.361,ns). Of the

total errors for regular words, there was no significant difference in the proportion of errors for regular high frequency words (x=.667) versus errors for regular low frequency words (x=.333) (Z=1.567,ns). The control group made a total of only two errors on the nonhomophone spelling task, and therefore these errors were not analyzed in terms of regularity and frequency.

Therefore, the AD group did not spell significantly more regular words correctly than they spelled irregular words. The AD group did not spell significantly more regular high frequency words correctly than they did regular low frequency words, nor did they spell significantly more irregular high frequency words correctly than they did irregular low frequency words.

8) What error types characterized subject performance in the nonword spelling task?

Because the AD group performed as poorly in the nonword spelling task as in the homophone spelling task, we were interested to know what types of errors characterized AD group performance in nonword spelling. The control group made errors on 13/360 (3.6%) nonword stimuli, while the AD group made errors on 144/360 (40%) nonword stimuli. As reported above, these group differences in nonword spelling performance were statistically significant (F=25.88,p<.0000). The frequency of occurrence of spelling error types by the AD and control groups in the nonword spelling task is listed in Table 3-8.

Table 3-8: Frequency of Occurrence of Error Types by Group--Nonword Spelling

Error Type*	Subject Group AD	Control
Letter Omission	9	1
Letter Addition	12	1
Letter Transposition	1	0
Unrelated Letter Substitution	28	5
Syllable Omission	4	0
Syllable Addition	9	0
Word Ending Omission	9	0
Lexicalization	45	4
Apparent Hearing Problem	10	5
No Response	21	0

*Some responses included more than one error type

All AD subjects made at least one error in nonword spelling, but the six AD subjects further along in the disease progression accounted for 69.4% of the errors made by the AD group in nonword spelling, as compared to 30.6% for the six subjects with milder AD. However, the milder AD group still made more errors on this task (24.4%) than did the control group (3.6%).

Therefore, the AD group produced a variety of error types in the nonword spelling task, most notably Letter Additions, Unrelated Letter Substitutions, Lexicalizations

and No Responses. Impairment in nonword spelling was observed even in some subjects with mild AD.

Summary

The primary findings of this study as they relate to the questions posed in Chapter One are as follows:

Research Question 1: The AD group in this study performed significantly worse than the control group on each of the experimental tasks;

Research Question 2: The AD group in this study performed better in nonhomophone spelling than they did in homophone spelling. However, they performed as poorly in nonword spelling as they did in homophone spelling;

Research Question 3: There is evidence that the AD group in this study may have demonstrated lexical spelling apart from semantic influence. The AD group selected irregularly spelled alternate homophones in 12.2% of possible instances in the spelling task, as compared to 1.7% in the definitions task.

Additional analyses yielded the following conclusions:

1) AD group performance in all experimental tasks was negatively correlated with dementia severity;

2) The AD group demonstrated a relative fatigue effect in the homophone spelling task;

3) The AD group produced a variety of error types in homophone spelling significantly more often than did the control group;

4) The AD group made a significantly greater proportion of alternate homophone errors in spelling than did the control group;

5) Within each group, there was no significant difference in the proportion of alternate homophone selections that were misspelled as compared to the proportion of correct homophone selections that were misspelled. Across groups, there also was no significant difference in the proportion of correct homophone selections that were misspelled or in the proportion of alternate homophone selections that were misspelled;

6) Across groups, there was no significant difference in the regularity and frequency characteristics of error responses. Within groups, the AD group demonstrated no regularity or frequency effect in homophone spelling responses, but the control group was more likely to select regular homophones over irregular homophones and to select high frequency homophones over low frequency homophones. Within each group, regular high frequency words were selected more often than regular low frequency words, but within each group there was no difference in the selection of irregular high frequency words over irregular low frequency words;

7) The AD group did not show a regularity effect in nonhomophone spelling, nor did they show a frequency effect

within regular nonhomophone or irregular nonhomophone spelling;

8) The AD group produced a large number of Letter Addition errors, Unrelated Letter Substitution errors, Lexicalization errors and No Responses in the nonword spelling task. Both subjects with milder AD and subjects further along in disease progression demonstrated impairment in nonword spelling.

DISCUSSION

This study has investigated the spelling and auditory comprehension abilities of Alzheimer's disease (AD) patients in an attempt to learn how AD affects aspects of lexical and semantic processing. Based upon a review of the literature suggesting progressively impaired semantic memory as the central neuropsychological disorder of early AD, we hypothesized that a possible dissociation between lexical spelling and semantic influence could be examined in the AD population. We have drawn comparisons between AD subjects and normal control subjects across a variety of spelling and auditory comprehension tasks, and these comparisons have allowed us to reach several conclusions about AD and control group performance in this study. In this chapter, we will discuss our conclusions as they relate to previous research, as they might reflect the conditions of this particular study, and as they may inform us about the cognitive neuropsychological mechanisms underlying normal spelling, and their degradation in Alzheimer's disease.

Twelve subjects with a clinical diagnosis of probable AD and 12 normal control subjects were tested. The experimental procedures included oral spelling of homophones, nonhomophones and nonwords as well as three

auditory comprehension tasks. We have compared performance on these tasks within and across groups, and have interpreted the results of these comparisons as they relate to the research questions posed in Chapter One.

Research Questions

Research Question 1: Do Alzheimer's disease subjects demonstrate an impairment of spelling or auditory comprehension when compared to normal control subjects? The null hypothesis was stated: AD subjects do not demonstrate an impairment of spelling or auditory comprehension when compared to normal control subjects.

In Chapter Three, we reported that for each experimental task, there was a significant difference in overall accuracy between the AD group and the control group. This finding supports the body of literature to date that has reported degradation of language abilities in Alzheimer's disease, as reviewed in Chapter Three. It was, therefore, as we predicted that the tasks requiring semantic processing (i.e., the homophone spelling task and the three auditory comprehension tasks) were impaired, and that the nonhomophone and nonword spelling tasks were also deficient as compared to control group performance.

The AD subjects in this study were selected based upon diagnosis by a physician and in accordance with NINCDS criteria (McKhann, et al., 1984), and the control group was closely matched to the AD group in age, sex and educational level. Therefore, that these experimental results may reflect inappropriate subject selection is unlikely. Also, since the selection of stimuli in this study, as well as

order of subtest presentation, scoring and tabulation of results were all carefully completed, these results are most likely not attributable to methodological/procedural problems with the study.

Research Question 2: Do AD subjects demonstrate particular difficulty in performing spelling tasks that demand semantic mediation compared to spelling tasks that do not demand semantic mediation? The null hypothesis was stated: AD subjects do not demonstrate particular difficulty in performing spelling tasks that demand semantic mediation compared to spelling tasks that do not demand semantic mediation.

In Chapter Three, we reported that the AD subjects in this study performed better in nonhomophone spelling (which may or may not demand semantic mediation) than they did in homophone spelling (which does demand semantic mediation). We also reported that the AD subjects performed as poorly in nonword spelling (which does not demand semantic mediation) as they did in homophone spelling. These findings suggest two separate questions for discussion: 1) Why did the AD subjects perform better in nonhomophone spelling than in homophone spelling; and 2) Why did the AD subjects perform as poorly in nonword spelling as they did in homophone spelling?

The relatively good performance of the AD subjects in nonhomophone spelling as compared to homophone spelling is what we predicted given the devastating effects of AD upon semantic memory. Homophone spelling requires semantic processing of sentence context so that the meaning of the homophone can be determined, but nonhomophone spelling does

not require comprehension of a distinguishing sentence context.

The AD group in this study performed well in the nonhomophone spelling task, each AD subject demonstrating many examples of intact lexical knowledge of irregular words. This result is in contrast to the report of lexical agraphia in AD subjects by Rapcsak et al. (1989), and supports the Smith et al. (1990) findings of intact lexical knowledge in the spelling of AD patients.

The AD group in this study demonstrated a relative fatigue effect in homophone spelling, as reported in Chapter Three. This fatigue effect cannot account for the poor performance of the AD group in homophone spelling as compared to nonhomophone spelling, however, because homophone and nonhomophone stimuli were presented in random order in the same word list. Therefore, if homophone spelling were influenced by fatigue during initial presentation of homophone stimuli, nonhomophone spelling would have been similarly affected.

Nonword spelling was as poorly performed as homophone spelling by the AD subjects in this study. This was an unexpected finding since nonword spelling does not require semantic processing and the nonlexical phonological mechanism by which nonword spelling is accomplished has typically been thought to be preserved until the severe stages of the disease. As reported in Chapter Three, we

examined nonword spelling performance as it related to dementia severity and found that even though the AD subjects in the moderate to severe range of disease progression accounted for the majority of errors made by the AD group in this task, the subjects with milder AD still made more errors in nonword spelling than did the control group. Therefore, this result suggests that the mechanism by which phonemes are converted to graphemes may be impaired in some AD patients even during the mild stage of disease progression.

To what can we attribute this impairment in nonword spelling? Errors such as unrelated letter substitutions, letter additions and syllable additions were produced more often by the mild AD group than the control group, suggesting a deficit in translating phonemes to letter names. It is possible that this deficit would not have been apparent had written spelling been tested rather than oral spelling; the static form of the written task provides an aid to memory that is lacking during oral spelling. However, errors due to a lost memory trace at the level of the Graphemic Buffer would more likely be errors such as omissions and transpositions rather than additions and unrelated substitutions. Also, the report by Rapcsak et al. (1989) of lexical agraphia in ten AD patients (who appeared to rely on the nonlexical phonological spelling route) was

based in part upon the performance of five of the AD patients in oral spelling.

Research Question 3: Do AD subjects demonstrate spelling apart from semantic influence? The null hypothesis was stated: AD subjects do not demonstrate spelling apart from semantic influence.

Two different arguments could be constructed to account for the data we have reported in Chapter Three: 1) That AD subjects in this study demonstrated the use of a direct lexical spelling route; and, 2) That the AD subjects in this study demonstrated lexical spelling influenced by semantics. We will discuss the strengths and weaknesses of each of these interpretations.

Previous arguments for a direct lexical spelling route have been based upon evidence similar to the findings of this study: examples of spelling of irregular words apart from appropriate semantic context. We have reported that the AD group in our study produced many responses in which they selected the irregularly spelled alternate homophone in place of a regularly spelled target. That is, they produced irregular homophones when the sentence context provided should have elicited the correct homophone spelling. Therefore, the direct lexical route argument would describe these irregular spellings as examples of lexical spelling that has bypassed the semantic system.

This theory argues that if a sentence context does not lead to correct comprehension of the homophone, then the only viable explanation for an irregular alternate homophone

error is that information from the Phonological Input Lexicon proceeded directly to the output lexicon and activated the alternate homophone. This argument has, however, what seems to be a crucial flaw: how can we know whether the alternate homophone error occurred during a "direct" nonsemantic spelling process when it could just as well have occurred within the malfunctioning Semantic System? That is, when an alternate homophone is retrieved in place of the target, is it not possible that the subject has made use of the spoken homophone alone to call up a corresponding semantic representation, even though the subject has not made use of the sentence context surrounding the homophone? By this explanation, the semantic representation accessed may often be for the wrong homophone, and then information transmitted from the Semantic System to the Graphemic Output Lexicon would activate the alternate homophone.

Is there any way to decide between these two possible loci of the alternate homophone error? One possibility may be to look for an imageability effect in the selection of homophones, since if the semantic meaning of a spoken homophone alone (i.e., apart from its sentence context) is accessed within the Semantic System, the member of the homophone pair with the stronger imageability may be more likely to be activated within the Semantic System than the other member of the homophone pair. The stimuli in this

study were not structured to allow a precise examination of imageability. However, there is a second source of information that may help us to decide if homophone misselection may occur without semantic influence at the level of the Graphemic Output Lexicon. This is the information we have accumulated in this study regarding homophone selection during the task in which subjects were asked to provide homophone definitions.

The homophone definitions task was included in this study to provide subjects the opportunity to express semantic knowledge of a presented homophone and its sentence context using any verbal or gestural means available to them. The goal of the definitions task was to provide information as to the existence of even partial semantic knowledge for a given stimulus item.

The definitions task provides information relevant to the argument regarding a direct lexical spelling route in the following way: The same homophones in the same sentence contexts were presented auditorily in the definitions task as had been presented auditorily in the homophone spelling task. We would expect that if homophone misselections were occurring within the malfunctioning Semantic System, they would occur with approximately equal frequency in the definitions task as they did in the homophone spelling task. We would expect this to be approximately equal since the definitions task and the homophone spelling task both depend

upon the same incoming auditory information, and both require that a homophone selection be made based upon the distinguishing sentence context.

The difference between the definitions task and the homophone spelling task in regard to this discussion is that the definitions task is inherently dependent upon semantic processing, whereas the homophone spelling task perhaps is not. As reported in Chapter Three, we found that of the possible instances in which irregularly spelled alternate homophone errors could have been selected, the AD group selected 44/360 in the homophone spelling task, as compared to only 6/360 in the definitions task.

Since performance in the homophone spelling task as well as in the definitions task were both dependent upon comprehension of a spoken homophone within a distinguishing sentence context, we would have expected the ability of AD subjects to comprehend auditory stimuli to be approximately equal in the two tasks. The fact that many more irregularly spelled homophone misselections occurred in the homophone spelling task as compared to the definitions task leads us to propose that at least some of these errors were due to the operation of a direct lexical spelling route. That is, rather than the locus of homophone error being within the malfunctioning Semantic System, we propose that in at least a portion of these responses the alternate homophone was misselected in the process of direct nonsemantic spelling.

Critics of the direct lexical spelling route theory (e.g., Hillis et al., 1990) have argued that studies purporting to provide evidence for this direct lexical route have not established the complete abolishment of semantic knowledge for those specific items that were misspelled. On the surface, this appears to be a valid criticism; however, upon closer examination it does not weaken the theory of a direct lexical spelling route.

The argument against the direct lexical spelling route implies that if partial semantic knowledge for a particular homophone can be established, then the influence of the semantic system on the spelling of that homophone cannot be denied. This idea is based on the theory that even partial semantic knowledge can be used, in combination with partial cues from the nonlexical spelling route, to activate lexical representations for irregular words at the level of the Graphemic Output Lexicon (Hillis et al., 1990).

This theory of the combination of partial cues does not explain why or how homophone misselections occur in the homophone spelling task. It is possible, although not proven by any means, that partial semantic and nonlexical cues could combine to activate lexical representations, but that possibility is not central to our discussion of a direct lexical spelling route. Rather, the critical issue is that IN SPITE OF partial semantic knowledge, often demonstrated for both members of a homophone pair, subjects

frequently selected the wrong homophone during the homophone spelling task. It might be predicted that activation of partial semantic knowledge about the correct homophone would be facilitated by the auditory sentence context provided; however, in many instances this sentence information still did not seem to aid selection of the correct homophone.

The combination of partial cues theory does not provide new information that might inform us as to why certain partial semantic knowledge (i.e., of the alternate homophone) may be used, while other partial semantic knowledge (i.e., of the correct homophone) is ignored. Neither does it inform us as to why partial semantic information may be used to perform one task (i.e., definitions), but may not be used to perform another task (i.e., homophone spelling). Thus, it cannot be assumed that the presence of partial semantic knowledge about an irregular word guarantees that it will be utilized during the spelling of that word.

Based upon the above arguments for and against the existence of a direct lexical spelling route, we conclude that the AD subjects in this study did provide evidence that they performed lexical spelling apart from semantic influence. Although the evidence is not conclusive, this study provides further evidence that the semantic knowledge of AD subjects may be utilized inconsistently and that the

spelling of irregular alternate homophones can occur with no apparent contribution from semantic knowledge.

Clinical Implications

The results of this study may have practical implications for the clinical evaluation and treatment of spelling disorders. Although this study does not provide conclusive evidence about the structure of cognitive neuropsychological mechanisms underlying normal spelling, our results provide further information about how spelling and semantic knowledge might be related. Therefore, these results may contribute to our understanding of normal spelling and to our understanding of how spelling may best be assessed clinically.

In addition to informing us about the effect of semantic memory impairment upon spelling abilities, this study may also provide clues as to the relationship between semantic knowledge and other language abilities, such as reading. In turn, such theoretical advances could have clinical implications for the assessment of reading and other language abilities.

The treatment of spelling disorders may be most effectively undertaken when based upon theoretical understanding of subsyndromes of linguistic agraphia and the levels of processing deficit implicated in these agraphias. For this reason, information provided from studies such as this can not only contribute to theoretical models of normal

spelling but can also have practical implications for the implementation of spelling treatment programs.

Implications for Future Research

The finding in this study that partial semantic knowledge does not appear to be consistently utilized by AD subjects in homophone spelling leads to further questions regarding the use of semantic knowledge in other language tasks. The question also arises as to what methods might best be employed in assessing the USE of semantic knowledge.

Further research into homophone selection ability in AD subjects or other subjects with semantic memory impairment might attempt to structure test stimuli to allow for examination of an imageability effect. Since the number of test stimuli that could be balanced for homophony, spelling regularity, word frequency and imageability would be limited, research examining the effect of imageability in homophone selection would require a large number of experimental subjects.

The finding that nonword spelling was impaired in the AD group in this study is in need of replication. Since so few studies have examined nonword spelling in AD, and since contradictory results have resulted, an assessment of nonword spelling using a large number of AD subjects is desireable.

Although the theory of the combination of partial semantic and nonlexical phonological cues (Hillis et al.,

1990) did not prove to be central to our discussion of homophone misselection in this study, it is a theory with interesting ramifications for spelling processing after homophone selection has occurred. Future spelling research will need to test the usefulness of this theory by examining specific spelling error responses. For example, the effect of a malfunctioning nonlexical spelling route upon lexical retrieval merits examination. Also, if the partial cues theory is tenable, one would think that certain aspects of lexical knowledge (e.g., morphological units in morphologically complex words) might be especially vulnerable to the effects of an impaired nonlexical spelling mechanism.

APPENDIX A
CRITERIA FOR THE DIAGNOSIS OF PROBABLE ALZHEIMER'S DISEASE

1. Dementia established by clinical examination and documented by the Mini-Mental Test (Folstein et al., 1975), Blessed Dementia Scale (Blessed, Tomlinson, & Roth, 1968) or some similar examination, and confirmed by neuropsychological tests.

2. Deficits in two or more areas of cognition.

3. Progressive worsening of memory and other cognitive functions.

4. No disturbance of consciousness.

5. Onset between ages of 40 and 90, most often after age 65.

6. Absence of systemic disorders or other brain diseases that in and of themselves could account for the progressive deficits in memory and cognition.

Source: National Institute of Neurological Communicative Disorders and Stroke--Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) (McKhann et al., 1984).

APPENDIX B

MATTIS SUBTEST SCORES FOR AD SUBJECTS

		Mattis Subtest				
Maximum:		I (37)	II (37)	III (6)	IV (39)	V (25)
AD Subject	Mattis Total					
01	129	36	30	6	38	19
02	122	35	33	6	37	11
03	118	32	31	3	37	15
04	115	37	32	4	29	13
05	104	35	28	3	33	5
06	101	34	17	3	39	8
07	82	32	8	3	37	2
08	81	33	21	2	22	3
09	73	32	10	2	19	10
10	67	33	12	2	13	7
11	66	30	9	3	12	12
12	41	23	5	1	11	1

Note: I = Attention
II = Initiation and Perseveration
III = Construction
IV = Conceptualization
V = Memory

Source: Mattis Dementia Rating Scale (Mattis, 1973, 1988)

APPENDIX C
NONWORD STIMULI

1. sweek	9. kise	17. hule	25. tay
2. buse	10. sade	18. hae	26. slee
3. clize	11. kire	19. hower	27. sayerd
4. ris	12. termel	20. wike	28. swide
5. wute	13. wum	21. luns	29. ite
6. sise	14. wud	22. hame	30. shoke
7. seeb	15. nane	23. bu	
8. uers	16. noi	24. kirule	

Note: Each nonword test item was created by changing one or two phonemes of each homophone test item.

APPENDIX D
HOMOPHONE STIMULI

Regular words higher in frequency:

1. sweet 68 suite 31
   She served something sweet.
   They went into the suite.

2. base 102 bass 16
   He tagged the base.
   His bass is loud.

3. close 174 clothes 89
   They are going to close.
   He has the clothes.

4. ring 43 wring 3
   She has a ring.
   Wring it out.

5. wait 263 weight 101
   Wait for me.
   It's a lot of weight.

6. size 148 sighs 28
   That size fits him.
   He sighs.

7. seen 1513 scene 135
   We have seen eachother.
   What a nice scene!

8. ours 4865 hours 325
   It is all of ours.
   That was hours ago.

9. cash 32 cache 1
   Get some more cash.
   He has a cache of goods.

10. side 476 sighed 28
    It's on the side.
    She sighed.

Note: Mean frequency for regular/high words = 768.4
Mean frequency for irregular/low words = 75.7

APPENDIX D--continued

Irregular words higher in frequency:

1. core 44 corps 103
   Throw the core away.
   He joined the corps.

2. kernel 6 colonel 47
   I ate the kernel.
   The colonel is home.

3. won 159 one 2737
   He won the race.
   Only one left.

4. wade 4 weighed 33
   He likes to wade.
   He weighed himself.

5. nun 6 none 108
   She is a nun.
   There are none left.

6. no 137 know 1473
   She said, "No."
   He wants to know.

7. hole 95 whole 259
   He dug a hole.
   He wants the whole thing.

8. hi 6 high 454
   Say "hi".
   It is high.

9. hire 47 higher 147
   He will hire him.
   He is higher.

10. wok 0 walk 287
    He owns a wok.
    He likes to walk.

Note: Mean frequency for irregular/high words = 564.8
Mean frequency for regular/low words = 50.4

APPENDIX D--continued

Regular and irregular words close in frequency:

1. lens 17 lends 29
   He broke the lens.
   He lends it.

2. him 0 hymn 15
   Call him to dinner.
   Start the hymn.

3. bow 13 beau 1
   Wear the bow.
   Her beau called.

4. coral 4 choral 2
   The coral is wet.
   The choral piece sounds good.

5. doe 1 dough 13
   The doe ran away.
   She mixed the dough.

6. slay 1 sleigh 0
   He will slay the bear.
   Go in the sleigh.

7. soared 9 sword 12
   It soared quickly.
   He has a sword.

8. swayed 13 suede 0
   They swayed.
   He wore suede.

9. ate 122 eight 104
   They ate everything.
   There are eight of them.

10. sheik 4 chic 7
    A sheik is visiting.
    This fashion is chic.

Note: Mean frequency of regular/close words = 18.4
Mean frequency of irregular/close words = 18.3

APPENDIX E
NONHOMOPHONE STIMULI

Irregular (n=13)

High Frequency (mean frequency=608.86)

1.	who (pronoun) 2678	He knows who it is.
2.	answer (verb) 133	Please answer the letter.
3.	friend (noun) 294	Her friend is visiting.
4.	thought (noun) 157	He had an interesting thought.
5.	light (noun) 306	The light was off.
6.	talk (verb) 275	Talk to this customer.
7.	once (adverb) 419	He visited there once.

Low Frequency (mean frequency=44.67)

1.	frighten (verb) 51	Dogs frighten the child.
2.	tomb (noun) 13	We saw the soldier's tomb.
3.	flight (noun) 60	We had a pleasant flight.
4.	ascend (verb) 7	The plane will ascend.
5.	bomb (noun) 68	The bomb exploded.
6.	engine (noun) 69	It's a noisy engine.

Regular (n=13)

High Frequency (mean frequency=694.42)

1.	hotel (noun) 147	They built a new hotel.
2.	open (verb) 259	She'll open the window.
3.	factor (noun) 176	We forgot an important factor.
4.	motor (noun) 108	The motor stopped.
5.	make (verb) 2312	Make cookies for us.
6.	method (noun) 284	Her method is very good.
7.	take (verb) 1575	They take the car.

Low Frequency (mean frequency= 45.5)

1.	target (noun) 68	He has target practice.
2.	mask (noun) 11	His mask was comical.
3.	graze (verb) 9	The cattle graze over there.
4.	path (noun) 58	We took a new path.
5.	jump (verb) 58	Jump out of the way.
6.	desk (noun) 69	This is my desk.

APPENDIX F
SPELLING SCORING SYSTEM

Error Type	Example Target	Example Response
Alternate Homophone	sleigh	slay
Alternate Homophone Misspelled:		
Phonologically Plausible	swayed	suead
Omission	sword	sored
Addition	lends	lense
Unrelated substitution	bass	wase
Transposition	chic	shike
Related word	wade	weight
Silent letter substitution	him	hyme
Morphological omission	ours	hour
Related word for letter	won	o-one-e
Correct Homophone Misspelled:		
Phonologically plausible and showing partial knowledge	sheik	sheek
Letter omission	sighed	siged
Letter addition	dough	dought
Letter transposition	clothes	choltes
Syllable omission	higher	high
Morphological omission	weighed	weigh
Morphological addition	wade	waded
Word ending omission	dough	dou
Unrelated letter substitution	base	wase
Silent letter substitution	hymn	hyme
Related word for letter	one	one-n-e
Undetermined Homophone Selection:		
Phonologically plausible	wait	wate
with part semantically related	kernel	cornel
Part phonologically plausible	colonel	conor
Word substitution:		
Related (Sem., phon., vis.)*	choral	chorale
Phonologically related	slay	slight
Word ending omission	hi	h
Unrelated spelling	core	oon

*Semantically, phonologically and visually related

APPENDIX G
RAW SCORES FOR AD SUBJECTS ACROSS TASKS

		Experimental Task					
Maximum:		I (30)	II (26)	III (60)	IV (60)	V (60)	VI (60)
AD Subject	Mattis Score						
01	129	29	26	48	58	47	59
02	122	15	24	49	58	51	60
03	118	26	22	29	50	41	57
04	115	22	25	58	58	51	60
05	104	23	25	49	54	37	56
06	101	21	23	37	53	39	59
07	82	6	21	26	50	36	54
08	81	21	23	36	56	41	57
09	73	7	15	25	47	41	55
10	67	20	21	28	45	36	56
11	66	14	22	19	46	35	51
12	41	12	21	28	11	0	54

Note: I = Nonword spelling
II = Nonhomophone spelling
III = Homophone spelling
IV = Picture matching
V = Semantic associates
VI = Definitions

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