PROCESSING OF VISUAL AND PHONOLOGICAL WORD CHARACTERISTICS IN GOOD, POOR AND UNEXPECTED SPELLERS

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by

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Abstract

A number of studies have investigated the ability to process visual and phonological information in good readers who spell well (good spellers), poor readers who spell poorly (poor spellers) and good readers who spell poorly (unexpected spellers). The focus of this research has been to associate a particular pattern of reading and spelling ability with a specific pattern of information processing deficits. Methodological concerns regarding subject age and possible confounding of visual and phonological processing routes, particularly for reading, suggest that little confidence can be had in the interpretation of past research. The present study employed university students and a promising new design (Van Orden, 1987) to further examine visual and phonological processing in reading. Three patterns of visual and phonological processing were identified, each associated with one of the three comparison groups. Patterns identified in reading were also found to closely resemble those found for reader/speller groups when spelling.

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One could reasonably expect a high degree of correspondence between reading and spelling ability. After all, spelling and reading both involve manipulations of written language, the former encoding language while the latter decodes it. Based on such expectations one would not be surprised to find that individuals good at reading are also good at spelling, while those poor at reading are also poor at spelling. Such correspondence is indeed what is found in the majority of cases (Frith, 1983). What is surprising is to find individuals who evidence gross differences in their abilities to read and spell. Yet, both good readers who spell poorly (Finucci, Isaacs, Whitehouse & Childs, 1983; Frith, 1978; 1980; 1983; Jorm, 1981; Nelson & Warrington , 1974; Waters, Bruck & Seidenberg, 1985) and poor readers who spell well (Finucci et al., 1983; Frith, 1983) have been identified.

An interesting question, provoked by the identification of these unexpected populations, is whether differences in reading and spelling ability are associated with differences in information processing ability. Differences in reading and spelling performance suggest that individuals within such populations may be experiencing difficulties processing written language. If these individuals were not experiencing some difficulty then their performance in both spelling and reading tasks would be expected to be at the same level. Patterns of reading and spelling by themselves, however, reveal little about the processes that may produce them.

A logical first step in investigating such populations is to identify processes for which groups differing in reading and spelling ability deviates from that of comparison groups (e.g., groups that don't differ in reading and spelling ability).

Authors already researching information processing in populations possessing differing levels of reading and spelling ability have looked first to the processing of visual and phonological information. Processing of such information is a basic prerequisite to encoding or decoding written material. As well, theoretical notions of the last decade regarding reading and spelling processes have developed such that they too focus on visual and phonological features (Coltheart, Davelaar, Jonasson & Besner, 1977; McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982; Seidenberg, 1985; Waters & Seidenberg, 1985).

Past research, however, possesses weaknesses that may invalidate inferences to visual and phonological processing. Difficulties in design of studies and selection of appropriate populations may invalidate inferences to processing routes. These are concerns which, quite possibly, may only be met by the advent of new methodology.

This introduction will critically examine past findings of groups differing in reading and spelling ability. Two large methodological concerns, age of subjects and confounding of measures of visual and phonological processing, will also be discussed. Finally, a promising new design will be introduced. First, however, a brief introduction to dual route models will be used to provide common ground for the review and discussion to follow.

Routes of Information Processing

Researchers studying information processing in individuals differing in reading and spelling ability have generally assumed a dual-access model. Dual-access refers to the hypothesized presence of two separate routes of access to an internal lexicon. This lexicon may be roughly construed as a dictionary, wherein a word's orthographic, phonological and lexical representations are stored. Word identification or production proceeds through the activation of the associated orthographic and phonological representations which mediate between word meaning and the written word. As a result, either or both of these routes could hypothetically enable a reader to recognize or produce written words.

The first hypothesized route employs visual characteristics in processing. This route has been variously termed "visual" (Frith, 1983), "direct" (Humphreys & Evett, 1985) or "lexical" (Coltheart et al., 1977; Davelaar, Coltheart, Besner & Jonasson, 1978) processing. In reading, the word's visual characteristics are mapped directly onto a stored orthographic representation. As an example, the visual components of the stimulus "read" could be compared with candidate representations in the lexicon. Once a sufficiently high degree of correspondence was found the decision would be made that "read" was indeed the word read, accessing the word's form and meaning. Hypothetically, this identification process could occur via whole word characteristics, e.g., shape (Smith, 1971), or through mapping of individual letters onto the stored lexical representation (Evett & Humphreys, 1981). The direct access of meaning in conjunction with visual identification suggested above is only one possible scenario of functioning. Another possibility would be retrieval of semantic and, possibly, phonological representations from associated addresses in the lexicon subsequent to visual identification (Coltheart, Masterson, Byng, Prior & Riddoch, 1983).

The second route employs phonological characteristics during processing. This route has also been given many labels, including "phonological" (Coltheart et al., 1977) "indirect" (Barron, 1986) or "nonlexical" processing. When reading, phonological processing operates by deriving phonological codes from the word's graphemic structure through the use of grapheme-to-phoneme correspondence rules. The codes are assembled and compared with candidate phonological representations until a match is found. Once identified, the associated semantic entry is activated to access the word's meaning. Because phonological processing requires an additional step to produce the sound equivalent of the written word, this process is also referred to as phonological mediation. Like visual processing, the mechanics of this route could assume many forms. One possibility is that the word is parsed into graphemes corresponding to individual phonemes, while another is that the word is broken into larger multi-letter units related to syllables (Humphreys & Evett, 1985).

In spelling, two routes of processing have also been hypothesized to operate (Ellis, 1982; 1984; Frith, 1983; Gerber & Hall, 1987). These routes correspond to those proposed for reading, but function, roughly, as the reverse of their reading counterparts. Visual processing accesses the visual characteristics of the word to be spelled via its semantic representation and produces the spelling in its entirety. Alternatively, the word's meaning could be used to activate its phonological representation, which could in turn be translated into written form via phoneme-to-grapheme correspondence rules. As with reading, access to both routes during processing is assumed (i.e., a dual-access model) (Ellis, 1984; Frith, 1983).

Particularly relevant to subsequent discussion is the assumption within dual-access models of independence of the visual and phonological routes of processing when reading words. The strong version of this assumption is that processing orthographic characteristics does not influence processing of phonological characteristics and vice versa, prior to initial recognition (e.g., Coltheart, Davelaar, Besner & Jonasson, 1977). This is a critical assumption for many studies of word reading. Development of a number of tasks used to assess information processing in word reading is based on the strong assumption of independent processing. For example, in many studies nonsense words are developed using grapheme-to-phoneme correspondence rules and are therefore assumed to tap only phonological processing. Similarly, exception words are selected such that correspondence rules do not apply to some or all of the words during reading and are assumed to involve only the visual route.

Recently, the assumption of independent routes of processing has been challenged. Humphreys & Evett (1985), in a review of the literature regarding word reading, found little evidence in support of a strong assumption of independence. They reported several studies which found evidence for the influence of visual information on reading tasks assumed to involve phonological processing exclusively and vice versa. Similarly, Campbell (1985) has found artifacts of visual processing in spelling. If Humphreys and Evett (1985) are correct about the interaction of visual and phonological processing in the identification and production of words, then any endeavour to isolate information processing deficits in individual routes will be difficult, and will require careful consideration regarding choice of stimuli and experimental design.

Information Processing Deficits

The last decade has seen a number of studies which attempt to delineate information processing deficits in populations identified on the basis of their reading and spelling abilities (to be referred to as reader/speller groups). Research efforts focussed on exposing patterns of processing deficits appear to be about equally split between studies of reading and studies of spelling, with reading receiving slightly greater interest. A small group of studies has assessed both reading and spelling conjointly with the aim of comparing patterns of processing deficits across the two abilities (e.g., Jorm, 1981; Waters, Bruck & Seidenberg, 1985).

In order to study reader/speller populations, artificial dichotomies of good and poor performance for both reading and spelling have been employed. Four combinations of ability are possible based on this scheme, all of which have been noted in the literature (Frith, 1983). Research, however, has been largely limited to populations representing only three of these possible combinations, including good spellers, who possess good levels of performance in reading and spelling, poor spellers, who perform poorly at both reading and spelling, and unexpected spellers, who evidence good performance when reading but poor performance when spelling. The "unexpected" label derives from the unexpected nature of the spelling deficit when ability is assumed to be continuous across reading and spelling.

Visual and Phonological Processing in Reading. The consensus among researchers studying information processing in reader/speller groups is that poor spellers show deficits in visual and phonological processing when reading, while unexpected spellers show deficits in phonological processing only (Frith, 1983; Jorm, 1981; Waters, Bruck & Seidenberg, 1985). A variety of techniques have been employed to assess processing in such studies, which leads further credence to the consensus view. However, many of the studies suffer methodological and interpretive problems. Further, irregularities in the findings in some studies suggest difficulties with manipulating word stimuli that may confound results and undermine inferences to information processing.

One technique employed to assess visual and phonological processing in reading is to use words grouped into types based on the regularity of grapheme-to-phoneme correspondence. Three types of words, regular, exception and nonsense, are usually selected or derived. Regular words are real words whose graphemes correspond directly with their phonemic counterparts. As such, regular words can be read directly via grapheme-to-phoneme correspondence rules. Exception words possess graphemes, or grapheme combinations, which correspond to phonemes that are not predictable from correspondence rules. These words are hypothesized to be read via direct access of their visual representations in the internal lexicon, as correspondence rules cannot be applied. Nonsense words are not real words, but are terms which are artificially produced using phoneme-to-grapheme correspondence rules. As a result, nonsense words can be read using correspondence rules and are unlikely to be read using direct access, as they possess no internal visual representation.

Grapheme-to-phoneme correspondence is assumed to dictate the route used to process the stimulus word. In general, words with strong correspondence are expected to be processed phonologically, while those with weak correspondence are thought to be processed visually (Treiman, 1984). Within this framework, nonsense words, by definition, will be read phonologically, while exception words will be read visually. So-called regular words are difficult to place, however. By definition they have high grapheme-to-phoneme correspondence and some research has shown evidence that in reading, at least, there is support for interpretations of regular words as being processed phonologically (Treiman, 1984). However, regular words, like exception words, possess internal visual representations and therefore it may also be argued that they may be read via the visual route.

The two studies that have used this methodology have both concluded that poor spellers suffer processing deficits along both routes, while unexpected spellers are only deficient in phonological processing. Waters, Bruck and Seidenberg (1985) divided 150 grade 3 students into good, poor and unexpected speller groups and had them read word lists comprised of five types of real words which varied in regularity of reading and spelling, and nonsense words. They found that the only word type in which unexpected spellers' performance was both superior to that of poor spellers and not inferior to that of good spellers was on exception words.

Jorm (1981) assessed word reading ability in 9- to 11-year-old children and found results consistent with Waters et al. The only difference in the findings of two studies was that unexpected spellers were also found not to differ from good spellers in the number of reading errors they made to nonsense words. Such a finding complicates the interpretation of the results, suggesting similar levels of phonological processing ability in good and unexpected spellers. This discrepancy, however, may be attributed to the small sample of unexpected spellers ($\underline{n}$=4) employed by Jorm.

Irregularities in the findings reported by Waters et al. (1985) suggest that another factor other than those used in their manipulations may be influencing performance. One irregularity was that good spellers, unlike the two comparison groups, did not make significantly more reading errors to "strange" words than to regular words. Another was that "strange" word performance for good spellers was significantly better than for either comparison group. "Strange" words were defined as having uncommon exceptional spellings which were ambiguous as to reading (e.g., yacht). They made up one of the two word types within the study that could be termed exceptionally-read words, of which exception words were the second. Thus, a significant difference between good and unexpected spellers' performance on strange words may be construed as inconsistent with the findings of no difference for exception words, which would be assumed to involve the same processes. As well, the pattern of differences between the three groups suggests that good spellers have as much facility with strange words as regular words, while the poor and unexpected spellers perform their worst on such items. All of this suggests strongly that some uncontrolled factor, or factors, is influencing responding.

Another technique used to assess information processing in reading is the semantic judgment task. Briefly, in such tasks a subject is presented with a phrase and is asked to state whether it is meaningful or not. To manipulate the variables of interest, words within the phrases may be altered along stimulus dimensions to test whether the subject is sensitive to these changes. For example, the spelling of a word may be altered so that it looks different but sounds the same, as in changing "peak" to "peack", in order to assess the ability to detect change along a dimension of visual similarity.

Only one study, concerned only with good and unexpected spellers, has used this paradigm. Frith (1978, Exp IV) asked 12-year-olds to indicate whether phrases they read sounded meaningful or not. In fact, all of the phrases they read lacked meaning, but half could be read such that they sounded meaningful. She found that unexpected spellers were less able to judge meaningfulness under these circumstances than were good spellers and she interpreted this to indicate a phonological deficit. This outcome could not be attributed to a general inability to detect meaningfulness as good and unexpected spellers performed equivalently on a similar task asking subjects to make judgments based on semantic information.

Performance in semantic judgment tasks, and in the visual search tasks to be discussed next, however, may be strongly influenced by item selection. Frith, has found at least one outcome in assumedly normal good speller populations that ran counter to her expectations when designing her experimental stimuli. For example, Frith (1978, Exp III) conducted an experiment whereby she had her subjects search two types of phrases for spelling errors. One set contained misspellings which sounded correct, while the second contained misspellings which did not maintain the correct sound. She hypothesized that misspellings which sounded correct provided fewer cues to identify them and therefore would provoke the greatest number of errors. Frith found, however, that good spellers made significantly more errors to misspellings which sounded incorrect. As Frith employed similar procedures in her other visual search and semantic judgment tasks reported herein, outcomes of these studies must be viewed cautiously.

One final technique that has been used to assess information processing is to test a subject's ability to detect targeted words within a list, a line or a paragraph of prose. Search tasks such as these may include target or stimulus foil items (i.e., an incorrect item that in some manner resembles the target whose purpose is to provoke errors) which can be manipulated so as to reveal processing ability. In general, targets that require identification based on visual characteristics are believed to test visual processing, while phonologically identified targets are believed to test phonological processing. Similarly, positive responses to foils are interpreted in terms of the process which would lead to a mistaken identification of them as targets.

Two studies that have used this technique have been interpreted as supporting a phonological deficit in unexpected spellers. Frith (1978, Exp II) assessed the ability of 12-year-old good and unexpected spellers to identify misspellings in prose passages containing either visually or phonologically preserved misspellings. To form her misspellings Frith removed one letter from each word leaving either the form or the sound similar to the original. She found that unexpected spellers were less able to identify misspellings which preserved sound and concluded that they suffered difficulties in phonological processing.

Frith (1978, Exp III) drew a similar conclusion based on performance in a task where subjects were asked to identify misspellings in short sentences. All misspellings in the sentences preserved the form of the words, but only half preserved their sound. Unexpected spellers' failure to show a significant improvement in performance across conditions was interpreted as an inability to make use of the increased number of phonological cues in the nonpreserved condition.

Both studies, however, suffer interpretative problems. In Experiment II, Frith interprets her findings in terms of features of the stimuli which are left unchanged. However, by omitting letters from real words Frith also systematically altered the remaining stimulus dimension. For example, in forming the visually preserved misspelling "tirng" the "ing" sound is no longer preserved. The result is a visually preserved misspelling that sounds different. Under such circumstances any inferences are confounded by nonpreserved features which also distinguish the conditions.

One study employing a visual search task has provided evidence of a visual processing deficit in unexpected spellers. Frith (1983) compared the ability of 12-year-olds, classified as either good or unexpected spellers, to detect letter groupings on lists of redundant (e.g., spect, encil, rease, etc.) and nonredundant (e.g., ihtsg, uetnn, aeylr, etc.) letter strings. The unexpected speller group was found to make significantly more errors than the good speller group only on nonredundant strings. Examination of redundant and nonredundant string stimuli suggests that the different visual and phonological processing requirements of each list might encourage different processing strategies. For example, the redundant list uses letter strings that may be sounded out. A useful strategy for this list then might be to read the words in the same way that a nonsense word would be read. The nonredundant strings, because they cannot be sounded out, do not lend themselves to a phonological processing strategy, instead they encourage the reader to examine visual characteristics. If unexpected spellers adopting a visual search strategy were impaired relative to good spellers, then it would be expected that they would evidence poorer performance on nonredundant stimuli.

In summary, researchers have concluded that, when reading, unexpected spellers evidence a deficit in phonological processing, while poor spellers appear deficient along both processing routes. Despite a remarkable level of agreement, evidence in favour of these conclusions is weak. Difficulties in design and interpretation mark the majority of studies reviewed. Possibly more telling, however, is evidence from some studies suggesting that extraneous factors not controlled for in selection of word stimuli may be influencing results.

It is also the case that some of the research findings are open to alternate interpretations. For example, Frith (1978) reports one experiment comparing performance on misspellings which preserved either visual or phonological information. In interpreting her findings, Frith attributes performance differences to the presence of the preserved features and draws conclusions in accordance with those from related studies. Had she made attributions to the nonpreserved features, which which were also systematically varied and provided more salient discriminating cues, her interpretations might not have been in agreement with those from comparable studies. Consensus within this body of research may thus be a product of both consistent findings and consistent interpretations.

Visual and Phonological Processing in Spelling. In general, processing deficits noted for poor spellers are comparable across reading and spelling (i.e., deficits in both visual and phonological processing are observed), while unexpected spellers evidence novel processing deficits in spelling. What this different pattern of processing may be, however, is not agreed upon. Two lines of evidence have been provided, each originating from a particular methodology and each giving a different interpretation of processing ability in unexpected spellers.

Analysis of phonetic accuracy of misspellings has lead to a widespread belief that unexpected spellers' use of phonological processing when spelling is equivalent to that of good spellers (Finucci, Issacs, Whitehouse & Childs, 1983; Frith, 1978; 1980; Jorm, 1981) and superior to that of poor spellers (Bookman, 1984; Jorm, 1981; Nelson & Warrington, 1974). Phonetic accuracy has been determined by examining the proportion of misspellings produced which preserve the sound of the word to be spelled but not its correct orthographic structure. The assumption is that such misspellings occur when the correct orthography cannot be accessed internally, possibly because of a visual processing deficit,such that a spelling which sounds correct is produced via sole use of phoneme-to-grapheme correspondence rules. Proportion of phonetically correct misspellings may thus be used to determine phonological processing ability.

Studies using all three comparison groups have generally found that around 70% of misspellings in good and unexpected spellers are phonetically correct, while only 50% of poor spellers' spellings have this characteristic (Finucci, Issacs, Whitehouse & Childs, 1983; Jorm, 1981). These figures are quite consistent with studies using either good and unexpected spellers only (Frith, 1978; 1980), or poor and unexpected spellers only (Bookman, 1984; Nelson & Warrington, 1974).

Interestingly, these differences in ability to produce phonetically correct misspellings have also been found when reader/speller groups are formed secondarily. Sweeney and Rourke (1978) divided a sample of 9- and 12-year-old poor spellers into two groups, those who predominantly made phonetically correct misspellings and those who made errors which were predominantly non-phonetic. They found that the phonetic misspellers were significantly better at word reading than the phonetically inaccurate misspellers, though the former were also significantly poorer at reading than a normal control group. Perin (1981) found that among adult illiterates better readers made a significantly higher percentage of phonetically correct misspellings than poor readers. Perin's groups, however, were tested in a non-standardized fashion and the poor spellers were found to be significantly poorer on spelling than the unexpected group.

Though much of the supportive evidence comes from studies employing children between the ages of 9 and 14, similar findings have been found in adult populations. Bookman (1984) used university students in her study of poor and unexpected spellers and found that the latter made a significantly higher percentage of phonetically correct misspellings than the former. Finucci et al. (1983) tested subjects up to twenty years of age and also confirmed the spelling pattern noted in children. On the other hand, one study using university undergraduates found good and poor spellers not to differ in the percentage of phonetically correct spellings they produced (Fischer, Shankweiler & Liberman, 1985). The distinction between good and poor spellers, however, was derived post-hoc and was based only on a significant group difference in reading performance. Rather than producing good and poor groups these authors may have formed good and unexpected speller groups, in which case their results are not inconsistent. In support of this contention both groups made around 75% phonetically correct misspellings, a figure in keeping with those found for good and unexpected spellers in previous research.

One notable exception to the above studies concluded that, based on percent of phonetically correct misspellings, poor and unexpected spellers shared a phonological processing deficit in spelling. Waters, Bruck and Seidenberg (1985) divided grade three students into good, poor and unexpected spellers and examined their spellings of single words. They found that unexpected spellers produced phonetically correct misspellings at the same rate as poor spellers, and that both had production rates inferior to good spellers. Examination of grade level performance on these tasks, however, reveals that though a label of poor reading indicated below normal achievement, spelling performance for the poor and unexpected spellers was at grade level. The authors argue that this may represent instrument bias and show that among the subjects tested, the poor and unexpected spellers performed approximately one standard deviation below the sample mean.

Three factors might be expected to mitigate comparability and generalizability of the above findings. The first is the use of different tasks to assess reading ability (reading comprehension and single word reading). Different reading tasks may make different information processing demands. However, Frith (1980) and Waters et al. (1985) assessed both single-word reading and reading comprehension in their studies and found that the tasks produced similar outcomes. A second concern is that studies have employed different criteria in choosing what misspellings to examine for phonological accuracy (i.e., first 10 words vs. all misspellings). Varying criteria may have resulted in spelling errors being used from words of differing difficulty in separate studies. Waters et al. (1985), however, repeated their analysis of all misspellings using only the first 10 errors made by each subject and found no significant deviance from the original results. Finally, though these studies have been grouped together, in some cases assignment was based on post-hoc differences (e.g., Fisher et al., 1985; Sweeney & Rourke, 1978).

Word types differing in regularity comprise the second line of evidence used to assess processing ability in spelling. As in studies of reading, nonsense words are believed to be more highly dependent on phonological processing, while exception words are believed to rely more heavily on visual processing (Ellis, 1984). Regular words, once again, may be construed as being potentially influenced by either or both routes. Examinations of spelling performance on these word types suggests that poor and unexpected spellers experience deficits in both visual and phonological processing (Jorm, 1981; Waters, Bruck & Seidenberg, 1985).

Waters, Bruck and Seidenberg (1985) tested the spelling performance of grade three students separated into good, poor and unexpected speller groups on six word types, which may be grouped roughly into regular, exception and nonsense words. Good spellers were found to make significantly fewer spelling errors on all word types than both poor and unexpected spellers. However, unexpected spellers made fewer spelling errors than poor spellers on one of the types of exceptionally-spelled words, coincidentally termed "exception words" in Waters et al.'s study.

Similar findings were noted by Jorm (1981), with the exception that unexpected spellers in his study also did not differ significantly from either good or poor spellers in their spelling of nonsense words. This inconsistency may be the result of the small sample in Jorm's study (n=4).

There is one final study which bears on the issue of processing ability in spelling that does not fit into either of the previously noted lines of enquiry. Frith (1980) examined the spellings of nonsense words to see if they were influenced by the stored representations of the exception words from which they were derived. It was hypothesized that use of the exceptional spelling components of the original word in producing the nonsense spelling would indicate the employment of the visual route during processing (e.g., using "kn" from knowledge, to produce knobbedge). Frith found that good spellers used significantly more exceptional components from the original words than unexpected spellers. Apparently, unexpected spellers are less able or inclined to assist nonsense word spelling with information from visual representations in the internal lexicon.

In summary, one line of evidence, based on the analysis of phonetically correct misspellings, suggests that good and poor spellers differ on both routes of processing, while unexpected spellers differ from good spellers only in their ability to employ visual processing when spelling. This latter conclusion is further corroborated by qualitative analysis of nonsense word spellings. A second line of evidence, based on the spelling of word types differing in regularity, concludes that in addition to the above noted deficits, unexpected spellers are also deficient when using the phonological route to spell.

There are several possible reasons for the difference noted between these two bodies of research in their assessment of phonological processing in unexpected spellers. One possibility is that the different paradigms made different demands on processing. A second possibility is that the difference is a product of subject age. While the studies of phonetically correct misspelling used subjects aged from 9-years-old to university students, word type studies employed children aged 8 to 11 years. Age is a potentially important variable influencing processing ability (Barron, 1986).

As a final point, the results of Frith's (1980) examination of processing influences in nonsense word spellings suggests the possibility that routes of processing may interact when spelling. The question raised is whether one is able to make an independent assessment of either visual or phonological processing employing experimental designs currently available.

Phonological Analysis and Processing Deficits. Studies employing phonological analysis tasks have found poor and unexpected spellers to show phonological processing deficits in relation to good spellers (Frith, 1978; Perin, 1983). The link to phonological processing is provided by the demands of the analysis which require that a word be broken down into its constituent sound components (i.e., phonemes, morphemes, etc.) prior to manipulation or comparison of these components. However, by the nature of the task, there is a high potential for confounding of visual and phonological processing, and, therefore, there are concerns about drawing inferences to cognitive processes.

Frith (1978) measured the number of rhymes identified as such in sixty seconds by good and unexpected spellers. She found good spellers identified significantly more rhymes during this time period. However, group differences may simply reflect differences in speed with which the words were read. Frith, herself, found unexpected spellers read significantly slower than good spellers in later experiments reported in the same paper.

Perin (1983) provided a more sophisticated assessment of phonological analysis skills by employing a segmentation task, which involved creating spoonerisms. Perin provided good, poor and unexpected spellers with a number of word pairs with instructions to mentally interchange the first grapheme in each word and pronounce the end product. Analysis of the number of correctly formed spoonerisms showed good spellers to be significantly superior to the other two groups, who did not differ. In further support of her phonological hypothesis, Perin noted that the good spellers made proportionally more phonetic errors than poor and unexpected spellers. A smaller proportion of phonetic errors in the latter two groups, she argued, was the result of an inability to perform segmentation tasks.

It is unclear, however, whether Perin's spoonerism task is purely phonological. Item analysis indicated that the majority of good speller errors (52%) were on words that possessed phonemes formed by grapheme combinations (e.g., ch). The type of error most commonly made on these grapheme combinations was to exchange only the first letter, such as c for ch. Transposition of smaller visually identifiable components rather than the larger phonological unit by good spellers suggests that they may have been performing some form of visual analysis. Instead of sounding out the word and using phonological cues to guide the exchange of graphemes, the good spellers may have been accessing the spelling of the words internally and using the visual information provided to carry out the task.

Perin (1983) also examined the ability of subjects to identify the number of phonemes in words with either high (one-to-one grapheme-to-phoneme) or low (more graphemes than phonemes) correspondence. Again she found good spellers to be significantly better at the task than either the poor or the unexpected spellers, who did not differ. Higher error rates on the low correspondence terms for all groups, however, provoked Perin to speculate that this task was not free of orthographic influences.

These findings suggest that poor and unexpected spellers are relatively less able at phonological processing. Perin's (1983) own comments, however, illuminate the greatest weakness of the phonological analysis tasks -- their potential to be confounded by visual processing. Given this concern, it is difficult to know how much confidence to place in inferences from these tasks.

Conclusions. Similar general conclusions may be drawn from reading and phonological analysis research. Unexpected spellers suffer a deficit in phonological processing, while poor spellers suffer deficits in both visual and phonological processing. These two research areas, however, also share a variety of methodological problems. Design flaws and other problems with method are present in a number of studies, while inferences from the results of several studies are problematic. Over and above these concerns is the suggestion that even relatively sound research may not have been able to control for the influence of extraneous variables, or even for the influence of one processing route when a second was being tested. Thus, despite high levels of agreement concerning where deficits lie, empirical support for these conclusions is equivocal and further study is needed.

Spelling research suffers less than reading research from serious methodological flaws and possesses at least one robust finding. Evidence across a range of ages and a variety of studies indicates that good and unexpected spellers produce equivalent proportions of phonetically correct misspellings, which are significantly greater than the proportion made by poor spellers. The inference is that, unlike poor spellers, unexpected spellers have only visual processing deficits when spelling. Despite some contradictory results, this appears to be a strong finding. It would be interesting to see if similar patterns of processing could be observed in reading if the methodological problems were overcome.

Threats to the Validity of Inference

Two methodological concerns undermine the confidence one has in inferences from performance to cognitive functioning of the previous review. Of course, one can never be positive that the functional relationship between observed behavior and any internal event is as hypothesized. However, findings from the above review and evidence presented herein suggest that unless these two concerns are appropriately handled in studies of reader/speller populations, invalid inferences to information processing could result. The first is subject age and the second is the confounding of visual and phonological processing.

Subject Age. It is generally accepted that information processing ability develops over the childhood years. Development has been noted in both reading (Backman, Bruck, Hebert & Seidenberg, 1984; Barron, 1986; Jorm & Share, 1983) and spelling research (Anderson, 1985; Hendersen & Beers, 1980). What course development takes, however, is controversial. In particular, there has been controversy as to whether development consists of qualitative shifts in processing ability (e.g., from use of one processing route to another, or to both) or simply improved performance with age (Barron, 1986). Shifts in development, for example, could proceed either from phonological processing (Doctor & Coltheart, 1980) or visual processing (Condry, McMahon-Rideout & Levy, 1979) to use of both processing routes. However this controversy is resolved, it still remains that relative use of processing routes changes through childhood.

If processing ability follows a developmental course, subjects might reasonably be expected to perform differently on assessments of information processing at different ages. Waters, Seidenberg & Bruck (1984) found that performance on a word recognition task varied with a variety of factors, including age. Information processing tasks, such as those employed by Waters et al. (1984) and in the research reviewed in the previous section, are often treated as if there is only one interpretation of performance. Children's development of information processing, however, may produce different outcomes for different ages on the same measure. To be valid, inferences regarding processing ability coming from observations of performance on these tasks must be put into developmental context.

Developmental changes have also been noted in comparisons between normally-achieving students and students who show poor performance in reading and spelling (Siegel & Ryan, 1988; Sweeney & Rourke, 1978). Siegel and Ryan (1988) examined grammatical-sensitivity, phonological skills and memory in 7- to 14-year-olds, described as normal, disabled (either in reading or math) or as meeting criteria for a diagnosis of attention deficit disorder. They found that though differences between groups on phonological processing and memory persisted across this age range, differences in grammatical-sensitivity resolved at the older ages. Sweeney and Rourke (1978) noted that observed differences in word reading between normally-achieving and disabled grade 4 and grade 8 students were apparent only at the grade 8 level. Though the developmental trends in these two studies appear to work in opposite directions, each demonstrates the possibility that at different ages during childhood assessment of processing is confounded by age. Further, the confounding by age may interact with level of skill (i.e., normally-achieving or not), which is the variable of focus in many studies of reader/speller groups.

Development of information processing has been observed to occur across a range of ages during early childhood. It is difficult to put a time frame to the development of information processing because of the small number of studies that have been completed. Some of these studies, employing longitudinal methodology, have tested children as young as five years of age and observed developmental trends in their ability to use phonological processing through to as high as eight years of age (Bradley & Bryant, 1985; Ellis & Large, 1987). Similarly, significant developmental changes have been noted across the middle childhood years (i.e., from 7 to 11 years of age) (Backman et al. 1984; Condry et al., 1979; Doctor & Coltheart, 1980). This suggests that assessments of processing during these periods may produce results specific to a given cohort.

By the end of this middle childhood period, however, processing, both quantitatively and qualitatively, is beginning to resemble that of adults. Condry et al. (1979) noted that the response times exhibited by 10-year-old students in a word reading task were not greatly different from those of adults, while 7-year-olds evidenced much slower times. Backman et al. (1984) examined visual and phonological processing across several age groups by comparing performance on words differing in phonological and orthographic regularity. They found that differences in word reading ability suggesting facility with only the phonological route, that were significant in grade 2 and grade 3 children, were not significant in grade 4 children or adults. The pattern of development appears to be one of ever closer approximations to adult-like performance as age increases, where adult-like performance is defined as facility with both routes of information processing (Barron, 1986).

It is interesting to note that the observations that both routes of processing are more likely to be employed in older children and adults is in keeping with models of information processing. However, this is not surprising given that models of information processing have been built predominantly on observations of young adult university students. Expectations of processing ability likely reflect information processing as defined by adult functioning.

It would seem that age is an important variable influencing both task performance and inferences about visual and phonological processing ability. One must be careful therefore to make inferences from the results of a specific age group only to appropriate populations. It would seem to be the case that until children have reached a certain age their levels of performance and quality of processing differ from those of adults. If one is to make inferences regarding processing employing models based on adult performance, then using children who differ in such critical fashions from adults is not a viable approach. Tests of visual and phonological processing concerning adult-based models may best be carried out on adults.

Nonindependence of Processing Routes. It has been argued that visual and phonological processing are not independent (Humphreys & Evett, 1985; Kay & Marcel, 1981). One implication of this argument is that measurement of the effects of one route unconfounded by the effects of the other may not be possible. The focus of research on reader/speller groups has been to associate deficits in one or the other (or both) processing routes with a particular pattern of reading and spelling ability. Valid inferences of processing deficits would require that assessments of processing isolate the effects of these two potentially interrelated routes.

Some confounding of visual and phonological processing seems apparent from the present literature review. Perin (1983) commented that despite attempts to formulate a task that involved cognitive manipulations only of sound characteristics, her experiments on phonological analysis exhibited effects of both visual and phonological processing. In spelling, Frith (1980) found that information from visual representations in the lexicon can influence nonsense word spellings, although these have been hypothesized to be processed only phonologically.

Possibly the paradigms employed in previous studies of reader/speller groups are not sufficiently powerful to separate the effects of the two routes of processing. Humphreys and Evett (1985) comment that currently used experimental stimuli confound assessments of visual and phonological processing. Support for the notion that word stimuli confound effects of processing routes is evident in studies which correlate reading of different word types. A number of studies have found that correlations in both reading and spelling of regular, exception and nonsense words, which are assumed to rely differentially on the two processing routes, are all significant and high (Jorm, 1981; Read & Ruyter, 1985; Treiman, 1984). Significant correlations suggest that there exists strong overlap between word types in their use of visual and phonological processing, though this does not necessarily imply sharing of these routes. Some support for differential reliance on processing routes is seen in significant differences in the relative magnitude of the correlations (Treiman, 1984). Even in this case, however, a veridical statement of the relationship to processing routes would have to be that of relatively stronger relationships to some routes for some stimuli, which would not rule out the potential for confounding.

It has also been demonstrated that tasks employing stimuli designed to assess only the effects of one processing route show effects of both routes (Humphreys & Evett, 1985). These effects have been noted in nonsense word readi... where phonological processing is assumed to be exclusive (Kay & Marcel, 1981; Manis, Szeszulski, Howell & Horn, 1986; Rossen, 1983). For example, Kay and Marcel (1981) examined word reading in word/nonsense word pairs having either similar or dissimilar orthography, where words also varied in regularity of pronunciation (regular vs. irregular sounding). These authors found that nonsense word readings were significantly biased by the previously presented word. This suggests that nonsense word reading could be influenced by visual similarity to a previously presented prime, an effect that should logically occur only via a visual route of processing. Visual priming of nonsense words has also been noted in spelling, with children (Campbell, 1985; Marsh, Freidman, Welch & Desberg, 1980) and adults (Campbell, 1983).

The influence of phonological processing where such processing is logically not expected is less substantiated. Humphreys and Evett (1985), in a re-analysis of prior research, argue that there is evidence of systematic effects of phonological characteristics (e.g., regularity) on stimuli and tasks believed to require visual processing. Parkin and Underwood (1983) provide some evidence in a study of regularity effects to suggest confounding in judgments of meaningfulness of exception words. The regularity effect is the finding that regularly pronounced words take less time to be identified than irregularly pronounced words. These authors found that when words were presented in upper case letters no significant difference in response time occurred between words which were both phonologically and orthographically irregular, and regular words. This suggests that under the right circumstances effects assumed specific to phonologically processed items may be revealed in stimuli assumed to require visual processing.

In summary, the ability to isolate the effects of visual and phonological processing also appears to be an important variable in drawing inferences about these processing routes. Examination of correlations between word type stimuli often employed in research underlying such inferences suggests that direct comparisons of such items may be of limited utility. As well, assessment of the interactions of visual and phonological processing suggests that either route can be found to influence performance on tasks designed to measure but one route. Confidence in drawing inferences from such material is thus undermined.

Conclusions. Two steps can be taken to address the threats to validity discussed in this section. The first is to employ adults as subjects, at least for initial investigations of a model of adult processing. Once the relationship between experimental tasks and information processing has been tested, then task-process relationships can be explored in other age groups. A second step is to look for alternate paradigms which are better able to isolate the effects of the two information processing routes.

An Alternative Word Reading Paradigm

One alternative to previous word reading paradigms is the matched-stimulus design proposed by Van Orden (1987). This design asks subjects to complete a categorization task, identifying whether visually-presented target words are members of previously presented categories. For example, the subject might be presented with the category "a feature of a person's abdomen" followed by a stimulus word such as "NAVEL". Unknown to the subjects a percentage of the targets, called foils, are incorrect items manipulated such that they may be confused with true category members. The unique aspect of these target foils is that their visual and phonological characteristics are matched such that the foils differ minimally from each other and, in some instances, from true category members along one of two stimulus dimensions. Performance of the subjects is measured in terms of false-positive errors, defined as incorrectly identifying a foil as a category member. The rate of false-positive errors is then compared across stimulus conditions to see the effect of foils on ability to make correct category judgments.

Van Orden employs two types of foils in his paradigm. The first are homophones, which are words selected such that they sound identical to a correct category member. For example, for the category "a deer" the homophone DOUGH would be a foil for the correct category member DOE. Homophone foils are thus identical to category members in phonological characteristics. The second are spelling controls, which are words selected such that they are as visually similar to correct category members as homophones but do not sound like either. For example, for the category "a deer" the spelling control foil DOUBT is as visually similar to the category member DOE as is the homophone DOUGH. Selection of spelling control foils is based on a formula for equating visual similarity of foils to category members which includes as variables the number of same order adjacent letter pairs, number of different order adjacent letter pairs, number of single letters, average number of letters in each foil and true category exemplar pair, and presence of same first and last letter shared with the category member. In this manner, spelling control foils are matched with homophones on the degree to which they share visual characteristics with true category members.

This design of target foils provides one possible solution to the confound of visual and phonological processing. By matching foils on characteristics assumed to be processed by one processing route, the effects of that route can be equated across stimulus conditions. Homophones are chosen to be phonologically identical to true category members. As a result, each homophone may be assumed to be as similar to its corresponding category member as any other and, therefore, provide the same amount of phonological information for distinguishing the two. Similarly, homophones and spelling controls share the same degree of visual likeness to category members. As a result, the effects of visual processing will be relatively constant across homophone and spelling control foils.

With the effects of one processing route held constant, the experimenter is free to investigate the influences of the second route by varying characteristics associated with it. For assessments of phonological processing this variation is provided by the comparison of homophones and spelling controls, which differ in how much they sound like a category member. For assessments of visual processing homophones are dichotomized into those which are high and those which are low in visual similarity to category members. This dichotomy varies the amount of visual cues available for processing.

Van Orden's comparisons appear well suited to the task of indicating the presence of visual and phonological processing, but they do not, by themselves, speak to the level of processing ability. For example, visual processing ability is inferred if the percent of false-positive errors to homophones was found to decrease significantly from the high (possessing fewer visual cues) to the low (having more visual cues) visual similarity condition. There is no indication whether the level of performance was good, poor, or average. Deficits in information processing, however, are measured as lesser ability to carry out certain cognitive functions. Thus, to detect deficits within the paradigm a standard is needed with which to compare level of ability to process visual and phonological information.

Additional comparisons of performance across several reader/speller groups may provide the necessary standard against which processing deficits may be detected. Borrowing from Van Orden's logic, visual processing ability may be revealed through comparison of performance between groups on homophones.

False positive identification of homophones as correct category members indicates that the foil has been mistaken for the member. That is, the visual representation of the category member has been accessed and a decision has been made that it matches that of the foil. This decision is not likely to have been made based on phonological processing as the foil and the category member are homophonic (i.e., phonologically identical) and unlikely to be discriminated on the basis of sound cues. Identification and resulting decisions must then occur as a result of visual cues. False positive errors to homophones may thus be interpreted as representing errors in visual processing, while group differences on these errors represent relative visual processing ability.

Comparison of performance across groups to spelling controls reveals relative strengths in phonological processing. Spelling controls differ from category members in both sound and orthography (i.e., phonologically and visually). As such, there is no inherent comparison between spelling controls and category members that speaks to either visual or phonological processing. The relationship of spelling controls to homophones, however, provides for an interpretation of phonological processing ability. Van Orden argues that because spelling controls are as visually similar to category members as homophone foils, any differences in performance between spelling controls and homophones must be a product of phonological processing. This same argument can be extended to group comparisons. Group differences in false positive errors to homophones have been argued to reflect relative visual processing ability. If performance on spelling controls was likewise influenced by visual processing, a similar pattern to that found for homophones should emerge. Any significant deviation from the pattern of performance expected from that on homophones must be a result of phonological processing.

In summary, the paradigm devised by Van Orden (1987) provides a promising alternative to assessing visual and phonological processing in word reading which provides independent tests of the two processing routes. When modified to include comparisons between groups this paradigm also becomes sensitive to deficits in processing of visual and phonological information.

Conclusions and Present Study

Much reading research employing good, poor and unexpected spellers suffers from methodological problems. In particular, validity of inference has been a concern because of the exclusive use of young children to test models of processing derived from an older age group and difficulties in devising paradigms which isolate the independent effects of processing routes. As a result, conclusions drawn from this research are equivocal and in need of further testing.

Van Orden's (1987) matched-stimulus design has many attributes which make it appropriate for the further study of reading. The paradigm employs word reading, making it roughly comparable in task demands to most previous studies. As well, the paradigm has the potential to better isolate the independent effects of visual and phonological processing. This is an important property in research which is focussed on associating specific processing deficits with differences in performance on academic tasks.

The present study has two primary purposes. First, the study set out to provide yet another assessment of visual and phonological processing in word reading. The basic question was whether or not good, poor and unexpected spellers would show the same ability to use visual and phonological processing. Second, the study sought to test the usefulness of the new paradigm proposed by Van Orden (1987) for assessing visual and phonological processing in reader/speller populations.

University students were selected as the subject population for this study. One reason for this choice was that in hoping to partially replicate Van Orden's study it made sense to employ a similar population (i.e., university students). A second reason was that the model of information processing that Van Orden purports to measure and which is assumed by the research reviewed previously is based on adult functioning.

Hypotheses for the present study were based on general findings in spelling. Logically, hypotheses for another study of reading should fall out of past research on reading. However, robust findings in spelling coupled with methodological weaknesses noted in reading research led to greater confidence in the outcomes expected from the spelling research.

It was expected that all groups would show both visual and phonological processing ability. It was hypothesized therefore that good, poor and unexpected spellers would show improved performance from high to low visual similarity homophones (indicating visual processing) and from homophones to spelling controls (indicating phonological processing).

It was predicted that there would be an interaction between group and the factor Homophony (homophones vs. spelling controls). This interaction reflects the differing relative performance of the groups at the two levels of this factor. Differences in processing ability specific to the individual processing routes were expected to be revealed by the comparisons across groups at each level of the Homophony factor. It was hypothesized that good spellers would make fewer false-positive errors (showing superior visual processing skills) on homophones than poor and unexpected spellers, who would not differ. It was also hypothesized that good and unexpected spellers would not differ from each other on spelling controls and both would make fewer false-positive errors than poor spellers.

Method

Subjects and Selection. An initial screening of 301 first year university students was employed to find 15 males and 15 females who met membership criteria for the three reader/speller groups of interest (i.e., 5 each of males and females for each group). Both males and females were chosen to assess processing differences based on gender, although these were not expected.

Screening Instruments. The measure of reading ability used was the Comprehension Subtest from the Nelson-Denny Reading Test (Form E) (Brown, Bennett, & Hanna, 1981). This test of reading comprehension is composed of eight reading passages and 36 multiple choice questions. The test has good reliability (alternate form reliability of r=.77) and is generally accepted as a valid and appropriate measure for isolating individuals experiencing reading difficulties when given in a group situation (Cummins, 1981; Webb, 1983). Testing using the comprehension subtest is limited to 20 minutes.

The measure of spelling employed was the Wide Range Achievement Test - Spelling Subscale (Level 2) (Jastak & Jastak, 1978). This subtest contains 46 terms arranged in order of increasing difficulty. The split-half reliability for ages 12 to 24 on the level 2 items is good (r=.97). The spelling subscale has also been well validated against other tests of spelling (e.g., the New Stanford Dictation Test, r=.97) (Jastak & Jastak, 1978). Words to be spelled were presented from a prerecorded tape of a male reading each word alone twice and in a sentence once.

Screening Procedures. Screening began with the spelling test (the Wide Range Achievement Test (WRAT) - Spelling Subscale (Level 2)) followed by the comprehension test (the Nelson-Denny Reading Test - Comprehension Subscale (Form E)). Total in class time was between 35 and 40 minutes. At the outset of testing, subjects were informed that participation was voluntary. As well, they were informed that these measures were to be used to gather a normative sample and that they might be subsequently contacted for further participation (see Appendix A).

Subjects were selected for inclusion in one of the three reader/speller groups based on *z*-scores derived from test results of the initial screening. To be included in the good speller group, a subject had to have a *z*-score of 0.0 or greater (i.e., at or above the sample mean) on both reading and spelling tests. Similarly, to be included in the poor speller group, a subject had to have a *z*-score of -0.750 or lower (i.e., three quarters of a standard deviation or more below the sample mean) on both reading and spelling tests. Finally, to be included in the unexpected speller group, a subject had to have a *z*- score of 0.0 or greater on the test of reading and -0.750 or lower on the test of spelling.

To ensure that good and poor performance was comparable across groups, where such comparability was expected, groups were matched on gender and test performance. This was accomplished by dividing subjects into sets of three, containing one good, one poor and one unexpected subject. For each set of subjects matching was performed such that all were of the same gender, with reading scores matched between the good and the unexpected subject and spelling scores matched between the poor and the unexpected subject. It was not

Table 1:

Z-Scores by Group on Reading and Spelling Tests

		Group	
Measures	Good	Unexpected	Poor
Reading			
$\underline{M}$	0.25	0.38	-1.12
$\underline{SD}$	(0.481)	(0.631)	(0.283)
Spelling			
$\underline{M}$	0.53	-1.60	-1.93
$\underline{SD}$	(0.497)	(0.727)	(0.740)

note Groups having the same mathematical sign do not differ significantly.

possible in all cases to have a perfect match on test scores. Where a perfect fit could not be achieved, scores adjacent to the best fit were examined in a widening search until the closest possible match was achieved. An analysis of variance of group differences found good spellers not to differ significantly from unexpected spellers on reading scores and poor spellers not to differ significantly from unexpected spellers on spelling scores (see Table 1).

Stimuli. The targets of interest were 20 homophone foils, 10 of which were highly visually similar to true category exemplars (e.g., NAVAL is homophonic and visually similar to NAVEL) and 10 of which were less similar (e.g., DOUGH is homophonic, but less visually similar to DOE), and 20 spelling control foils matched with homophones such that 10 were highly visually similar to exemplars (e.g., NOVEL is non-homophonic, but as visually similar to NAVEL as NAVAL) and 10 were less similar (e.g., DOUBT is non-homophonic, but as visually similar to DOE as DOUGH), as derived by Van Orden (1987) (see Appendix B). According to Van Orden, control for orthographic similarity was achieved through calculations of visual similarity based on number of same order adjacent letter pairs, number of different order adjacent letter pairs, number of single letters, and average number of letters in each foil and true category exemplar pair. As well, control for possible differences in word frequency had been achieved by equating the groups on Kucera and Francis (1967) frequency counts. No foils were presented more than once.

Filler stimuli were comprised of category exemplars (true members of the category) and nonexemplars (terms chosen not to be in any way like a true category exemplar) in equal proportions. Design of fillers was nonsystematic, with the exception that neither exemplars nor nonexemplars could be homophones. Assignment of nonexemplars to categories was random. As with foils, fillers were presented only once each.

Procedure. Following subject selection, each subject was tested in the semantic categorization task. Equipment and procedures were designed such that they approximated as closely as possible the categorization task described in Van Orden's (1987) first and third experiments. Subjects were seated in front of a microcomputer console and screen upon which stimulus materials were presented. Each subject was introduced to the equipment and given a set of instructions (see Appendix A) to familiarize them with the task. Instructions stressed both speed and accuracy of responding.

Practice and experimental trials began with the presentation of a fixation point (i.e., a "+" sign) at mid-screen and a category name exhibited directly above that point. Subjects were instructed to read the category name silently and then look to the fixation point. When the target word appeared subjects indicated whether it was a member of the previously presented category by pressing either a "yes" or "no" key clearly identified on the computer console and then named the target word. No feedback as to performance during testing was provided. Subjects' verbal responses (i.e., word names) were recorded by the experimenter. Response latency was recorded employing a set of two response keys on the keyboard manipulated by the subject's preferred hand. "No" responses were always indicated by the middle finger and "yes" responses by the index finger.

Fifty practice trials, including four trials with foils, were given during the practice period so as to acclimatize subjects to both filler and foil items. One hundred and twenty experimental trials were presented following the practice. Of these trials, 33.3 percent were target foils. A low rate of foils was employed to reduce the likelihood of subjects engaging in processing strategies that could have invalidated the manipulation (Van Orden, 1987).

Order of presentation of practice and filler items was constant across subjects, with key trials containing homophone foils or spelling controls randomly interspersed among filler experimental trials. Positioning of foils was constrained by two decision rules. First, at least two, and no more than three, filler items fell between foil presentations. Second, the order of foils was block randomized such that a foil from each condition was presented within each successive block of four foils. That is, one high visually similar homophone, one low visually similar homophone, one high visually similar spelling control and one low visually similar spelling control foil was presented in each successive block of four foil trials. Ten presentation lists were created following these rules. These lists were employed such that the first subject in each condition was tested using the first list, the second subject in each condition received the second list, and so on.

Debriefing of the subjects included a short statement regarding the populations of interest in the study (see Appendix A). The necessity of not disclosing the experimental procedure to others was stressed to the subjects. Subjects who asked to know why they were included in the study were informed of their test performance, but reassured that such performance does not reflect academic potential. Subjects who requested help related to their reading and spelling problems were referred to an appropriate service agency on the university campus.

Viewing conditions. All stimuli were printed in capital letters and presented by an IBM PC computer on a Princeton Max-12 monitor in amber on a dark background. Timing functions were carried out by a Tecmar Labmaster board with a 1 msec resolution. Brightness and contrast were adjusted individually to achieve clear viewing for each subject.

Presentation of stimuli occurred in the following temporal sequence: The fixation point and category name were presented for 1,500 msec, and were then replaced by the target word for 500 msec. Following offset of the target word, a patterned mask was presented for a further 1,500 milliseconds.

The fixation point occurring at the same position on the screen for every trial, indicating where the target word would appear. Depending on the number of letters in the target word, the fixation point either anticipated the central letter in words with an odd number of letters or the lead letter of the two central letters in words with an even number of letters. The pattern mask was constructed of random characters strung across the visual field where the stimulus materials were presented so as to to prevent continued processing subsequent to the presentation of the mask (Cheeseman & Merikle, 1987).

Design. The design of the present study was a 2 (gender) by 3 (groups) by 2 (homophony) by 2 (visual similarity) factorial. Groups was a between-subjects factor with each of its levels corresponding to one of the reader/speller groups, good, poor and unexpected spellers. Homophony was a within-subjects factor composed of two levels of target foils, homophones (same sound as true category exemplars) and spelling controls (different sound from true category exemplars but as visually similar to them as homophone foils). Visual similarity was also a within-subjects factor having two levels, high visually similarity and low visually similarity (as compared to the true category exemplar).

Results

The trials of interest were those containing either homophone (e.g., NAVAL for NAVEL and DOUGH for DOE) or yoked spelling control (e.g., NOVEL and DOUBT) foils. These items were designated as key foils. The independent variables were homophony (homophones vs. spelling controls), visual similarity (high visual similarity foils, such as NAVAL, vs. low visual similarity foils, such as DOUGH), group (good, poor and unexpected spellers) and gender (male vs. female). The dependent measure for the error analyses was the percentage of false positive responses to key foils. Mean reaction times for false positives and correct rejections served as dependent variables for analyses of response latencies.

The present data were initially tested using a four factor analysis of variance (gender by homophony by visual similarity by group) (see Appendix C). The main effect of, and interactions with, gender were not significant. As a result, this factor will not be discussed in either the results or discussion sections. Following the initial ANOVA simple main effects were tested using statistical procedures modelled on the comparisons of interest identified by Van Orden (1987) and modified to accomodate the group variable.

Visual and Phonological Processing Dimensions

Findings of this study strongly replicate those of Van Orden's (1987) original research. Processing ability across both visual and phonological dimensions was found for all groups.

Comparison with Van Orden (1987). Comparison between Van Orden's (1987) and the present study was restricted to findings for false positive errors because Van Orden was not able to measure reaction times. Statistical comparisons were modelled on the original analysis, such that effects of phonological processing were tested by comparing performance on homophones and spelling controls, and effects of visual processing were tested by comparison of high and low visual similarity homophones. Scores from the present study used for comparison with Van Orden's findings were derived by collapsing across all three comparison groups.

Table 2 shows the percentage of false positive errors for the total samples in each study. Mean percentage of false positive errors was surprisingly similar in the two studies. Only one large difference was apparent. Subjec:_ in Van Orden's study had an average of 29% errors to high visual similarity homophones, while subjects in the present study had, on average, 37% such errors. Statistical comparisons were also consistent across studies. As with Van Orden's study, percentage of false positive errors on homophone foils (24.7%) was significantly greater than that for spelling control foils (4.5%) [$F(1,24)= 50.59$, $p < .001$]. As well, a significantly greater percen*:ge of false positive errors to high visual similarity homophones (37%) than to low visual similarity homophones (12%) was found [$F(1,24)= 4.76$, $p<.05$], also replicating Van Orden's findings.

Table 2:

Percent of False Positive Errors to Homophone and Spelling Control Foils at Two Levels of Visual Similarity for the Present Study and Van Orden (1987)

Foil Type	High Visual Similarity	Low Visual Similarity	Overall
		Present Study	
Homophones			
M	37.33	12.00	24.67
SD	(23.479)	(12.972)	(18.226)
Spelling Controls			
M	8.00	1.00	4.50
SD	(11.861)	(4.026)	(7.944)
		Van Orden (1987)	
Homophones			
M	29.00	8.00	18.50[a]
SE	(6.9)	(2.9)	
Spelling Controls			
M	5.00	1.00	3.00[a]
SE	(3.1)	(1.0)	

[a] The value of SE was not provided for the overall score.

Significance of these effects provides further support for the importance of visual and phonological processing in reading.

The present study provides a strong replication of Van Orden. Despite inclusion of subjects from groups expected to evidence processing deficits, the pattern of responding first noted in Van Orden (1987) was found again here for the collapsed sample. Further, finding these results with the present sample provides evidence that this is a robust technique for assessing visual and phonological processing.

Processing within groups: False positive errors. Testing of individual groups was also carried out. Once again statistical comparisons were modelled on those outlined in Van Orden's (1987) first experiment.

Significant effects for homophony and visual similarity across homophones were found for all groups when false positive error rates were tested for each individual group. Percentage of false positive errors for the three reader/speller groups to homophones and spelling controls having high and low visual similarity can be seen in Table 3. Comparisons between the mean percentage of false positive errors to homophones (11.5%, 25% and 37.5%, respectively for good, unexpected and poor groups) and spelling controls (.5%, 2% and 11%, respectively for good, unexpected and poor groups) using tests of simple main effects were significant for all groups [$F(1,24) = 6.54$, $p < .05$, for good spellers; $F(1,24) = 23.59$, $p < .01$, for unexpected spellers; and $F(1,24) = 37.96$, $p < .01$, for poor spellers]. As well, tests of the simple main effects of error rates to high (18%, 38% and 56%, respectively for good, unexpected and poor spellers) and low visual similarity homophones (5%, 12% and 19%, respectively for good,

Table 3:

Percent False Positive Errors to Homophone and Spelling Control Foils at Two Levels of Visual Similarity by Reader/ Speller Group

	Group		
Condition	Good	Unexpected	Poor
Homophone/High Visually Similar			
M	18.00	38.00	56.00
SD	(16.866)	(15.492)	(21.187)
Homophone/Low Visually Similar			
M	5.00	12.00	19.00
SD	(12.693)	(4.216)	(11.972)
Spelling Control/ High Visually Similar			
M	1.00	4.00	19.00
SD	(3.162)	(9.661)	(11.972)
Spelling Controls/ Low Visually Similar			
M	0.00	0.00	3.00
SD	(0.000)	(0.000)	(3.162)

unexpected and poor spellers) were found to be significant for all groups [$\underline{F}(1,24) = 4.57$, $\underline{p} < .05$, for good spellers; $\underline{F}(1,24) = 18.27$, $\underline{p} < .01$, for unexpected spellers; and $\underline{F}(1,24) = 37.00$, $\underline{p} < .01$, for poor spellers]. This replicates the pattern of significance found in Van Orden (1987) for all three groups, and suggests that all groups can benefit from increasing numbers of phonological and visual cues, which Van Orden has argued indicate working phonological and visual processing routes.

Tests of comparisons across factors of homophony and visual similarity for homophones indicates performance of all groups improved in the presence of an increased number of processing cues, whether visual or phonological. This is in keeping with the hypotheses which predicted that good, poor and unexpected spellers would evidence visual and phonological processing ability.

Processing within groups: False positive reaction times. Comparison of false positive reaction times were not tested because of violations of the assumptions underlying the analysis. Mean false positive response times, standard deviations and cell counts (i.e. numbers of subjects contributing data to each cell) for each group are listed in Table 4. False positive reaction times were calculated as the total reaction time in all false positive trials divided by the number of trials in which false positive responses occurred. As with false positive error scores, reaction times were derived for each of the four conditions.

Violations of assumptions included selective attrition from conditions. Cell counts were lowest in the good speller group, followed by the unexpected speller group and then the poor speller group. Such differences were also very large, with differences between cell counts as high as 7 (with a maximum possible count

Table 4:

False Positive Reaction Time Scores to Homophone and Spelling Control Foils at Two Levels of Visual Similarity by Reader/Speller Group

	Group		
Condition	Good	Unexpected	Poor
Homophone/High Visually Similar			
M	1627.12	1375.52	1517.35
SD	(1208.527)	(381.589)	(1176.773)
Count	7	10	10
Homophone/Low Visually Similar			
M	1427.12	2648.85	1431.40
SD	(927.547)	(2633.850)	(662.362)
Count	2	10	9
Spelling Control/ High Visually Similar			
M	1343.00	1135.66	1385.39
SD	(0.00)	(436.049)	(578.557)
Count	1	2	8
Spelling Controls/ Low Visually Similar			
M	-	-	2539.50
SD	-	-	(1864.641)
Count	0	0	2

of 10). This association between number of subjects in each cell and group is critical because attrition in this case is a product of test performance. Subjects who did not make false positive errors could not be included in the analysis, introducing an uncorrectable selective bias. The most likely reason for the variability in cell count was a floor effect in the spelling control conditions. Performance in these two conditions for the good and unexpected spellers suggests that this condition did not provide a difficult enough challenge for these groups.

A second violation is that means and standard deviations were not independent. Examination of Table 4 shows that the higher the mean, the greater the standard deviation. This relationship between mean and variance violates a fundamental assumption of ANOVA that these two parameters remain independent (Pedhazur, 1982). Finally, any interpretation or analysis is complicated by the lack of variance in three cells, two of which lack any findings whatsoever.

Processing within groups: Correct rejection reaction times. Correct rejection responses were defined as a "no" response to key foils coupled with a phonetically accurate pronunciation of the foil. As with false positive reaction time scores, mean correct rejection reaction times were calculated as the arithmetic mean of correct reaction times divided by the number of such responses within each condition.

Table 5 shows reaction times, standard deviations and cell counts for the three groups. The only significant finding was a main effect of homophony. Mean reaction time to homophone foils (1346.78 msec) was significantly higher than

Table 5:

Correct Rejection Reaction Time Scores to Homophone and Spelling Control Foils at Two Levels of Visual Similarity by Reader/Speller Group

	Group		
Condition	Good	Unexpected	Poor
Homophone/High Visually Similar			
M	1334.57	1456.37	1464.90
SD	(450.123)	(400.951)	(441.080)
Count	10	10	10
Homophone/Low Visually Similar			
M	1174.02	1277.17	1373.65
SD	(372.354)	(323.144)	(405.965)
Count	10	10	10
Spelling Control/ High Visually Similar			
M	1245.61	1351.18	1371.32
SD	(415.786)	(410.385)	(448.157)
Count	10	10	10
Spelling Controls/ Low Visually Similar			
M	1146.04	1244.96	1358.77
SD	(328.313)	(374.778)	(510.984)
Count	10	10	10

that to spelling control foils (1286.32 msec) [$F(1,24) = 8.45$, $p < .05$]. This effect of homophony suggests that all groups benefitted equally from increased phonological cues. This analysis suggests that phonological representations influence the rejection of erroneous stimuli, and likely, word reading as well.

Relative Performance

Significant interactions of Homophony with Group [$F(2,24) = 6.20$, $p < .01$] were found in the overall ANOVA using false positive error rates. This pattern of significance suggests that the effects of homophony on group were not the same at both levels of the factor. To test for hypothesized relationships between groups at each level of homophony, multiple comparisons were made of group performance using Scheffe's method (Winer, 1973). In contrast to the previous section, comparisons explored herein are based directly on differences between groups. Two sets of comparisons were made. The first tested the prediction that good spellers have superior visual processing ability to that of poor and unexpected spellers. Performance on homophone foils was employed in these comparisons. The second tested the prediction that good and unexpected spellers have phonological processing ability superior to that of poor spellers. Analysis of the spelling control foils was employed in these comparisons.

Between group comparisons on false positive errors. Comparison of performance on homophones between groups suggests that, in keeping with the hypothesized outcomes, good spellers are superior to poor spellers at visual processing. However, performance of unexpected spellers suggests that they too are superior to poor spellers in visual processing, which is not in keeping with the hypothesized relationship. As expected, comparisons of performance on spelling controls suggests that good and unexpected spellers are superior to poor spellers in phonological processing.

The significant group by homophony interaction (see Figure 1) can be understood in terms of differences in the relationship between groups on homophones and spelling controls. The mean percentage of false positive errors to homophones for good spellers (11.5%) was significantly lower than that for both unexpected (25%) and poor spellers (37.5%), while unexpected spellers were found to make a significantly lower percentage of errors than poor spellers. This effect of group on false positive errors to homophones indicates that that all three groups differ significantly from each other in visual processing ability. This was not the case on spelling controls. The mean percentage of false positive errors to spelling controls for good (0.5%) and unexpected (2.0%) spellers did not differ, while both were superior to that of poor spellers (11%). This pattern of processing differences can be interpreted as indication of phonological processing deficits in poor spellers only.

Thus the results of this series of comparisons confirms differences in processing abilities. This pattern indicates relative processing deficits in reader/speller groups performing below expected either in spelling and/or reading.

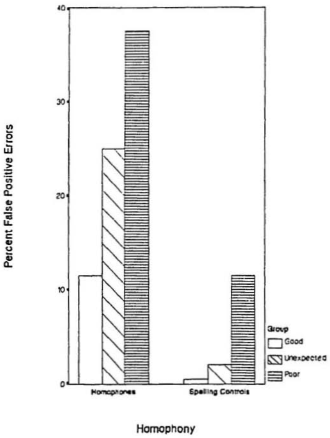

Figure 1: Mean Percent False Positive Errors by Homophony by Group

Discussion

The present study generally replicated the effects of homophony and visual similarity found by Van Orden (1987). More false positive errors were made to homophones than to spelling controls and more false positive errors were made to high visual similarity homophones than to low visual similarity homophones. This replication held for all three groups studied. As well, a reasonable approximation of the expected pattern of deficits was present when error rates were compared between groups on homophone and spelling control foils.

Patterns of Processing Deficits. Relative performance findings (i.e., between group comparisons) on homophone and spelling control foils suggest that the three reader/speller populations make up three distinct information processing subgroups. Unexpected spellers are distinguished from good spellers by their significantly higher rate of false positive errors to homophones. Poor spellers are distinguished from good and unexpected spellers by their higher rate of errors to both homophones and spelling controls. The findings concerning performance on homophones may be interpreted to indicate visual processing deficits in both poor and unexpected spellers. While the interpretation of findings concerning spelling control foils is problematic because of the confounding of visual and phonological similarity, unique difficulties with these words may be taken to suggest an additional phonological processing deficit in the poor speller group.

Information processing ability was also assessed through comparisons across stimulus conditions within the homophony and visual similarity factors. Processing ability is suggested if performance improves (i.e., fewer false positive errors occur) with an increase in the number of features which aid discrimination of foils and true category members. Within subjects comparisons from the present study suggest that all of the three groups possess visual and phonological processing ability. Comparisons across stimulus conditions found all three groups to improve performance when increased numbers of processing cues were present, whether such cues were visual or phonological. If any group were unable to process such cues, then that group should have failed to improve their performance when more cues were provided.

Findings from the present study suggest patterns of processing abilities which appear largely inconsistent with those found in previous studies of information processing in reading. Those studies have determined that unexpected spellers' performance is akin to that of poor spellers, with both these groups showing evidence of phonological processing deficits. Waters, Bruck and Seidenberg (1985) found that reading performance in poor and unexpected spellers suggests a shared phonological processing deficit when compared to good spellers. This similarity in performance between unexpected and poor spellers was attributed to shared difficulties with spelling-sound correspondence rules. Similarly, Jorm (1981) found unexpected spellers not to differ from poor spellers when reading regular and nonsense words. Though the small sample size of that study precludes any firm conclusions, the shared performance on regular and nonsense words is suggestive of a shared phonological processing deficit.

A probable explanation for differences between these comparison studies and the present research is the difference in the ages of the samples employed. Comparison studies employed subjects aged 8 to 10 years. In contrast, the present study used university students. The case has been made that shifts in the employment of information processing routes may occur during development. Different results may therefore reflect differences in cognitive development in samples selected for study. Comparisons having greater validity might be made to studies by Frith (1978; 1983) in which older, 12-year-old, children were used.

Frith's results (1978; 1983) may be interpreted as indicating visual processing deficits which are in keeping with the relative performance findings of the present study. Frith (1978, exper. II) examined good and unexpected spellers' ability to detect misspellings that left either the sound or the appearance of the words intact. In creating these stimuli Frith preserved the sound of words by omitting letters which visually altered the word but left the sound intact. Similarly, her visually preserved items were formed by removing letters which changed the sound of the word, but minimally altered its general form.

Frith found that good spellers' performance was superior on errors which preserved sound, but not on those that preserved appearance, which she took to indicate a phonological deficit in unexpected spellers. These outcomes, however, could equally be attributed to the nonpreservation of visual and phonological features which was a by-product of the initial manipulation. This latter possibility seems more likely when one considers that the discrimination of incorrect from correct words proceeds on the basis of a search for dissimilar features (i.e., "Does it look right or sound right?"). Under such circumstances a dissimilar rather than a similar feature would provide the necessary information to identify misspellings. Given this argument, misspellings in the preserved sound condition would be most likely to be detected based on the nonpreserved visual features. Group differences may thus be reflecting difficulties in visual processing.

Similarly, the anomalous performance of good spellers in Frith's (1978) third experiment might be interpreted to suggest that unexpected spellers suffer a visual deficit. Good spellers in the study were better able to detect misspellings which preserved both visual and phonological features than misspellings which preserved only visual features. If the good spellers had been using a phonological processing strategy (i.e., looking for incorrect sounding misspellings), then more errors should have been made to misspellings which preserved phonological features as they provided the least amount of erroneous sound cues. This may be interpreted as indicating a deliberate shift by good spellers to a visual processing strategy. Unexpected spellers, however, evidenced no significant difference in their responding to the two conditions, suggesting the possibility that they were unable to make use of such a visual strategy.

A third study, Frith (1983), provides the most straightforward support for a visual deficit. Performance of good and unexpected spellers was compared on a task which required subjects to identify target letter strings from a series of redundant and nonredundant strings. Redundant strings were formed of pronounceable letter groupings (e.g., spect), which could be discriminated from others in the list using both phonological and visual reading strategies. Nonredundant strings were formed of unpronounceable letter groupings (e.g., ihxgv). Discriminating strings within these lists would be limited to visual processing. Frith found good spellers to be superior on nonredundant strings, while no significant differences were found for redundant strings. As a salient difference between series was the availability of sound features in the redundant string condition, group differences may be seen to be a product of a visual processing deficit in unexpected spellers.

These three studies suggest that there may be some prior support for a visual processing deficit in unexpected spellers. Such interpretations must be made tentatively, however. In two cases such interpretations contradict the conclusions of the original author, while in the third case the study was not intended to assess visual and phonological processing.

Caution must also be exercised in comparing the results of the present study with those of past research because of a potential problem with floor effects. There is some possibility that the pattern of responding found for good and unexpected spellers to spelling control foils is the result of a floor effect. Both groups had near zero errors in both spelling control conditions. This floor effect may have effectively masked any differences in phonological processing between good and unexpected spellers. Detection of a phonological processing deficit in poor spellers, however, suggests that the paradigm would have been sensitive to a phonological deficit in unexpected spellers. Percentage of false positive errors to spelling controls was high for poor spellers, at least in the high visual similarity condition (19%). As well, these error rates proved significantly different from those of good and unexpected spellers. If unexpected spellers possessed a phonological processing deficit equivalent to that of poor spellers, as has been suggested (Jorm, 1981; Waters et al., 1985), then it is unlikely that they would have shown a floor effect similar to good spellers.

Processing Deficits. Results of the present study rule out reading deficits in the form of an inability to process either visual or phonological features. Had processing deficits in poor and unexpected spellers been of this form, some of the across stimulus comparisons (i.e., within group) would have been found to be nonsignificant. Significant improvement in performance by good, poor and unexpected spellers across both the homophony and visual similarity factors indicates the presence of visual and phonological processing ability in all groups. Similarly, Waters et al. (1985) concluded that poor and unexpected spellers evidenced knowledge of spelling-sound correspondence.

Yet group differences persist in both visual and phonological processing, suggesting that visual and phonological processing in poor spellers and visual processing in unexpected spellers may be present but degraded from that of good spellers. There are, however, a large number of steps involved in completing a categorization task and processing could break down at any step along the way. Two alternative explanations, one suggested by subject performance and the other by theory, are discussed below.

One alternative is speed of word reading. Apparent difficulties of subjects and observations recorded during testing suggest that some members of the poor and unexpected groups found stimulus presentation to be too fast. Several subjects maintained that both the words and phrases were presented so quickly that they had difficulty reading them. Apparent difficulties with too quick a presentation were also informally documented in the recordings from the warm-up prior to the experimental trials. A number of subjects during this period missed words and were unable to respond on those trials. As inability to completely read stimulus foils could lead to an increased rate of false positive errors, reading speed may have been responsible for differences between groups.

Speed of reading is also a useful hypothesis to examine as it is testable within the confines of the present research. If the experimental groups differed in reading speed, these differences would be apparent in their correct rejection reaction times. Groups with slower rates of word reading would take longer to correctly reject foils due to the longer period needed to process the stimulus. No significant group differences were found for these reaction times, however. Differences in processing speed between conditions might also be expected if slower reading rates were associated with processing deficits. That is, groups might be expected to show longer reaction times in the area for which they have demonstrated difficulties. Lack of significant interactions in the correct rejection findings does not support this notion.

A second alternative explanation is that different strategies are being employed in word reading. Frith (1983) has hypothesized that, for unexpected spellers, poor spelling performance is a product of a particular reading strategy, termed the partial cues hypothesis. She proposed that unexpected spellers attend to only enough cues while reading to produce recognition. If subjects in the present study were attending to only some of the features in the words, then it would be expected that they would be more likely to make false-positive errors.

One concern with such an interpretation of the present data is that deficits for unexpected spellers were noted only for visual processing. This raises the question of the modality-specific nature of partial cue reading. Unexpected spellers might be inattentive to one type of cue in words leading to higher rates of processing related errors within that processing route, although this seems to be more likely for phonological than visual processing. Phonological processing proceeds from grapheme (a visual identification) to phoneme. As a result, inattention in phonological processing is more likely to occur without inattention to visual processing than the reverse. Present outcomes are also difficult to reconcile with Frith's own predictions from the model, in that she hypothesized that inattention to full cues (i.e., all cues) would lead to a phonological deficit. Thus, though it is possible that unexpected spellers are employing a partial cues strategy specifically in relation to visual processing, it is difficult to relate such an interpretation to present findings and the partial cues theory itself.

If it is difficulties with visual and phonological processing that underlie poor performance, one must consider where in these processes the difficulties are occurring. One possibility is that the deficit in processing occurs at the stage of verifying stored representations against visual and phonological information. Several authors have proposed that one step of the word reading process is an iterative comparison of featural information with stored representations of words (Grossberg & Stone, 1986; Paap, Newsome, McDonald & Schvaneveldt, 1982; Van Orden, 1987). This verification is hypothesized to proceed by comparing features of the word, visual or phonological, with a series of internal representations until a strong enough match is made to lead to a decision regarding the word's identity. A verification process is attractive as it allows for individual processing of visual and phonological features onto their respective internal representations (i.e., dual routes of processing).

Despite the attractiveness of a verification explanation of relative performance findings, no evidence for or against this possibility can be derived from the present study. Frith (1980), however, noted the lack of a reversed context effect in unexpected spellers in visual searches for correctly and incorrectly spelled words, which may suggest verification problems in this population. A reversed context effect, defined as easier identification of a well known item among a list of novel items than the reverse, implies that the subject is able to readily compare a known correct item with some internal representation. Lack of such an effect for correct spellings in unexpected spellers indicates that they either possess poor internal representations, or suffer an impairment to the process that carries out the comparison. The above evidence, along with the suitability of a verification hypothesis to present findings, suggests that this may be a good direction for future research.

Relationship to Spelling Deficit. Deficits in information processing identified in the present study for reading are consistent with those found for spelling elsewhere. Good and unexpected spellers have been found to possess phonological processing ability superior to that of poor spellers in studies of phonetically correct misspellings (Finucci, Isaacs, Whitehorse & Childs, 1983; Frith, 1980; Jorm, 1981). As well, unexpected spellers have been shown to be less influenced by internal visual representations of spellings than good spellers (Frith, 1980). That is, unexpected spellers appear less able to make use of visual processes when spelling than good spellers. Finally, poor spellers have been shown to evidence visual and phonological deficits when spelling.

One interpretation of this similarity between spelling findings and those for reading from the present study is that information processing deficits are continuous across reading and spelling. Frith (1983) has argued that demonstration of discordant levels of performance in reading and spelling suggests discontinuity of information processing across the two abilities. She stated, however, that direct evidence of such discontinuity would have to come from examinations of the underlying processes themselves. If deficits in information processing differed from reading to spelling, then discontinuity of processing would be supported. Conversely, if processing deficits were found to correspond, then continuity of processing would be supported. The present study found a good match between reading and spelling abilities.

Waters et al. (1985) also make a case for continuity of processing deficits. They found that in both reading and spelling, poor and unexpected spellers were less knowledgeable and less skilled with letter-sound correspondence rules than good spellers. Based on these findings the authors concluded that a phonological processing deficit affecting both reading and spelling was present in both groups. These authors, however, conclude that unexpected spellers possess a continuous phonological deficit, while the present study suggests this population may suffer from visual processing deficits in reading and spelling.

Conclusions. In summary, the present study replicated the effects of homophony and visual similarity first noted by Van Orden (1987). This replication occurring with each of the three groups. Three distinct patterns of information processing were identified with each corresponding to one of the reader/speller groups studied. Though these patterns were not in keeping with conclusions drawn from previous reports, reinterpretation of some of these earlier studies suggests there may be prior support for the results of the present study.

Finally, comparison of present findings with those from previous spelling studies suggests continuity of processing deficits across reading and spelling.

One of the implications of this study is that methodological issues are critical when studying reader/speller populations. Results of the present study are inconsistent with those from studies employing children aged 8 to 10 years. Employment of a young adult sample appears to produce different results. Similarly, design seems to have an effect on findings. Though between group comparisons may be seen to be in accordance with some previous studies, results of these comparisons are not in agreement with all previous reports. Further, within groups comparisons produce results that if examined alone could be interpreted as inconsistent with past research.

Several possible explanations for the present results were examined briefly. Two of these did not explain the pattern of responding found within the study itself. A third, the verification hypothesis, was not testable within the present study. Theoretically, however, deficits in the verification process would adequately explain present results. A viable route for future research with reader/speller populations would be to study the ability to verify words visually and phonologically.

References

Anderson, K. F. (1985). The development of spelling ability and linguistic strategies. The Reading Teacher, 39, 140-147.

Backman, J., Bruck, M., Hebert, M. & Seidenberg, M. (1984). Acquisition and use of spelling-sound correspondences in reading. Journal of Experimental Child Psychology, 38, 114-133.

Barron, R. (1986). Word recognition in early reading: A review of the direct and indirect access hypotheses. Cognition, 24, 93-119.

Bookman, M. O. (1984). Spelling as a cognitive-developmental linguistic process. Academic Therapy, 20, 21-32.

Bradley, L. & Bryant, P. (1985). Rhyme and reason in reading and spelling. Ann Arbour: The University of Michigan Press.

Brown, J. I., Bennett, M. & Hanna, G. (1981). Nelson-Denny reading test (Forms E and F). Riverside Publishing Co.

Campbell, R. (1983). Writing nonwords to dictation. Brain and Language, 19, 153-178.

Campbell, R. (1985). When children write non-words to dictation. Journal of Experimental Child Psychology, 40, 133-151.

Cheeseman, J. & Merikle, P. (1987). Word recognition and consciousness. In D. Besner, T. G. Waller and G. E. MacKinnon (Eds.), Reading research: Advances in theory and practice, Vol. 5 (pp. 311-352). New York: Academic Press.

Coltheart, M., Davelaar, E., Jonasson, J. & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), Attention and performance, VI. New York: Academic Press.

Coltheart, M., Masterson, J., Byng, S., Prior, M. & Riddoch, M. J. (1983). Surface dyslexia. Quarterly Journal of Experimental Psychology, 35A, 469-496.

Condry, S., McMahon-Rideout, M. & Levy, A. (1979). A developmental investigation of selective attention to graphic, phonetic, and semantic information in words. Perception and Psychophysics, 25, 88-94.

Cummins, R. P. (1981). Test review: The Nelson-Denney Reading Test (Forms E and F). Journal of Reading, 25, 54-59.

Davelaar, E., Coltheart, M., Besner, D. & Jonasson, J. (1978). Phonological recoding and lexical access. Memory and Cognition, 6, 391-402.

Doctor, E. A. & Coltheart, M. (1980). Children's use of phonological encoding when reading for meaning. Memory and Cognition, 8, 195-209.

Ellis, A. W. (1982). Spelling and writing (and reading and speaking). In A. W. Ellis (Ed.), Normality and pathology in cognitive functions (pp. 113-146). London: Academic Press.

Ellis, A. W. (1984). Reading, writing and dyslexia: A cognitive analysis. Hillside, N.J.: Lawrence Erlbaum Associates.

Ellis, N. & Large, B. (1987). The development of reading: As you seek so shall you find. British Journal of Psychology, 78, 1-28.

Evett, L.J., and Humphreys, G.W. (1981). The use of abstract graphemic information in lexical access. Quarterly Journal of Experimental Psychology, 33A, 325-350.

Finucci, J., Isaacs, S., Whitehouse, C. & Childs, B. (1983). Classification of spelling errors and their relationship to reading ability, sex, grade placement, and intelligence. Brain and Language, 20, 340-355.

Frith, U. (1978). From print to meaning and from print to sound, or how to read without knowing how to spell. Visible Language, 12, 43-54.

Frith, U. (1980). Unexpected spelling problems. In U. Frith (Ed.), Cognitive processes in spelling (pp. 495-515). London: Academic Press.

Frith, U. (1983). The similarities and differences between reading and spelling problems. In M. Rutter (Ed.), Developmental neuropsychiatry (pp. 453-472). New York: Guilford Press.

Gerber, M. M. & Hall, R. J. (1987). Information processing approaches to studying spelling deficiencies. Journal of Learning Disabilities, 20, 34-42.

Grossberg, S. & Stone, G. (1986). Neural dynamics of word recognition and recall: Priming, learning and resonance. Psychological Review, 93, 46-74.

Hendersen, E. H. & Beers, J. W. (1980). Developmental and cognitive aspects of learning to spell: A reflection of word knowldege. Newark, DE: International Reading Association.

Humphreys, G. W. & Evett, L. J. (1985). Are there independent lexical and nonlexical routes in word processing? An evaluation of the dual-route theory of reading. The Behavioral and Brain Sciences, 8, 689-740.

Jastak, J. F. & Jastak, S. (1978). The wide range achievement test: Manual of instructions (1978 rev. ed.). Wilmington, Delaware: Jastak Associates Inc.

Jorm, A. F. (1981). Children with reading and spelling retardation: Functioning of whole-word and correspondence rule mechanisms. Journal of Child Psychology, Psychiatry and Applied Disciplines, 22, 171-178.

Jorm, A. F. & Share, D. L. (1983). Phonological recoding and reading acquisition. Applied Psycholinguistics, 4, 103-147.

Kay, J. & Marcel, A. (1981). One process, not two, in reading aloud: Lexical analogies do the work of non-lexical rules. Quarterly Journal of Experimental Psychology, 33A, 397-413.

Kucera, H. & Francis, W. (1967). Computational analysis of present-day American english. Providence, RI: Brown University Press.

Manis, F. R., Szeszulski, P. A., Howell, M. J. & Horn, C. C. (1986). A comparison of analogy- and rule- based decoding strategies in normal and dyslexic children. Journal of Reading Behaviour, 28, 203-218.

Marsh, G., Freidman, M., Welch, V. & Desberg, P. (1980). The development of strategies in spelling. In U. Frith (Ed.), Cognitive processes in spelling (pp. 339-354). London: Academic Press.

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

Nelson, H. E. & Warrington, E. K. (1974). Developmental spelling retardation and its relation to other cognitive abilities. British Journal of Psychology, 65, 265-274.

Paap, K. R., Newsome, S. L., McDonald, J. E. & Schvanveldt, R. W. (1982). An activation verification model for letter and word recognition: The wordsuperiority effect. *Psychological Review*, *89*, 573-594.

Parkin, A. J. & Underwood, G. (1983). Orthographic vs. phonological irregularity in lexical decision. *Memory and Cognition*, *11*, 351-355.

Pedhazur, E. J. (1982). *Multiple regression in behavioral research: Explanation and prediction* (2nd ed.). New York: Holt, Rinehart and Winston.

Perin, D. (1981). Spelling, reading and adult illiteracy. *Psychological Research*, *43*, 245-257.

Perin, D. (1983). Phonemic segmentation and spelling. *British Journal of Psychology*, *74*, 129-144.

Read, C. & Ruyter, L. (1985). Reading and spelling skills in adults of low literacy. *Remedial and Special Education*, *6*, 43-52.

Rossen, M. B. (1983). From SOFA to LOUCH: Lexical contributions to pseudoword pronunciation. *Memory and Cognition*, *11*, 152-160.

Rumelhart, D. E. & McClelland, J. L. (1982). An interactive activation model of context effects in letter perception: Part 2. The contextual enhancement effect and some tests and extensions of the model. *Psychological Review*, *89*, 60-94.

Seidenberg, M. (1985). The time course of phonological code activation in two writing systems. *Cognition*, *19*, 1-30.

Siegel, L. S. & Ryan, E. B. (1988). Development of grammatical-sensitivity, phonological and short-term memory skills in normally achieving and learning disabled children. *Developmental Psychology*, *24*, 28-37.

Smith, F. (1971). *Understanding reading*. New York: Holt, Rinehart and Winston.

Sweeney, J. & Rourke, B. (1978). Neuropsychological significance of phonetically accurate and phonetically inaccurate spelling errors in younger and older retarded spellers. *Brain and Language*, *6*, 212-225.

Treiman, R. (1984). Individual differences among children in spelling and reading styles. *Journal of Experimental Child Psychology*, *37*, 463-477.

Van Orden, G. (1987). A ROWS is a ROSE: Spelling, sound, and reading. *Memory and Cognition*, *15*, 181-198.

Waters, G. S., Bruck, M. & Seidenberg, M. (1985). Do children use similar processes to read and spell words. Journal of Experimental Child Psychology, 39, 511-530.

Waters, G. & Seidenberg, M. (1985). Spelling-sound effects in reading: Time-course and decision criteria. Memory and Cognition, 13, 557-572.

Waters, G., Seidenberg, M. S. & Bruck, M. (1984). Children's and adult's use of spelling-sound information in three reading tasks. Memory and Cognition, 12, 293-305.

Webb, M. W., II (1983). A scale for evaluating standardized reading tests, with results for Nelson-Denny, Iowa, and Stanford. Journal of Reading, 26, 424-429.

Winer, B. J. (1973). Statistical principles in experimental design (2nd ed.). New York: McGraw-Hill.

APPENDIX A

Instructions, Forms and Debriefing

Instructions to Subjects for Normative Sample

Hello. My name is Bryan Acton. I am here today to request your participation in a study in the area of information processing.

Before asking you to participate I would like to outline what you will be asked to do. I am interested in whether people with different reading and spelling abilities respond differently in the way they make use of written information. Before I can do this, however, I need to find out a little about spelling and reading abilities of first year students. So today I will be asking you to complete brief tests of reading and spelling. If you meet the criteria for the groups I am interested in, I will ask you to participate in the study, for which you will be paid.

If you are interested in participating in the second study I have provided a cover sheet on which you can provide your name, a phone number at which you might be contacted and a time period at which you think it likely that you might be reached. These cover sheets will be destroyed as soon as they are no longer needed, and until then will be kept strictly confidential.

You should also be aware that your participation in this study at any point is voluntary. That is, you can refuse to complete any or all of the tasks I set before you now or in the future. If you think you would like to participate at both times please fill out the cover sheet on the top of the stack in front of you. If you prefer to participate only in today's testing, simply leave the cover sheet blank. Finally, if you do not wish to participate at all, you may turn your sheets over and do some reading.

<u>When class finishes testing</u>.Thank you for your participation in this portion of

the study. Would you please make sure that all your sheets are attached, then, pass them to the front of the rows, thank you.

Cover Letter

If you have chosen to participate in the present testing and would like to be contacted for future paid participation ($3.75 per one session) please place your name, a phone number at which you can be reached and the best time of day for getting in touch with you in the appropriate spaces provided below.

Name (first and last) ______________________

Phone Number ______________________

Time at which you might be reached ______________________

Informed Consent Form

The study you are participating in today has been approved by the Faculty of Science Ethics Review Committee for research involving human subjects.

Your task will be to identify whether certain words are members of certain categories. All materials will be presented to you on a computer screen. Manual responding will be recorded by the computer, while spoken responses will be recorded by the experimenter. For your participation today you will receive payment at a rate of $3.75 per hour.

Participation in this experiment is voluntary. Should you wish to end your involvement at any point you may do so. If you have read the statements herein and agree to participate in the study please sign below.

I, _________________________, have had the experimental procedure described to me and do agree to participate.

Signed ____________________________

Witnessed ____________________________

Instructions to Experimental Subjects

Once the experiment begins you will see a number of phrases, words and other visual stimuli presented on this computer screen. In front of you, as well, has been placed the keyboard of the computer terminal. On this terminal you can see that two keys have been specially marked, one with the word "yes" and one with the word "no". You will be using these keys to provide some of your responding on the experimental task. The purpose of the keys is to indicate the length of time required for you to respond in the task.

Today you are to perform the task of identifying whether certain words are members of certain categories. You will be presented with a category and a word that may or may not be an instance of that category. Your task is to indicate whether the word is a member of that category, or not, and to name the word. To elaborate, you will be presented with a phrase that indicates a category presented above a fixation point, in this case a "+" sign. You are to read this phrase and then look to the fixation point. After a brief period a word which you are to read will appear in place of the fixation point. Decide whether the word given is a member of the previously presented category, respond "yes" or "no" by pressing the appropriate key and then say the word that you saw aloud. The word about which you are making your judgements will be covered after a brief period.

Your decision regarding category membership will be indicated on the response keys, "yes" will be indicated by a press of your index finger and "no" by a press of your middle finger. I will record what you say.

Once more I would like to remind you that your participation at this stage is voluntary and you can ask to quit the experiment at any time. Do you have any questions?

Good, then I would like you to place your dominant hand on the block such that your index and middle fingers rest on the response keys. Remember a "yes" response is indicated by the index finger and a "no" by the middle finger.

Before we get started with the experiment proper a series of practice trials has been devised to give you some experience with the task itself. Please continue through these trials to the end unless there is something that you just do not understand. Please watch the screen now.

Now that you have completed the practice trials do you have any other questions?

You will now begin the experimental trials. These trials will follow the same format as the practice trials but there will be quite a few more items. Are you ready? Then proceed.

Debriefing

I would like to thank you for your participation in this study. At this point you must have several questions about what the task was about and what reading words on a computer screen has to do with reading comprehension and spelling. The task you completed today is being used to study how groups differing in reading and spelling abilities make use of visual and sound cues when reading words. Groups that I am interested in include good readers who spell well, poor readers who spell poorly and good readers who spell poorly. The types of words used are specially chosen so that they have certain visual and sound characteristics. As you may guess the words play an important role. That is why I ask that you do not discuss the contents of this study with anyone for the next six weeks. This is particularly important for the words. If you have noticed anything peculiar about the words please do not tell anyone.

If you would like to know more details about the study and its findings you can leave your name and a mailing address and I will forward this information to you at the studies completion.

Once again I would like to thank you for your participation. As well, I would like to ask you once again to refrain from discussing the contents of the study with anyone for the next while.

APPENDIX B

Stimulus Materials

Table B

Category Names, Homophone Foils and Their Spelling Control Foils for Highly Visually Similar and Less Visually Similar Foils from Van Orden (1987)

Category Name	Homophone	Spelling Control
Highly Visually Similar		
A FEATURE OF A PERSON'S ABDOMEN	NAVAL	NOVEL
A FEATURE OF AN OCEAN SHORE	BEECH	BENCH
A SMALL STREAM	CREAK	CHEEK
ORGANIZED GROUP OF PEOPLE	TEEM	TERM
PART OF A DRESS	SEEM	SLAM
PART OF A HORSE'S BRIDLE	RAIN	RUIN
PART OF A MOUNTAIN	PEEK	PECK
TYPE OF FOOD	MEET	MELT
A KITCHEN UTENSIL	BOLL	BOIL
A BIBLICAL RELIGIOUS LEADER	PROFIT	PROTEST
Less Visually Similar		
A DEER	DOUGH	DOUBT
PART OF A PERSON'S FACE	KNOWS	SNOBS
TYPE OF HOTEL ROOM	SWEET	SHEET
A SERVANT	MADE	MAIN
A MEMBER OF A CONVENT	NONE	NINE
AN ANCIENT MUSICAL INSTRUMENT	LOOT	LOST
A FLOWER	ROWS	ROBS
SOMETHING CAUSED BY GRAVITY	WAIT	WRIT
A WILD ANIMAL	BORE	BORN
A BREAKFAST FOOD	SERIAL	VERBAL

APPENDIX C

Analysis of Variance Summary Tables

Table C-1

ANOVA Summary Table for False Positive Errors

SOURCE	df	MS	F	p
Between				
Group (Gr)	2	3365.83	13.69	.000
Gender (Ge)	1	187.50	.76	.391
Gr x Ge	2	242.50	.99	.388
$E_{(swg)}$	24	245.83		
Within				
Homophony (Ho)	1	7840.83	50.59	.000
Gr x Ho	2	960.83	6.20	.007
Ge x Ho	1	7.50	.05	.828
Gr x Ge x Ho	2	317.50	2.05	.151
$E_{(Ho \times swg)}$	24	155.00		
Visual Similarity (VS)	1	12200.83	136.83	.000
Gr x VS	2	660.83	7.41	.003
Ge x VS	1	367.50	4.12	.054
Gr x Ge x VS	2	47.50	.53	.594
$E_{(VS \times swg)}$	24	89.17		
Ho x VS	1	2520.83	40.88	.000
Gr x Ho x VS	2	75.83	1.23	.310
Ge x Ho x VS	1	.83	.01	.908
Gr x Ge x Ho x VS	2	135.83	2.20	.132
$E_{(Ho \times VS \times swg)}$	24	61.67		

Table C-2

ANOVA Summary Table for "No" Reaction Times

SOURCE	df	MS	F	p
Between				
Group (Gr)	2	286761.83	.53	.594
Gender (Ge)	1	118570.80	2.19	.152
Gr x Ge	2	453334.83	.84	.444
$E_{(swg)}$	24	539021.00		
Within				
Homophony (Ho)	1	351384.63	8.45	.008
Gr x Ho	2	24191.67	.58	.567
Ge x Ho	1	20551.08	.49	.489
Gr x Ge x Ho	2	11749.19	.28	.756
$E_{(Ho \times swg)}$	24	41579.35		
Visual Similarity (VS)	1	109688.53	1.93	.177
Gr x VS	2	553.11	.01	.990
Ge x VS	1	61106.36	1.08	.310
Gr x Ge x VS	2	178811.93	3.15	.061
$E_{(VS \times swg)}$	24	56692.56		
Ho x VS	1	37686.66	3.04	.094
Gr x Ho x VS	2	204.29	.02	.984
Ge x Ho x VS	1	6768.91	.55	.467
Gr x Ge x Ho x VS	2	3272.55	.26	.770
$E_{(Ho \times VS \times swg)}$	24	12385.77		