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THE RANSCHBURG EFFECT
IN WRITTEN LANGUAGE: ITS RELATION TO THE PROBLEM
OF SERIAL ORDER AND ITS IMPLICATIONS FOR THE STUDY OF DYSLEXIA

by

CELIA USPRICH

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

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Abstract

THE RANSCHBURG EFFECT

IN WRITTEN LANGUAGE: ITS RELATION TO THE PROBLEM

OF SERIAL ORDER AND ITS IMPLICATIONS FOR THE STUDY OF DYSLEXIA

by

Celia Usprich

Adviser: Professor Mitchell L. Kietzman

The Ranschburg effect (RE) is the occurrence of more errors on experimental strings containing repeated items than on control strings without repeated items. Contemporary studies have shown the RE to be reliable for strings composed of randomly ordered alpha-numeric items. The effect has not been experimentally investigated in sequences in which the order of items is constrained by rules--within language sequences. The purpose of the present investigation was to determine whether repetition effects in spelling and handwriting are isomorphic to those in alpha-numeric strings.

The 26 college age subjects were all native speakers of English who had no reading or spelling disabilities. The subjects' task was to write 64 sentences to dictation containing the target words, the 32 experimental words with repeated letters and the 32 control words with all different letters. To obtain a sufficient corpus of errors the target words were selected from lists of spelling demons for adults, they were placed in transformationally complex sentences,

an interference task was given, and speeded writing was required. The target words were matched for length and frequency. Spelling difficulty was controlled via use of the Stanford study of phoneme-grapheme correspondences. A detailed method was devised for deciphering writing containing a large number of errors--experimentally dysgraphic writing--and a second rater scored the data.

The scoring procedure was highly reliable, and thus fills an experimental lacuna by providing a method which can be applied to various problems concerning experimental dysgraphia. The RE in language sequences, specifically spelling, was found to be isomorphic to the RE in alpha-numeric strings. Direct analysis of errors showed that the kinds of errors associated with the RE are omissions of and substitutions for repeated letters.

Repeated letters within words were, in addition, found to produce misspellings that were nongraphemic options for the phonemic input. These misspellings, making no apparent sense, show that the effect of repetition structure is to fragment the lawfulness inherent in language sequences. This finding further clarifies the nature of the RE and is possible only with language sequences since in alpha-numeric strings the order of the elements is random. The RE was not found in handwriting since the nature of the spelling errors precluded the observation of handwriting errors on the repeated letters.

Comparison of the present results with experimental dysgraphics to the findings from a previous study for a developmental dysgraphic suggest that the two groups have a systematic error in common, the RE. The results provide hypotheses for the study of dyslexia, particularly adult dyslexics.

The present investigation shows an associative explanation of the RE to be inadequate, that the problem of the RE is specifically related to the serial order problem, and suggests that while an adequate explanation of the latter is not yet available, future understanding of that problem and of the RE have a reciprocal relationship.

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A number of others assisted me in various aspects of this work for a reason which is noteworthy, their strong commitment to those engaged in the scientific enterprise: Dr. Jack Orbach, who spent many hours, even before he was a committee member, discussing various portions of the work; Dr. Louis Gerstman, an unusually gifted experimental psychologist with an indefatigable interest in data and an equally indefatigable generosity to students; the linguists, Dr. Michael Hall, Dr. Beatrice Hall, and Dr. Charles Cairns; the psycholinguists, Dr. Helen Cairns and Dr. Steve Krashen; Dr. Arthur Steinberg, a mathematician, who lent his superior capacities to the mundane task of checking the logical structure of the complex scoring rules, and who served as a pilot rater; Dr. John Jahnke, a most kind, thoughtful, and thorough correspondent; and John Comisa, my final rater, whose dependability and capacity for taking infinite pains with a boring task permitted my confidence in the scored data.

I am deeply grateful to my family, my mother, Ray Usprich, and my son, Joshua, for their support and understanding.

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CHAPTER I

THE PROBLEM

The present study was designed to determine whether or not the Ranschburg effect occurs in the spelling and writing of normal adults.

The Ranschburg effect (RE) is the production of a greater number of errors given strings containing repeated elements, usually digits, e.g., 236539, relative to the errors on control strings containing all different elements, e.g., 237649 (Jahnke, 1969b). The effect was experimentally observed at the turn of the century by Paul Ranschburg (1902, 1905). Ranschburg used digits as stimuli, but he claimed that the phenomenon was a general one that also accounted for errors in spelling and writing. Interest in the effect has revived in the past two decades because it posed a paradox (e.g., see Jahnke 1969b, 1972a). It predicts results that are contrary to expectations from the literature on memory and learning. Repetition is generally viewed as improving performance, and so the string 237639 which contains a repeated digit ought to be remembered better than the string 236549. The RE, however, predicts poorer performance on the string containing repeated digits.

Well controlled studies of what has come to be called the Ranschburg effect have employed strings of digits, randomly selected letters, or words in random sequence in a short-term memory paradigm (Crowder, 1968a, 1968b; Crowder & Melton, 1965; Harris & Jahnke, 1972; Hinrichs, Mewaldt & Redding, 1973; Jahnke, 1969a, 1969b, 1970, 1972b, 1974; Lee, 1976; Malmi & Jahnke, 1972; Mewaldt & Hinrichs, 1973; Obonai & Tatuno, 1954; Tatuno, 1961; Wickelgren, 1965, 1966). The stimuli used in all the cited studies are termed here alpha-numeric strings to contrast them with sequences of elements in which language constraints are preserved. The latter sequences are referred to here as language stimuli. Although the elements within the alpha-numeric strings are language elements, the order governing their sequence is random. Within language sequences, e.g., within words or sentences, the order of the elements is not random but is constrained by the rules of the language.

The presence of the Ranschburg effect within language sequences as those are defined here has not been demonstrated. Moreover it has been asserted, but not tested, that contrary to Ranschburg's claims it is unlikely that the effect occurs in spelling and writing. In a review paper on the RE the following statements were made. It remained to be shown that all the repetition phenomena Ranschburg mentioned are reliable, namely repetition effects in spelling and writing, and further, that it is not likely that such repetition phenomena "are isomorphic with the particular variety considered in the recent literature on the RE" (Jahnke, 1969b, p. 593). Doubt was expressed again in a later paper. It was predicted that the inhibitory effect of intraserial repetition in alpha-numeric short-term memory studies, the RE, would be different from such an effect in spelling and writing since in the latter two cases "short-term memory seems minimally involved" (Jahnke, 1974, p. 184).

If these predictions are true, then the RE is a restricted phenomenon of limited interest and limited neuropsychological importance. The phenomenon would occur only in the processing of nonlanguage sequences, i.e., strings of randomly ordered alpha-numeric elements, but not in the processing of language sequences, such as words, in which language constraints are preserved among the elements. The matter is not only one of generality. The domain to which the RE would not apply--language--is a crucial domain for those engaged in understanding brain mechanisms.

Thirty years ago, Lashley (1951) raised the question of the mechanisms that govern the correct serial order of behavior. He viewed language as a principal exemplar of serial ordering mechanisms, and noted the importance of observing systematic errors of language for the insights they might provide into those mechanisms. The RE by definition concerns systematic errors. If the RE is observed in the spelling and writing errors of normals, the RE will have been shown to be a more important phenomenon than recently thought. The RE would not only be a paradox to be explained, but when its characteristics are known a phenomenon to be taken into account in models of serial order.

The issue is whether or not repeated letters in a word result in decrements in the accuracy of the spelling and handwriting of normal adults such that the effect of intraserial repetition is isomorphic to the effect seen in studies with alpha-numeric strings.

Positive findings would have implications for the study of dyslexia. The most striking correlate of the reading disability is the concommitant spelling and writing difficulty. This correlate has not been well delineated. It has frequently been described as bizarre; yet it has been considered a pathognomic indicator of dyslexia (Gallagher, 1960; Walker & Cole, 1966; Rawson, 1968; Critchley, 1970). Positive evidence of the RE in spelling and writing would suggest testable hypotheses about dyslexic writing which might help to elucidate the nature of the disorder.

In order to determine whether or not repetition effects in spelling and writing are isomorphic with the RE as described in alpha-numeric studies, it is necessary to delineate the RE as seen in the latter literature. The next section deals with the referent for the Ranschburg effect in the alpha-numeric literature.

CHAPTER II

THE RANSCHBURG EFFECT IN MODERN ALPHA-NUMERIC STUDIES

The classic RE study was performed by Ranschburg in 1902. He used six digit strings, and presented each string for one-third of a second. He noted the greater number of errors on experimental strings containing the repeated digits and observed that the differences between experimental and control strings were principally due to errors on the repeated elements themselves.

There were several other early studies (e.g., Kleinknecht, 1906; Schmitz, 1922; Turley, 1906). More recent investigators considered that the phenomenon had not been well established by the early investigators (Crowder & Melton, 1965; Crowder, 1968a; Wickelgren, 1965). The early experiments were inadequate by modern standards. They lacked statistical treatment so the results may have been due to chance (Wickelgren, 1965), and in some instances adequate control stimuli were absent (Crowder & Melton, 1965).

The Influential Summary of the Early Work

McGeoch's 1942 summary of the early findings concerning the Ranschburg phenomenon[1] has been frequently

[1]The summary was deleted from the second edition, written by McGeoch and Irion (1952).

referred to by RE investigators (Crowder & Melton, 1965; Crowder, 1968a; Harris & Jahnke, 1972; Jahnke & Melton, 1968; Jahnke, 1969b; Mewaldt & Hinrichs, 1973), and has served as a starting point for some studies (e.g., Jahnke & Melton, 1968). McGeoch stated:

> A repeated item tends to be omitted or to be incorrectly reproduced. Thus, the series 147556 may be given as 14756 or as 147636. Similarity of items, as well as identity, may produce omission or error. The influence of the repeated item may spread to adjacent items, in that, although the repeated item is given correctly, an item adjoining it may be omitted or given erroneously. (p. 100)

McGeoch went on to note that the RE can be observed when repeated digits occur in telephone numbers, license plate numbers, or memory span lists presented for the first time.

Since the early evidence was not accepted, the first purpose of the investigators of the 1960's was replication with control stimuli and with inferential statistical analysis of the data in order to verify that recall is poorer for experimental strings containing repeated elements than for control strings (Crowder & Melton, 1965; Wickelgren, 1965).[2] The effect was substantiated. Once adequate evidence for the effect had been obtained, research activity concerning the phenomenon increased primarily because of the apparent paradox it posed for associative theories of memory.

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[2]The Japanese studies (Obonai & Tatuno, 1954; Tatuno, 1961) were criticized as difficult to interpret, providing no information about scoring procedure, and lacking inferential statistics. The evidence from these studies, along with the earlier studies, was questioned necessitating replication.

> Ordinary associationism presumes that the effect of repetition of an element is always to increase the trace strength of that element. In fact, however, it appears that repeated elements are retained less well than corresponding control elements when it is necessary for S to output all occurrences of the repeated elements. (Jahnke, 1969b, p. 604)

The Nature of the RE as Reviewed in 1969

The modern studies, those performed after McGeoch's 1942 summary, were integrated and the effect was summarized in a review paper (Jahnke, 1969b) as follows:

1. The RE is defined by poorer recall of strings containing repeated elements relative to recall of control strings.

2. The effect occurs primarily on the repeated elements themselves but the nonrepeated items of the experimental strings containing the repetition may also be affected.

3. It occurs when there are at least two nonrepeated items between the repeated elements (a separation, or lag, as it has been variously called, of at least two).

4. The RE is manifested not only by omissions and substitutions (as McGeoch indicated in 1942) but also by misplacements and erroneous repetitions.

While not stated in the summary of the nature of the RE, it was observed that although the effect is larger on the second of two repeated items than it is on the first, the effect sometimes does occur on the first item as well (Jahnke, 1969b).

Some amplification of and comment upon these statements is in order. The poorer recall of the repeated elements themselves has been termed one aspect of the RE (Jahnke, 1969b). A second aspect is an accompanying effect on the nonrepeated items of experimental strings when compared to items in corresponding positions in control strings (Jahnke, 1969b). Concerning this second aspect, Wickelgren (1965) reported a lower error rate, facilitation; Jahnke and Melton (1968) and Jahnke (1969b) reported a larger error rate when a particular kind of error was examined, namely erroneous repetitions; and Crowder (1968a, 1968b) reported no difference.

A third aspect of the RE was stated (Jahnke, 1969b) which had been discovered by Wickelgren (1965, 1966). It is called associative intrusion. Associative intrusions are a particular kind of order error which occurs systematically only on the nonrepeated items of strings containing repetition. There are two types of associative intrusions. The defined precondition for both types is that both given repeated items of a pair be present in the response (Wickelgren, 1966). Forward associative intrusions are the inversion of the items succeeding the repeated items, e.g., 239536 for 236539. Backward associative intrusions are the inversion of the items preceding the repeated items, e.g., 936532 for 236539. These errors, especially forward associative intrusions, were claimed as compelling evidence for an associative theory of short-term memory (Wickelgren, 1965, 1966).

A clear answer has not been available in the RE literature to the question concerning the nature of the errors on the repeated items themselves, where the effect is primarily located. The four manifestations of the RE included erroneous repetitions and misplacements along with omission and substitution errors (Jahnke, 1969b). Erroneous repetition of the repeated items themselves had not been examined. The relevant findings concerned only erroneous repetition of the nonrepeated items in strings containing repetition (Jahnke & Melton, 1968; Jahnke, 1969b).

The evidence for order errors, misplacements, as a type of repeated item error has been largely inferential based upon scoring methods. Poorer recall of repeated items has been found by two methods, free recall scoring and ordered recall scoring.[3] In free recall scoring, an item is scored as correct if it is present in the subject's response sequence regardless of the position in which it appears. In ordered recall scoring an item has to be both present and in the correct serial position to be scored correct.

[3]Equivalent terms in the RE literature for free recall scoring are item recall and overall correct recall. Equivalent terms for ordered recall scoring are serial position recall and completely correct recall.

The RE had been found by some investigators using free recall scoring as well as by other investigators using ordered recall scoring. It was inferred that misplacements are part of the effect, as shown by ordered recall scoring, although they are not the only type of errors which occur, as shown by free recall scoring (see Jahnke, 1969b). In ordered recall scoring, an error could be due to either the absence of the correct item (by omission or substitution) or to the misplacement of that item. The occurrence of the first sort of event alone is sufficient for that item to be scored as incorrect by ordered recall. The validity of the inference that order errors are manifestations of the RE is not compelling based upon integration of studies which used different scoring procedures for different sets of data.

Wolf and Jahnke (1968) used both scoring methods on the same data. They found an RE by ordered recall scoring but not by free recall scoring but only when the second item of a pair of repeated elements was in the last serial position. This observation was cited as further evidence for order errors (Jahnke, 1969b). It does appear to be evidence for order errors for the case in which a repeated item occupies the last serial position. It is however restricted evidence upon which to base the general assertion that order errors are part of the RE.

Using a scoring method he devised termed _position recall scoring_, Wickelgren (1965) reported a significant RE and order errors when repeated items were in several loci. He claimed that position recall was statistically independent of free recall. In position recall, only those items that were correct by free recall scoring were scored for correctness of position. He scored repeated items as a group. They were correct by position recall if, as a group, they occupied the correct serial positions. The corresponding control items were scored similarly. For example, for the control items, _41_, corresponding in position to a pair of repeated items, e.g., _33_, either of the two responses _41_ or _14_ were scored as correct if both digits _4_ and _1_ were in the serial positions occupied by _41_ in the stimulus string. It may be observed that this scoring procedure results in scoring some order errors on control strings as correct responses, not as errors, thereby inflating the experimental minus control error difference, the RE. The nonrepeated items in experimental strings and the corresponding items in control strings were scored individually, not as groups.

The reader may remember that Wickelgren had explicitly criticized prior studies (e.g., Obonai & Tatuno, 1954; Tatuno, 1961) for absence of inferential statistical analyses and so did not accept their findings (Wickelgren, 1965). Yet, having made an issue of the point, he repeatedly used a test of doubtful validity for his data throughout his paper. Although he provided the reader with a statement of caveat lector,[4] he based his conclusions on significant versus nonsignificant results. Those conclusions included statements about order errors, position recall, and the RE.

Similar to the case of order errors, as far as can be determined from the published papers, the evidence has been inferential that both omissions and substitutions are part of the effect. Both types of errors are possible by either free recall or ordered recall scoring. By either scoring method the subject makes an error if he does not include a given item in his response string whether it is omitted entirely or replaced, and no distinction between these two types of errors has been made from data. In most of the experiments, subjects were instructed that they could use "blank" as a response (e.g., Crowder, 1968a; Jahnke & Melton, 1968; Wickelgren, 1965; Wolf & Jahnke, 1968). These instructions make it likely that at least some omission errors occurred when errors were made. They do not assure that there will be more omission errors for experimental strings than for control strings so that

[4] "χ^2 tests were used to provide a rough measure of the significance of differences....Since all subjects and all trials for the same subject are pooled, the χ^2 test must be interpreted accordingly" (Wickelgren, 1965, p. 16). Jahnke concurred with the present writer in questioning Wickelgren's statistical analyses (Jahnke, 1972, Note 1).

omission errors are to be particularly associated with the RE. In no case did any investigator report direct analyses of data so that substitutions and/or omissions may be considered part of the effect.

Mechanisms

In the 1969 review paper, Jahnke proposed four mechanisms that might contribute to the RE and reported two experiments specifically designed to test some of them. The mechanisms were described as follows:

1. Mechanism I is a failure to encode. The subject fails to detect the repetition.

2. Mechanism II is a failure of memory for the structure of a repetition series. The subject detects the repetition but forgets that the series contained a repeated element.

3. Mechanism III is a failure of memory for specific elements. The subject detects the repetition and remembers that the series contains a repetition but forgets which element was repeated.

4. A fourth mechanism was suggested for the cases in which there is more than one pair of repeated items in the series. In such cases, it was observed, the encoding of the number of repetitions might be particularly important.

The main point is the dichotomy between input mechanisms, such as encoding, attentional, and/or perceptual processes, and output mechanisms, such as memory and response processes (see Jahnke, 1969b, for the use of these referents for the terms input and output). This dichotomy is characteristic of the modern RE literature appearing in papers published after 1969 (e.g., Mewaldt & Hinrichs, 1973) as well as in papers before that date.

The first and fourth of the listed mechanisms were held to pertain to input; the other two mechanisms were viewed as pertaining to output (Jahnke, 1969b). Jahnke concluded that his two experiments provided evidence for Mechanisms I and III, but not for Mechanism II. The latter was nevertheless included in his list since he considered that his test may have been inadequate. Support for Mechanism III was based on two studies (Jahnke & Melton, 1968; Jahnke, 1969b). It was reported that there were more erroneous repetitions of nonrepeated items in experimental strings than of items in corresponding position in control strings. It was observed that such erroneous repetition accompanied the loss of a repeated item in the subjects' responses (free recall scoring). The authors concluded that erroneous repetition of nonrepeated items in experimental strings replaced correct repetition of given repeated items. Almost all of the RE experiments have used only one pair of repeated items.[5] The fourth mechanism

[5]The studies by Wickelgren (1965) and Jahnke (1969a) are the exceptions.

accordingly has received little attention.

Recent Research

After the review paper, the RE research was determined primarily by a concern with mechanisms, in terms of input versus output mechanisms (Harris & Jahnke, 1972; Hinrichs et al., 1973; Jahnke, 1970, 1972a; Lee, 1976; Malmi & Jahnke, 1972). When the nature of the effect was examined, the questions concerned (a) stimulus variables (Mewaldt & Hinrichs, 1973), (b) boundary conditions (Jahnke, 1972b, 1974; Lee, 1976), and (c) locus, i.e., the occurrence of the effect on the nonrepeated items in strings containing repetition as well as on the repeated items themselves (Hinrichs et al., 1973; Mewaldt & Hinrichs, 1973).

Support for output mechanisms was found by Jahnke (1970) and Harris and Jahnke (1972). Support for and interpretations in terms of input mechanisms, particularly detection, was reported by Jahnke (1972a), Malmi and Jahnke (1972), Hinrichs et al., (1973), Mewaldt and Hinrichs (1973), and Lee (1976).

The arguments in these studies supporting the role of input mechanisms are tenuous. Essentially they consist of statements that the data were compatible with input interpretations of the RE (Jahnke, 1972a; Malmi & Jahnke, 1972), or that the data would be explained if failures of detection had occurred (Hinrichs et al., 1973; Lee, 1976;

Mewaldt & Hinrichs, 1973). By contrast, in the studies in which output mechanisms were concluded to be important, the bases for the arguments were experimental manipulations which provided some cogent evidence for the conclusions. For example, Jahnke (1970) used a probed recall technique to determine whether or not the subjects had detected repeated items and found no RE. The subjects recalled the repeated items as well as the corresponding control items. When he required the subjects to produce all the items of the stimulus string in the given order, the RE was observed.

The stimulus variables, auditory or visual modality, string length (7 or 10 items), and presentation rate (.4, .8, or 1.6 sec/item) were found to have little, if any, effect on the RE (Mewaldt & Hinrichs, 1973). Jahnke (1972b, 1974) reported that interserial as well as intraserial repetition is a boundary condition for the effect. Set size, the total number of elements from which strings of any given length in any single experiment could be drawn, was reported as a separate boundary condition (Jahnke, 1974). Using vocabularies of sizes 8, 10, 14, and 78 words (presented in random sequence), Jahnke (1974) found the RE only with size 8, no difference with size 10, and a facilitative effect for the repeated elements with sizes 14 and 78. Lee (1976), examining only the repeated items in nine letter strings, found the RE only when there was a separation of at least two items intervening between repeated items, no difference between experimental and control strings with a separation of one, and better recall of repeated items with a separation of zero. Mewaldt and Hinrichs (1973) specifically examined the locus of the RE in terms of an inhibitory effect on repeated items themselves and an additional inhibitory effect on the nonrepeated items of experimental strings. They found no differences between experimental and control strings when only nonrepeated items in the former and corresponding items in the latter were compared. They did find the inhibitory effect when only the repeated items and their corresponding control items were examined.

Is There an RE?

The Hinrichs et al. paper in 1973 was an apparent challenge to the RE itself. The main point of the paper was that the RE was largely due to guessing strategies. They considered that subjects, a priori, had a guessing bias against including repetitions in their responses unless repetitions were specifically detected. Consequently, subjects would tend to be wrong on experimental strings where they had to include a repetition, and right on control strings where they were not supposed to include repetitions. The single guessing bias, operating differentially on experimental and control strings, would thus account for the experimental minus control difference which defines the RE.

The authors did not consider the RE entirely artifactual. They accepted Jahnke's Mechanism I, failure to detect repetition, and hence a real RE. However, they considered that subjects' guessing strategies were primarily responsible for the previously reported findings. They reported three experiments in their paper. The strongest evidence in support of their hypothesis was from one experiment in which an RE was found with set size 8 but not found with set size 24.

> In particular, the difference between Group 8 and Group 24 in Experiment I forms the strongest evidence for the guessing interpretation. The fact that performance on the repeated items remained approximately the same in both groups while performance on the control (nonrepeated) items markedly declined in Group 24 is most consistent with the interpretation that improved guessing is responsible for the superior performance on the control items in Group 8 and, therefore, the occurrence of the Ranschburg effect. (Hinrichs et al., 1973, p. 73)

The Hinrichs et al. hypothesis is contraintuitive when either letters or digits are used as stimuli since subjects come to the laboratory with a great deal of exposure to repeated letters and digits from everyday life. Evidence that a guessing bias against including repetitions in responses is not primarily responsible for the RE was provided by Horstmann (Note 2), Jahnke (1974), and Usprich, Schapiro, and Horstmann (Note 3). Jahnke argued that if Hinrichs et al. were correct, subjects who guess frequently should show a larger RE and more errors in general than subjects who make few guesses since not all guesses could be correct. There should be a positive correlation between the magnitude of the RE and the total number of errors. Using data from a study with set size eight, where he found an RE, Jahnke did not find evidence for the predicted correlation.

Direct evidence against the guessing strategy hypothesis was obtained by Usprich et al. (Note 3) from an RE study with digit strings as stimuli (set size, nine). Erroneous repetitions in control strings were found to account for a third to more than half of all errors in control strings. These data suggest a bias toward including repetitions in responses. Yet a significant RE was found. Horstmann's results (Note 2) were similar from an RE digit study using an A-B-A design. _A_ represented presentation of control strings only, and _B_ represented the usual RE paradigm in which experimental and control strings are mixed in presentation. Horstmann found that subjects tended to produce as many erroneous repetitions in the first part of the experiment, _A1_, when only control strings were presented, as in the control strings of the _B_ or _A2_ parts of the study, when strings containing repetition had been presented. There was a large proportion of such errors and there was a significant RE.

Subjects guessing biases may play some role in the RE. It would appear that they do not in any major way explain, or explain away, the Ranschburg effect.

The Referent for the RE

The referent for the RE as presented in the 1969 review paper requires some modification and addition given the later research. The boundary conditions of the RE as summarized by Jahnke in 1974 need to be taken into account. The RE continued to be defined by poorer recall of the experimental list in general as well as of the repeated items specifically (e.g., Malmi & Jahnke, 1972; Mewaldt & Hinrichs, 1973). But whenever the data have been partitioned to determine whether the effect occurs on the nonrepeated items of the experimental strings as well as upon the repeated items, the error rates for the nonrepeated items of the experimental strings were not significantly greater than the error rates for the corresponding control items (Crowder, 1968a, 1968b; Hinrichs et al. 1973; Mewaldt & Hinrichs, 1973).

In summary, the referent for the RE, from the modern alpha-numeric literature, against which to test for its presence in spelling and handwriting is:

1. The RE is the production of more errors on sequences containing repeated elements relative to control sequences containing all different elements.

2. The effect occurs primarily on the repeated elements themselves.

3. The number of errors on the nonrepeated items of

the experimental sequences is not significantly different from the number of errors on corresponding items in control sequences.

4. The effect occurs when there are at least two nonrepeated items between the repeated elements, when the stimulus sequences are drawn from a small set of items, and when there are interserial as well as intraserial repetitions.

5. The effect on the repeated elements themselves may be manifested by omissions, substitutions, and misplacements.

A demonstration of the isomorphism of repetition effects in spelling to the RE in the alpha-numeric literature depends upon how closely the effect in spelling resembles the referent for the effect in the latter, point for point. In the present study, the problem is defined similarly for handwriting. That is, to demonstrate the RE in handwriting in terms of the alpha-numeric referent, there would have to be more handwriting errors in sequences containing repeated letters, the errors would have to occur primarily on the repeated letters themselves, and they would have to occur when the boundary conditions for the RE are met.

In correspondence with the present writer, Jahnke stipulated additional requirements that should be met to show the RE in language, namely, spelling and writing.

First and foremost is the necessity to devise appropriate controls, a requirement that appears exceedingly difficult to meet when the stimuli are language sequences, not alpha-numeric strings (Jahnke, Note 1, Note 4, Note 5, Note 6). Secondly, it is necessary to exclude other, non RE, interpretations of any obtained positive differences between experimental and control sequences, e.g., response biases or guessing habits (Jahnke, Note 1). Finally, it would have to be shown that the psychological mechanisms responsible for repetition effects in language are the same as those responsible for the RE in the alpha-numeric literature (Jahnke, Note 6).

Perhaps because of the difficulties posed by the problem of the RE in language, and perhaps because the main interest in the RE has stemmed from its relation to theories of short-term memory, particularly associative theories, (e.g., Crowder, 1968b; Jahnke, 1969b, 1970; Wickelgren, 1965) RE researchers have tended to ignore several papers which provide some evidence for the RE in language. A review and assessment of that evidence is pertinent to the present investigation.

CHAPTER III

SOME EVIDENCE FOR THE RANSCHBURG EFFECT IN LANGUAGE SEQUENCES

Three studies dealing with repetition effects in words in sentences appeared about the time that the RE review paper (Jahnke, 1969b) was written. All three studies were generated from a different perspective than that of the verbal learning and short-term memory viewpoint of most of the RE researchers. All the authors were primarily interested in repetition effects because of the relation of these effects to Lashley's serial order problem. None of the studies represented an attempt to investigate the RE in written language. Two of the three papers, which deal with written language responses, provide some evidence suggesting that the RE occurs within words as well as in strings of randomly sequenced alpha-numeric elements (Lecours, 1966; MacKay, 1969). The third study, which concerned typing errors, also had data suggestive of the RE (MacNeilage, 1964).

Lee Harvey Oswald's Diary

Interested in developmental dysgraphia, Lecours (1966) performed an analysis of Lee Harvey Oswald's Russian diary which had been published, errors intact, by *Life Magazine*. Lecours found a pattern in Oswald's remarkably poor spelling. He observed that almost all the errors could be attributed to a problem involving pairs of identical or similar letters. Lecours defined dysgraphics as poor spellers who shared a common feature which characterized them as a relatively homogeneous clinical group. That feature is "bizarre misspellings [which] reflect a deficit in the serial ordering of letters in their proper conventional sequence" (Lecours, 1966, p. 221). He stated that sequential errors are not to be interpreted as random misplacements but are a specific phenomenon "the abnormal interference within a temporal or tempero-spatial series between identical or similar acts" (Lecours, 1966, p. 239). He further defined sequential errors as those made by creating or destroying a pair of identical letters or by modifying the letters between the elements of such a pair, e.g., habituatated for habituated, eldery for elderly, and buiding for building.

He termed these errors type I, type II, and type III, respectively. A type I error, creation of a pair, could be made by addition or by substitution. In either event, he considered type I errors as occurring when a letter is erroneously repeated. Type II errors, destruction of a pair, could occur by deletion or by substitution. Type III errors could occur by addition, substitution, or deletion. The only form of type III errors which occurred with any frequency were deletions, and he restricted his analysis of this type of error to the deletion form.

All three types of errors have analogues in the modern RE literature, at least to the time of the RE review paper. The destruction of a pair, type II error, involves the omission and substitution errors associated with errors on the repeated letters themselves. The modification of letters between a pair, type III, is an error analogous to the second aspect of the RE, errors on the nonrepeated elements in strings containing repetition. When Oswald created pairs, type I error, he tended to create them in words which had repeated letters.[6] The analogue in the RE literature would be erroneous repetition of nonrepeated elements in strings containing repetition. Jahnke and Melton (1968) and Jahnke (1969b) had reported such errors.

An interesting interpretation of order errors and substitutions was presented. Lecours considered order errors to be the end product of a combination of two other types of errors, addition and deletion. For example, the misspelling <u>freind</u> for <u>friend</u> is the result of <u>freiend</u> succeeded by deletion of the second <u>e</u>. Substitution errors were similarly interpreted as the end result of a two step process, deletion followed by

[6] Lecours states that a large proportion of type I errors were in repeated letter words. He did not specify the number or proportion.

addition. In any event, inversions accounted for a relatively small proportion of Oswald's errors by Lecours' calculations.

Type II errors, destruction of a pair, accounted for the largest proportion of Oswald's errors (Lecours, 1966). Lecours was aware of Ranschburg's work. "All the errors of type II represent in a sense various applications of the Ranschburg effect to writing" (Lecours, 1966, p. 227). Oswald made omission errors occasionally when there was no letter intervening between a pair, but he usually made omission errors when the letters of a pair were separated by one or more letters. This description is very similar to one of the important boundary conditions stated for the RE, the separation of repeated items (see Jahnke, 1969b, 1974). Furthermore, Lecours observed that type II errors tended to occur on the second member of a pair about twice as frequently as on the first member of the pair. This observation is also similar to the RE data where the effect had been observed as larger on the second element than on the first (e.g., Jahnke, 1969b).

Lecours referred to similar as well as to identical acts. The RE has been associated not only with identical elements but also with similar elements (Jahnke & Melton, 1968).

Lecours study was insightful and innovative. It was however clinical in nature, as opposed to experimental, lacking controls and statistical evaluation of the data.

The Repeated Letter Effect

Oswald's diary was later re-analysed and statistically treated (MacKay, 1969). MacKay credited Lecours with having discovered a "repeated letter effect" (MacKay, 1969, p. 102). MacKay had two purposes. One was to verify Lecours' results from Oswald's diary. The other was to determine whether the repeated letter effect could be found with normal subjects, i.e., nondysgraphics. If normal persons found repeated letter misspellings difficult to perceive and to recall, then the repeated letter effect should be considered a general problem for models of serial order in Lashley's terms (MacKay, 1969).

MacKay found that Oswald made twice as many deletion errors as he did addition errors when repeated letter misspellings were made, and that the difference was significant. The order effect in Oswald's misspellings was found to be significant. The second of two repeated letters was misspelled much more frequently than the first. He also found what he termed a degree of separation effect. Oswald made most of his repeated letter misspellings when there was one letter intervening between repeated items with a trend toward correct spelling as the degree of separation of repeated letters increased. The RE differs from the repeated letter effect on this point. The RE is not observed unless there is a separation of at least two (Jahnke, 1974), and there is some evidence that the RE increases, not decreases, with increasing separation up to a point (Jahnke, 1969b).

MacKay tested normal subjects for recall of repeated letter misspellings by presenting them with misspelled words in sentences. The subjects were instructed to write the sentences as they were spelled. He tested for perception of misspellings by showing the subjects the sentences a second time and asking them whether or not they had observed any misspellings. He found that repeated letter misspellings were significantly more difficult to perceive and to recall than nonrepeated letter misspellings. The normal subjects showed an order effect similar to that seen in Oswald's diary both for perception and recall. However, the effect was not significant either for perception or for recall. He reported a degree of separation effect for normals similar to what he had observed in Oswald's diary. MacKay stated that the repeated letter effect had been verified for normal subjects.

He reported one discrepancy between the repeated letter effect in normals and the repeated letter effect as seen in the diary. Normal subjects found repeated letter deletion misspellings, such as eldery, easier to recall than repeated letter addition misspellings, such as elderdly. MacKay considered that this finding might be due to a basic difference between production and recall. However, when MacKay referred to more addition errors compared to deletion errors, he was referring to the type of misspelled word he presented subjects. He was not referring to an analysis of the nature of the subjects' behavior when they had to reproduce the stimulus misspellings. When subjects did not correctly reproduce elderdly, and so were counted as having made an error on an addition type of misspelled stimulus word, they may have made errors by deleting one of the repeated letters. It may be observed that in this example, taken from MacKay's paper, there are three pairs of repeated letters.

MacKay's experiment with normal subjects is difficult to interpret. It appears that his control words, the nonrepeated letter misspellings, had repeated letters. He cites eldery (for elderly) as an example of a repeated letter misspelled stimulus word. He gives eldely as an example of a nonrepeated letter misspelled stimulus word, apparently because the omission in eldely is not on a repeated letter (MacKay, 1969, p. 104). In terms of the modern alpha-numeric RE studies, MacKay did not have the appropriate control stimuli. Furthermore, like Wickelgren (1965), MacKay used a chi-square test for each of his results from the experiment with normals such that all subjects and all trials for all subjects were pooled.

Typing Errors

MacNeilage's study (1964) is less directly relevant to the RE than the work of Lecours and MacKay. His observations are provocative and pertain to the concerns of the present study since the data show that repeated letters within a word have an interesting relation to systematic language errors.

MacNeilage classified typewriting errors into essentially two types, spatial and temporal. The spatial errors were mainly associated with keyboard variables, and the left hand, and were subclassified as horizontal, vertical, and diagonal errors. The temporal errors were mostly associated with variables pertaining to language structure, were made equally often with both hands, and were subclassified as reversal, omission, equivocal, and anticipation errors.[7] He observed that temporal errors were always significantly associated with letters which occurred twice in a word. It is not possible to pursue the similarities of his data to the RE any further since he was apparently unaware of a literature on repetition effects and analyzed his data accordingly.

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[7] Equivocal errors were so classified as a result of his instructions. The subjects were instructed to stop in the middle of a word as soon as they noticed an error and then to type the word again. Since these errors seemed similar to either reversal or omission errors but could not be classed as either one with any certainty, they were classed as equivocal.

In one respect MacNeilage's data are in striking discord with the alpha-numeric RE literature and with Lecours' and MacKay's results. Both temporal and spatial errors were found to occur in the first half of the word and not in the second half. Examination of his procedure suggests that his instructions may have produced a bias toward this result. Subjects had to stop as soon as they noticed an error. They were instructed not to complete the word but instead to retype it. Errors in these partially completed words were counted as well as any errors in the subject's retyping of the same word. The first typing of such partially completed words were called equivocal errors. It seems reasonable to suppose that with such instructions the subjects would proceed cautiously when they retyped the words, thus reducing the number of errors which otherwise might have been made on the second half of these words. Furthermore the instructions precluded observation of errors on the second half of the first typing of such words because the second half was not present. His data show that about 50% of the temporal errors were equivocal errors.

MacNeilage considered and rejected association explanations of serial order behavior. He interpreted his data along Lashley's lines of thought. MacNeilage suggested that a programming mechanism and a separate executive mechanism contributed to the correct serial order of behavior. Failures of the executive mechanism were held to be responsible for the spatial errors. Temporal errors were due to failures of the programming mechanism. It is of interest with respect to the RE that he considered errors on letters occurring two times in one word as providing special support for the postulation of a programming mechanism.

Status of the Evidence

MacNeilage's data provide a hint that the RE may be found in spontaneous typing errors. As he analysed his data, they do not constitute evidence for the RE. Oswald was a dysgraphic. His errors may not be typical of the errors normal writers make. It was for that reason MacKay performed his experiment with normals. However the data of MacKay's normal subjects cannot be assessed in terms of the RE since, at the least, he did not have the necessary nonrepeated letter control sequences. With respect to Oswald's diary, neither MacKay nor Lecours adequately corrected for opportunity for error on repeated letter versus nonrepeated letter words (Jahnke, Note 4). Proportions were needed with which to compare repeated letter misspellings to nonrepeated letter misspellings. The denominators should have been the number of repeated letter words and nonrepeated letter words, respectively, which appeared in the diary.

The data of these studies, especially the data of

Lecours and MacKay, do suggest that the RE occurs in language. An adequate demonstration of the RE with language stimuli and with normal subjects remained to be performed. In particular, from the viewpoint of the alpha-numeric literature, it remained to be shown that the RE occurs in the spelling and writing of normal adults. There were several methodological problems attendant upon such a demonstration. These are considered in the next chapter.

CHAPTER IV

SOME PRELIMINARY METHODOLOGICAL PROBLEMS AND DECISIONS

Nature of the Task

Since the overall purpose was to examine errors in as close to a normal communicative setting as possible given experimental requirements, a simple spelling task was rejected. Instead, the stimulus words were embedded in sentences which the subjects wrote to dictation. The stimulus words were experimental words containing repeated letters and control words having no repeated letters.

Experimental Dysgraphia

Because normals produce serial order errors in any magnitude only under conditions of fatigue, haste, distraction, etc. (Lashley, 1951; Lecours, 1966) it was necessary to provide several levels of task difficulty to create experimental dysgraphia, that is, a sufficient corpus of errors to provide data for analysis. Words were selected from lists of spelling demons for adults; they were placed in transformationally complex sentences, e.g., one embedding, "That the study of behavior is irresistible to psychologists is clear."; an interference task was provided such that subjects had to remember random two digit numbers to write after writing the sentences; and subjects were required to write at the fastest possible speed.

Equating Experimental and Control Words for Spelling Difficulty

A crucial experimental problem concerned equating experimental and control words on the variables relevant to spelling errors. It is well known in educational research that word length and frequency are important variables (e.g., Cahen, Craun, & Johnson, 1971). It has also been apparent that these two factors combined leave a large portion of error variance unexplained. To provide an unconfounded demonstration of the RE in spelling, this additional source of variance, termed here general spelling difficulty, had to be controlled.

Educational research until recently has not provided adequate data to use in controlling for the general spelling difficulty of words. For example, using a sophisticated statistical approach to find the factors involved in spelling errors, a multiple regression model with interactions, Cahen, Johnson and Wiley (Note 7) found only two important variables. One was word length. The other was a variable they termed opportunity to learn, a modified form of word frequency. The relation of length and frequency to spelling errors had been well established previously, as the authors noted.

The discipline of linguistics has generally ignored spelling both in terms of spelling to sound correspondences and of sound to spelling correspondences. Written language was considered at best secondary to speech in importance. In fact a typical attitude of linguists, verbalized by Ferdinand de Sassure, was that the nature of language is obscured and disguised by writing (Venezky, 1970).

It is only recently that this view has been questioned and these correspondences have begun to be studied. The most linguistically complete work was done by Venezky (1967). Venezky examined spelling to sound correspondences. His work could not be used for this experiment since he stated that the correspondences he found cannot be assumed to work in reverse, from sound to spelling. The investigations of Hanna, Hanna, Hodges and Rudorf (1966) have provided a comprehensive corpus of data on sound to spelling correspondences. Their work, frequently referred to as the Stanford study, was used as the source for the solution of this experimental problem.

The major purpose of the Stanford study was to determine the extent to which the alphabetic principle holds in the American-English writing system. The alphabetic principle means an invariant relationship between each phoneme and each grapheme, i.e., a simple one-to-one coding of phonemes to graphemic symbols. American-English orthography is complex. The alphabetic principle does not apply completely. The question for Hanna et al. was how well the principle approximates the phoneme-grapheme correspondences of American-English.

If the alphabetic principle is sufficiently approximate, then the graphemic correspondence for each phoneme should be highly predictable.

A word corpus of over 17,000 words was selected as being representative of the entire American-English lexicon of an educated U.S. citizen. In the first phase of the study, a computer searched the graphemic spelling of each word and determined the percentages of occurrence of each grapheme. As was expected by the authors, for each phoneme the computer produced a list of possible graphemes, i.e., a list of graphemic options. Nevertheless the findings substantiated the alphabetic principle as at least approximately true according to the criterion which had been determined upon by Hanna et al. Individual phonemes were found to be represented by a single graphemic option over 84% of the time. The data corpus includes tabulations of the percentage of occurrence of the various graphemic options for each phoneme. Each percentage could be used as the probability of occurrence of each grapheme for each phoneme. The probability of correctly spelling any word could then easily be calculated and words matched according to those calculated probabilities.

This solution was rejected. Although the computer substantiated the alphabetic principle for single phoneme-to-grapheme correspondences in the first phase of the study, it did not do so for whole words, its task in the second phase. The computer was able to spell correctly only about 50% of the 17,000 word corpus. This was the case even though the algorithm the computer was given to predict the spelling of whole words included an additional phonologic level, environment, along with the phonologic levels, position and stress, employed in the first phase of the work. As Hanna et al. observed, for some relevant questions a word is wrong whether it has one incorrect grapheme or several. Furthermore, the data corpus was based solely on phonology, the authors being unable to program for morphology and syntax. It is to be expected that the numerical value of the percentages given in the corpus would change if these higher language levels had been included. Consequently matching experimental and control words on the basis of calculated probabilities of correct spelling would have provided spurious precision.

The solution adopted was to use the Stanford data in a simpler manner. It was decided to restrict the stimulus words to those the computer spelled correctly, i.e., to those words capable of being correctly spelled via phonology alone, so that at least on a phonologic level experimental and control words would be of equal difficulty.

The remaining question was as follows. If Hanna et al. had included higher linguistic levels, would some of the words now found in the computer correctly spelled list be found in the error corpus? If so, selection of stimulus words from those the computer correctly spelled would be an inadequate control of general spelling difficulty since some experimental words, repeated letter words, might be the ones which would actually belong to the error corpus. In a critical review of the Stanford study from the point of view of a linguist, Reed (1967) stated that it would be the other way around. Reed projected that inclusion of more complex linguistic levels such as morpheme boundaries and diaphonemes would have reduced the corpus of error words to near zero rather than result in transferring computer correctly spelled words to the error corpus.

Control Analysis of Errors as Nongraphemic Options

As the Stanford study showed, with a single standard pronunciation of a word each phoneme had an accompanying list of graphemic options, i.e., a list of possible graphemes for that phoneme. This was true even though a single phoneme was represented by a particular grapheme over 84% of the time the phoneme occurred (the alphabetic principle), and even though, with a few exceptions, there is only one correct spelling for each word in the lexicon, i.e., for a given sequence of phonemes there is only one correct sequence of graphemes. With a variety of acceptable pronunciations of a word, the list of possible but incorrect graphemic options increases. A preliminary study showed that these considerations mandated a control analysis of errors.

Pilot work for this experiment revealed that the spelling of some subjects may be in accord with their pronunciation. For example, the experimental word unusual was written unusal. The subject reported that he wrote the word as he habitually pronounced it, although he knew he had made a spelling error while he was writing the word. The subject's error was not only in agreement with his speech but also in agreement with prediction from the RE, i.e., an error on a repeated letter. This pilot finding raised the possibility of an alternative explanation of the data if more errors were to be found on experimental versus control words. It might be argued that such results are not due to the RE but show merely that a word may be misspelled in a way that follows from the subject's speech. To discount this alternative explanation it was necessary to ask whether there would be more errors on experimental than on control words after allowing for errors which might follow from acceptable pronunciation variations. The term graphemic option errors is used here for the latter errors. The term nongraphemic option errors is used here for spelling errors that do not follow from any acceptable pronunciation.[8]

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[8]As will be seen further in this section, the terms graphemic option errors and nongraphemic option errors as used in the data analysis are more detailed.

<u>Phonemic Input</u>. One of the major criticisms of the Hanna et al. study (e.g., Reed, 1967) is that too few people speak like the Merrian-Webster Collegiate Dictionary which was used for phonemic input. Therefore the allowable phonemic input had to be broadened for the purpose of determining which strings of graphemes were to be scored as nongraphemic options.

The decisions were as follows. Allowable pronunciation was based on Kenyon and Knott (1953) which is still generally considered the authoritative guide to American-English speech, or on the Hanna et al. corpus, or on Webster's Third New International Dictionary unabridged (WIII). The spelling of a word was considered a graphemic option spelling if it represented a string of phonemes considered acceptable for a given word by any one of these three guides. Both WIII and Kenyon and Knott take cognizance of New York speech. WIII was included because it gives a much larger list of pronunciation variants and is more recent than Kenyon and Knott. WIII also includes common substandard variations which were allowed as phonemic input in keeping with the overall conservative strategy of this experiment, e.g., <u>revalent</u> for <u>relevant</u> and <u>atheletic</u> for <u>athletic</u>. Consideration was given to broadening the allowable pronunciation variants even further. As even Kenyon and Knott admit, the notion of standard colloquial speech is something of a fiction.

However, in view of the point that the definition of dialect can be stretched to include idiolect, which would make any idiosyncratic speech acceptable, the decision to limit acceptable pronunciation as indicated seemed the most reasonable decision.

Nongraphemic options: Use of the Stanford study. A nongraphemic option could have been defined as a very rare option defining rare by some cut off point of percentage of occurrence, e.g., less than 1%, or a nongraphemic option could have been defined as a grapheme which is not listed as an option, i.e., one which does not appear in the tabulations.

The nonconditional tables of phoneme-grapheme options could have been used, or the conditional tables, or the conditional tables together with the algorithm. There are two sets of conditional tables, one for options dependent upon position within syllables and another for options dependent upon stress dependent upon syllable position. The algorithm contains additional information in the form of rules for spelling depending upon phonemic environment.

Exclusion of rare options appeared desirable to eliminate strange, i.e., contra-intuitive, spellings which would otherwise be accepted as graphemic options, Utilization of the conditional tables appeared necessary to reflect important constraints in the language. However such a strategy while apparently involving more precision than the looser alternatives actually introduces more error, whereas the decision to define nongraphemic options as literal zero frequency graphemic options in the nonconditional tables yields the lesser amount of error.

Hanna et al. do not have adequate data to warrant the stronger approach. For example, in the tables listing options conditional upon position, it is syllable position which was examined, not morpheme/word position. The latter is a constraint actually imposed by language. Had it been employed the magnitudes of the probabilities of conditional graphemic options would have to be different from the stated magnitudes. Environment was considered only in the second phase of the study, in the algorithm given to the computer. The bases for decisions concerning environment were admittedly ad hoc, and no tabulations of graphemic options given environment were made.

Use of the nonconditional tables to define a nongraphemic option as one which is not present in the list of options for any given phoneme implicitly reflects all the constraints inherent in written language, although grossly. If a graphemic option exists under any condition, that event must be reflected in some numerical percentage in the nonconditional tables. Conversely, if it does not appear in these tables, it would not appear in any improved conditional table. Of course, a low graphemic option could be a high one under relevant conditions while some low options are probably low under any conditions, and these cases which are of considerable interest cannot be separated. The attempt to do so in the absence of better data can only yield a spurious impression of sophistication and precision. Finally, use of the non-conditional tables obviates the difficult questions about how many rules (i.e., conditions) adult subjects actually know, and then how many and which ones should be expected of them.

To summarize, the decisions made were: (a) to utilize the nonconditional tables of graphemic options, (b) to define a nongraphemic option literally as one which is not given, and (c) to accept as a graphemic option any one which is listed no matter how low the percentage of occurrence.

The remaining major question these decisions leave open is the following one. Had Hanna et al. used a larger word corpus, some additional very low option percentages might have appeared; the percentage of occurrence of a defined nongraphemic option may be above a true zero in an unknown number of cases. However, it is likely that these cases would be very rare indeed and probably pertain mainly to words which are borrowings from other languages. The words which reflect borrowings from other languages account for the rarer options (Venezky, 1967). In any event, this objection would arise from any proposed use of the Stanford study tables.

Linguists in general have only scattered impressions to bring to bear on the phoneme-grapheme issue since spelling is only recently beginning to interest this discipline. Used in the manner outlined above, with the correction for phonemic input described, the nonconditional tables of Hanna et al. are not only the only available data base but are reasonable strong data and hence a preferred alternative to subjective judgments.

Resultant procedure and examples. Using all variants given in WIII, in Kenyon and Knott (including those variations discussed in the introduction as well as in their vocabulary), and the pronunciation given in Hanna et al., decisions were made for each phoneme separately in the word. A word was judged to be a graphemic option if any grapheme combination resulted in an option after an allowable phonemic input. In the following examples the material enclosed in brackets represent graphemes. The capitalized phonemes enclosed in parallel lines stand for the Hanna et al. phonemic notation. The other phonemes enclosed in parallel lines represent standard International Phonetic Alphabet notation.

1. banqueut for banquet

    a) Pronunciation variants

(1) All guides agree that the third consonant is /kw/.

(2) Hanna et al.: the second vowel is /ɛ/, or /E3/, therefore, /---kwɛt/.

(3) Kenyon and Knott: the second vowel is /ɪ/ or /I3/, therefore, /---kwɪt/.

b) Graphemic options

(1) [que] is a zero graphemic option for /kw/; the only graphemic options for /kw/ are [qu] and [cqu].

(2) [eu] is a zero graphemic option for /E3/.

(3) [eu] is a zero graphemic option for /ɪ/.

Therefore banqueut is not a graphemic option for banquet.

2. belive for believe

a) Pronunciation variants

All three guides concur that the second vowel is /i/ or /E/.

b) Graphemic options

[i] is an option for /E/, occurring 1.49% of the time. Therefore, belive is a graphemic option for believe.

For a word to be scored as a graphemic option, there need be only one graphemic possibility for each phoneme, but each phoneme had to be represented by a grapheme so that the phonemes of any allowable pronunciation of a word map one-to-one on the graphemes the subject wrote for that word.

The complete definition of a graphemic option error, as used in the data analysis, is a permissible but incorrect grapheme for an allowable phoneme when the allowable strings of phonemes for each word had been determined by including acceptable pronunciation variants. The string of phonemes of any allowable pronunciation variant then map one-to-one on the string of permissible graphemes that the subject wrote for that word. A nongraphemic option error is either (a) an impermissible grapheme for an allowed phoneme, or (b) a missing grapheme for a required phoneme as determined by allowable pronunciation variants, or (c) an added grapheme for any added unallowable phoneme. In either of these three cases the string of phonemes of any allowable pronunciation variant does not map one-to-one on the string of permissible graphemes written by the subject.

Procedure for Scoring Errors

Pilot work showed that a special method was needed for determining what were to be considered errors. The subjects' writing was extremely difficult to decode; they were, temporarily, very dysgraphic. There were two levels of decisions to be made.

The first level of decision concerned which words were to be included in the corpus for further scoring as correct or incorrect and which words were to be removed from the data and not further scored. Given the multiple levels of task difficulty, it was to be expected that some of the responses to the stimulus words might be missing from the subjects' data or replaced by substitutions. Subjects might simplify or transform sentences and omit the stimulus words or substitute words of approximate semantic value for these words. For example, given the word quantity, the response amount would not appear to warrant designation as a spelling error. However, given the sentence "A formal law or statute to prevent pillage prompted a skeptical remark." substitution of the word status for statute would result in nonsense and is more clearly an error. Unfinished stimulus words also required decisions since, under the speeded conditions of writing, a word might not be completed because the subject was at the time limit or incomplete because the subject did not know how to spell the word. In order to make these decisions, detailed rules were needed.

The second level of decision concerned the remaining corpus of stimulus words. Experimental dysgraphics as well as true dysgraphics not only produce clear spelling errors but also produce incomplete and peculiarly formed characters. On the other hand, adult normal writing under normal conditions varies vastly as to style. It is idiosyncratic. Some adults characteristically write the letter _m_ with two curves and write the letter _n_ with one curve. For others such an occurence is so rare that it may be properly considered an error, e.g., _alunimum_ for _aluminum_. Since the cross bar is often the only distinguishing feature between a cursively written _t_ and _l_, the response _athlelic_ might represent either a Ranschburg error or a writing simplification characteristic of the subject under the conditions of the experiment. Rules were needed so that each letter in each word in the remaining corpus would be judged as correct or incorrect. If incorrect, the rules had to specify which errors were to be designated as spelling or as writing errors, the latter being malformed characters where character means a written form representing a letter of the alphabet. Since judgments at this decision level had to be dependent upon the subject's writing style in general and under the conditions of this experiment in particular, counting rules were necessary so that decisions could be made about which characters were typical for each subject and which were rare, hence errors.

No method was found to be capable of handling these problems. The dysgraphia literature in general was inadequate for the purpose. Researchers tend to use a subjective, unarticulated standard of what the normal variations in writing are. The handwriting literature deals mostly with personality assessment from handwriting.

The literature which best approximates solutions to the issues at hand is that on the methodology for detecting forgery (Conway, 1959; Hilton, 1956). However the forgery expert asks the question "Did X or some other person produce this specimen of writing?" not the question asked in this experiment "Given that X wrote this word, what is it and is it correct or incorrect?" A detailed set of rules was devised to deal with these problems and to provide for the scoring of events observed in the pilot study (see Appendices C and D for the complete rules).

Scoring Critical Item and Noncritical Item Errors

The most recent RE literature defines the RE by the occurrence of more errors on critical items in experimental versus control strings and by the absence of a difference between the errors on noncritical items of experimental and control strings (Mewaldt & Hinrichs, 1973; Jahnke, 1974; Lee, 1976). Both of these cases had to be examined in addition to analysis at the whole word level.

Critical items are the repeated elements in experimental strings and the elements in corresponding position in control strings. *Noncritical items* are the remaining elements when critical items are excluded from consideration. In the following example the critical items are underscored in the experimental word and in its matched control word: perform and exhaust; the noncritical items are the remaining letters in both words. For critical item and noncritical item analyses, all relevant items are combined. Critical item analysis is performed as follows. If free recall scoring is used, the element is correct if it is present irrespective of correctness of position. For example, for critical item analysis, if the stimulus is 236439 and the response is 233867 the response is scored as correct. If ordered recall scoring is used, the item has to be both present and in the correct position, so the response 233867 would be incorrect. How should the response 236433 be scored? Both critical items are present and in the correct position, but there is an erroneous repetition of the digit 3. The scoring of erroneous repetitions of critical items is not explicit in the RE literature. In the only two experiments in which erroneous repetitions were studied, they were examined for another purpose than that of a critical item analysis, and there is no mention of how the critical items themselves were scored if they were erroneously repeated (Jahnke & Melton, 1968; Jahnke, 1969b).

Apparently, the concern in critical item analyses has been with the fate of the given repeated elements from a restricted viewpoint, whether one or all were present in the response, so that erroneous repetitionsof critical items were scored as noncritical item errors. In general, the RE researchers have not directly pursued the question of the kinds of errors which occur. Looked at from this point of view, the fate of given repeated elements might include erroneous repetition, e.g., barbararous, a response to the stimulus barbarous. From inspection of the data, there appeared to be a substantial number of erroneous repetitions. Should they be scored as critical item errors or as noncritical item errors?

The point is to answer the question: Are the critical items or the noncritical items or both responsible for more errors in experimental than in control strings or words? To answer the question without prejudice it is highly desirable that the categories of critical item and non-critical item errors be mutually exclusive and exhaustive of all errors. The error should be attributable to critical item error categories or to noncritical item error categories so that a single error should not be counted twice for both sets of items and every error should be accounted for. The same word could be counted in both the critical item and noncritical item analysis if there were errors on both critical items and on non-critical items. For example, in the response barbus to the word barbarous, the critical items a and r are missing, and the noncritical item o is also missing. Therefore the response barbus is incorrect for both the critical and noncritical item analyses.

It was decided to score erroneous repetitions in the following manner to best balance critical and noncritical item analyses and to allow for later examination of the kinds of errors made.

1. Critical item analysis

a) Erroneous repetition of repeated letters (and corresponding letters in control words) were scored as critical item errors only if they were additions to word length and not scored as errors if they replaced noncritical items, e.g., eenemy was scored as a critical item error but relevent was not since the third e in the latter case replaced the noncritical item, a.

b) Erroneous repetition of noncritical items were scored as critical item errors only if they replaced critical items since in that case the critical item was missing, e.g., auxillary for auxiliary was scored as a critical item error.

2. Noncritical item analysis

a) Erroneous repetition of noncritical items were scored as noncritical item errors only if they were additions to word length. For example, auxillary for auxiliary was not scored as a noncritical item error because the erroneously repeated l replaced the second i which was a critical item, but mannual for manual was scored as a noncritical item error.

b) Erroneous repetition of critical items were scored as noncritical item errors only if they occurred in the place of noncritical items, e.g., relevent.

Given concern with the kinds of errors made, and from this perspective with the fate of the critical items, an analogous problem arose concerning scoring of order errors. Should the response strenth for strength be scored as an error in the critical item analysis? All critical items are present, none are erroneously repeated, but the second t is in the wrong place because a noncritical item, g, was omitted. It was decided that critical items in the wrong position because of an addition, deletion, or erroneous repetition of a noncritical item were not to be scored as critical item errors. For example, the control word surgon for surgeon and the experimental words partical for partial and alluminum for aluminum were not scored as errors for the critical item analysis but were scored as errors for the noncritical item analysis. Order error words, for the purpose of the critical item analysis, were defined as follows: words containing all the correct letters but in the wrong order, e.g., axiuliary for auxiliary, and incoulate for inoculate; and words containing critical items in the wrong place not due to additions, deletions, or erroneous repetitions of noncritical items, e.g., vitiam for vitamin. It may be observed that where all the correct letters were present but in the wrong order, the word was counted in both the critical item and non-critical item analyses since if a critical item was misplaced so was a noncritical item. There was no nonarbitrary way to treat order errors so that they were classed as either critical item errors or as noncritical item errors.

CHAPTER V

METHOD

Experiment

Subjects. Twenty-six volunteer undergraduate college students were selected as subjects. Selection was based upon responses to a questionnaire such that all subjects were native speakers of English who had no reading or spelling disabilities.

Stimulus material. The stimulus words were selected from four lists: 335 spelling demons for college students (Furness & Boyd, 1959), 606 spelling demons for adults (Furness, 1965), a Remington Rand list of about 500 most commonly misspelled words for adults (in Furness, 1965) and a list of 1,100 most frequently misspelled words (Lewis, 1963). Most words were selected from the first three lists since the shorter lists were composed of the more difficult words. There were 32 experimental and 32 matched control words.

Experimental words contained at least one pair of repeated letters, e.g., *publicly*, *unusual*. Words containing pairs of repeated letters which had no intervening letters were excluded, for example, *battle*. This restriction was placed since problems with double letters in English might be attributed to a source other than the RE[9] and thus artifactually inflate the effect. Control words contained no repeated letters, e.g., playwright.

Words were matched by pairs for length and frequency. The experimental list as a whole was matched with the control list as a whole for general spelling difficulty. Matching for length was based on the number of letters in a stimulus word. Frequency matches were obtained from Computational Analysis of Present-Day American English by Kucera and Francis (1967) which is based on a one million word corpus. As indicated previously, matches for spelling difficulty were obtained from the Stanford study computer printout of correctly spelled words. Perfect matches were impossible due to the constraints on the selection of stimulus words. In keeping with the conservative strategy underlying this first attempt to demonstrate the Ranschburg effect in normal spelling and writing, control words were made harder where choice had to be made. That is, they were less frequent, and about

[9]The frequency of given double letters varies considerably in English (see Baddeley, 1960), their presence in words depends upon both phonologic and morphemic considerations (see Venezky, 1967), and their correct spelling depends upon the writer's knowing these rules. Thus, within words, they may represent a special case of repeated letters in which confusion concerning these rules might be a large contributor to what appears to be the RE. Double elements in alpha-numeric strings have no comparable independent relation to any rules governing the sequence of the elements in the strings. In this first examination of the RE in spelling and writing, in which the problem concerns the isomorphism of repetition effects within words to repetition effects in alpha-numeric strings, it seemed the better strategy to eliminate this pattern.

one third (10) of the control words were selected from the computer error corpus, whereas all experimental words were words the computer had spelled correctly.[10]

Linguistically difficult sentences were constructed in pairs, one for each experimental word and one for its matching control word so that each pair of sentences had about the same linguistic difficulty. The experimental and control words of each pair were placed in analogous positions in the matched sentences to control for variance due to serial position effects. Restrictions were imposed such that no stimulus word was the first word in a sentence for serial position reasons, nor too close to the end in order to reduce the number of words which might be missing due to lack of time. The assistance of linguists was utilized to construct the paired sentences with the stated restrictions.

To provide an interference task and to ensure speeded writing, two-digit numbers from the set 11-99 were randomly selected and presented before each sentence. These numbers were to be recalled by the subjects and to be written, after the sentence had been completed, in backwards order from the given number to zero, if the subject was finished before time was up. These numbers were not scored.

[10]One control word was longer than its experimental match by one letter.

Instructions. Subjects were told they were participating in a study of the way people write English and numbers. They were instructed to write the dictated sentence cursively as quickly and correctly as possible and then to write the given number and as many numbers as possible in backwards order from the given number to zero until they were told to stop. Subjects were told to write as many zeros as possible should they reach zero on any sentence before time was up. Subjects were cautioned not to cross out, rewrite, or in anyway correct anything they had written.

Procedure. The 64 sentences were randomly ordered via a table of random numbers. The instructions, eight practice sentences and the 64 experimental sentences were tape recorded and presented to the subjects as a group. Fifteen seconds of blank tape time followed by a stop signal constituted the interstimulus interval during which subjects wrote their responses. A ready signal preceded each dictated sentence.

Scoring procedure. The set of rules by which the subject's response to each stimulus word was judged contained 18 categories of errors. Detailed rules were provided to determine inclusion of an event in any of these categories (see Appendix C). Two of these categories represented missing or substituted words. These words were listed on the subjects' protocols but they were not counted as error words nor scored further since the transformational difficulty of the sentences might have accounted for these occurrences independent of the RE. Each written character in the residual experimental and control words was judged as correct or as incorrect.

The remaining sixteen categories by which such judgments were made included: one category for breaks in the cursive link between characters, one category for abbreviations, five categories of spelling errors, one category for corrections that were not spelling errors, and eight categories of malformed characters.

The five categories of spelling errors were as follows:

1. Spelling errors such that there was at least one incorrect character, or an added character, or missing character.

2. Words that were possible substitutions but not judged as substitutions by the rules and so were scored as spelling errors.

3. Words that contained a correction such that it could be determined what the first writing of the word was and the first writing before the correction was a spelling error.

4. Words that were incomplete but not scored as missing according to the rules.

5. Words that were possible substitutions but

were incomplete and so were not judged as substitutions by the rules.

The eight error categories of malformed characters were as follows:

1. Non-English characters.

2. Characters written much above or much below the writing line.

3. Contaminated characters, i.e., apparent combinations of two characters.

4. Uncrossed characters representing t.

5. Vestigial characters, i.e., unusually small sized characters.

6. Characters containing a break in continuity within the character.

7. Incomplete characters.

8. Characters that were malformed such that the nature of the malformation did not fit any of the other categories, i.e., any other malformation.

Malformed characters were defined as formations that did not well represent a letter and were rare for the subject, i.e., not the subject's style. Determination that a character was malformed and not the subject's style necessitated counting rules. There were more than a dozen such rules, some of which included letter context. In brief, a 10% criterion was applied to define rarity of occurrence (see Appendix D). That is, if the questionable character representing a given letter of the alphabet occurred 10% or fewer of the times that character was written in the entire sample, that character was designated as malformed. For the above purpose, the entire sample consisted of all words written, non-stimulus as well as stimulus words, excluding the practice sentences. The counting rules had specifications for close decisions and small denominators mandating recounting.

Since each character in a word was examined individually, words listed on the protocols as error words could contain more than one error. However, to be listed as an error word, there had to be at least one error on one character of a word that was not listed as a missing word or as a substitution.

Scoring reliability procedure. A second rater, naive about the Ranschburg effect and the purposes of the experiment, was used. The rater was given the scoring rules and trained on a set of sample data from three subjects from a pilot study. Following training, during the time the rater scored the experimental data, no questions concerning scoring procedure or problems were answered by the experimenter. The rater was instructed to proceed as best he could to make judgments in accordance with the rules. The rater was instructed to recheck his scoring of the entire experimental data in the subject order in which he performed the initial scoring.

Control Study

Subjects. Twenty-five volunteer undergraduate college students who did not participate in the main experiment were selected as subjects for this study. Selection was based upon responses to a questionnaire such that all subjects were native speakers of English who had no reading or spelling disabilities.

Stimulus material, instructions, and procedure. The stimulus words of the main experiment were presented as a spelling test. The stimulus word was presented first, followed by a sentence containing the word, and then the stimulus word was presented again. The sentences used were the same as in the main experiment. Subjects were told they were participating in a study of the spelling of college students. They were instructed to write cursively only the given word, not the sentence, and they were told not to write until after the last presentation of the word. They were cautioned not to go back over anything they had written. Response time was 10 seconds following the last presentation of the word. A ready signal preceded the first utterance of the stimulus word. All material including the instructions and the three practice words were tape recorded and presented to the subjects as a group.

Scoring procedure. The simple conditions of this study obviated the scoring difficulties of the main experiment. As was found in pilot data, all written characters were sufficiently well formed to be unambiguous and to present no judgment problems. The detailed rules devised for deciphering dysgraphic data were not used. Errors were any incorrect characters.

Scoring reliability procedure. Since the scoring did not present judgment problems, the data were not scored by a second rater.

Statistical Considerations

Because of the considerable number of significance tests performed, and in keeping with the general conservative strategy underlying this experiment, a probability value of .01 was set as the maximum acceptable result probability. One-tailed tests were used unless otherwise indicated since there were clear directional alternate hypotheses in most cases. Inferential statistics were not applied where there were very small differences between experimental and control words, or where there were small numbers of error words in each condition, or both. In such cases there were a large number of zero differences leading to violation of the assumption of a continuous distribution underlying all significance tests except the binomial test, and in turn leading to nonsignificant binomial test results. In several cases in which the Wilcoxon Signed-Ranks Matched-Pairs test was used, the observed T values were very much larger or very much smaller than the tabled critical values. Where it was of interest, the z transform was used to obtain a better indication of the probability of the observed result than the tabled probabilities afforded. According to Siegel (1956) the z transform is an excellent approximation to calculated probabilities of T even for sample sizes as small as eight. In every case in which the z transform was used, N was larger than 20. Wherever the z transform was used it is so indicated in the results.

CHAPTER VI

RESULTS AND COMMENTS

Reliability of the Scoring Procedure

The measure of scoring reliability was the percentage of agreement between the experimenter and the second rater. The denominators in each case are the relevant opportunities to agree or to disagree, while the numerators are the number of agreements.

There were three levels of reliability analysis. They were: (a) the reliability of the judgments about which words were missing words or substitutions, (b) the reliability of judgments about which remaining words were correct or had errors, and (c) the reliability of judgments about the nature and locus of errors within a word. The last two levels were further divided for reliability assessment in order to determine how well the detailed rules worked in deciphering experimentally dysgraphic writing, and in order to determine the reliability of the scoring of subgroups of errors that were to be examined for the RE in spelling and writing.

Reliability of judgments about missing and substituted words. There were 1664 possible opportunities to agree or to disagree (64 stimulus words x 26 subjects). There were six disagreements, two disagreements on whether or not a word was missing, and four disagreements on whether or not a word was a substitution. There was 99.64% agreement on whether or not a word was to be included in the residual corpus for further analysis.

Reliability of judgments about error words and correct words. An error word contained at least one writing or spelling error. The number of opportunities to agree or to disagree was 1506 words (1664 words, minus 152 words for which there was agreement about the words as either missing or substituted, minus the 6 words for which there was disagreement about the words as either missing or substituted). Multiple errors could and did occur within a word and character. Judgments that a word was correct reflected judgments of each character as well formed, correct, and in the right place. Therefore the same denominator, 1506, was used to obtain all agreement percentages. As Table 1 shows, there was 90.90% agreement on whether a word was an error word or not, counting all categories of errors together by which a word was judged as an error word or as a correct word if the word was present and not a substitution. Most of the 137 disagreements involved disagreements concerning how well formed a character was (see Table 1). That is, one rater scored a word as an error word because only one character was judged as malformed while the other rater judged that character as well formed and so judged the word to be

Table 1

Agreement on Scoring Words as Correct or as Error Words

Scoring category	Number of Disagreements	Percentage Agreement[a]
Malformed characters as a group	113	92.50
Spelling errors as a group	9	99.40
Nonspelling error corrections	12	99.20
Discontinuity between characters	3	99.80
All categories combined	137	90.90

[a]The denominator was 1,506.

correct. There were 113 such disagreed words; there was 92.50% agreement on words judged as correct or incorrect based solely on judgments concerning malformed characters. It may be of interest that with eight subcategories of malformed characters, about 75% of the time that both raters judged a character as malformed it was placed in the catch-all category, any other malformation (see Appendix C for details about categories). Agreement was very high that the word was correct or an error word based on judgments that the word contained at least one spelling error. There was 99.40% agreement on words as error words or not according to the spelling rules.

Reliability of judgments about the nature and the locus of errors. This level of reliability analysis pertained to agreement on judgments of each character within each word. The number of opportunities to agree or to disagree was the total number of characters within each word written by each subject across all subjects. The disagreed missing or substituted words were included at this level of analysis as a conservative measure of the reliability of scoring the nature and locus of errors within a word since many of the subsequent results depended on that scoring. The agreed missing or substituted words were excluded. As indicated previously, more than one error could occur on a single character. Some characters were scored both as spelling and as writing errors. Judgments that a character was correct reflected judgments that it was well formed and represented the correct letter in the right place. Therefore, the same denominator, 11,361, was used to obtain all agreement percentages. Some cases arose in which one rater deciphered a word as containing a different number of characters from those deciphered by the other rater. The experimenter's count was reflected in the denominator. The numerator reflected the number of characters whose presence was disagreed upon.

As Table 2 shows, the agreement on the nature of the error at a particular locus within a word was very high. The percentage of agreement on what each character was and whether or not it was malformed was over 97%. There was 95.74% agreement that some error occurred at a given place including nonspelling error corrections and breaks in continuity between characters, 97.22% agreement that the error was a malformed character (i.e., a writing error), and 98.01% agreement that the error at a given locus was a spelling error. It should be noted that the agreement on spelling errors at a given locus would have been even higher if the disagreed missing and substituted words were excluded. Each character within these words was counted as a spelling error disagreement, increasing the numerator of the percentage relatively more than the denominator was increased.

Table 2

Agreement on the Nature and Locus of Errors within a Word

Kind of error at a given locus	Number of Disagreements	Percentage Agreement[a]
Any kind of error	484	95.74
Malformed characters	316	97.22
Spelling errors	226	98.01

Note. The sum of disagreements of malformed characters and spelling errors is larger than the number of disagreements that any error occurred at a particular locus since both writing and spelling errors did obtain at times for the same character.

[a]The denominator was 11,361.

In summary, the agreement between raters on the scoring of the data was generally high. The rules were quite successful as guides for deciphering dysgraphic writing. Agreement was very high on judgments concerning which letter each character represented, and whether or not it was malformed. These are the judgments of most importance for deciphering dysgraphic writing and for the subsequent data analyses of this experiment. Given these results, the experimenters' scoring of the data was used for all subsequent analyses.

Missing Words and Substitutions

It was expected that there would be missing and substituted words particularly because of the transformational difficulty of the sentences. Although not predicted, there were significantly more such errors for the experimental than for the control words as Table 3 shows, $t(25) = 3.39$, $p < .01$, two-tailed t-test for correlated samples. The less likely of two possible explanations is that with transformationally difficult sentences repeated letter words are harder to process than control words having no repeated letters. The presence of substitutions indicates that the subjects were able to process these words on both semantic and grammatic levels, since both requirements had to be met in order for a word to be scored as a substitution. The more likely explanation is that included in the pool of

Table 3

Incidence of Missing and Substituted Words

Scoring category	Experimental words	Control words	*t*
Missing	59	40	
Substituted	35	21	
Total number	94	61	
Mean number	3.62	1.27	3.39*

*$p < .005$

missing words and substitutions were words the subjects had trouble spelling given the speeded writing condition and the interference task.

The verbal report of one subject supports the second view. At the conclusion of the experiment she stated that when she forgot how to spell a word she tried to find one of the equivalent meaning and if that failed she left the word out. More substantive support for the second alternative depends on the presence of more spelling errors on experimental than on control words showing that repeated letter words are harder to spell under these experimental conditions than the control words, i.e., that the RE occurs in spelling.

What was not there could not be scored for spelling or writing errors. Many substitutions were undoubtedly due to forgetting the precise word to be written and so are not strictly spelling errors, e.g., amount for quantity. All substituted and missing words were removed from the data for the succeeding analyses. All analyses were in terms of proportions, the number of error words to the number of remaining words written. The numbers of remaining experimental and control words were 738 and 771, respectively.

Presence of the RE in Spelling

All categories of spelling errors were grouped together to answer the question of whether or not the RE is present in spelling. Each of these kinds of errors is by common consensus a spelling error. Corrections, such that the weight of the judgment was that the character did not represent a spelling error even though it had been altered by the subject, were not included among the spelling errors. There were 28 such corrections in the experimental words and 30 in the control words, across all characters in all words, and across all subjects.

Spelling errors: Whole word level. To be scored as an error word, there had to be at least one character in the word that was wrong by the spelling rules. As Table 4 shows, there were more spelling errors on experimental than on control words and the difference was significant by the Wilcoxon Signed-Ranks Matched-Pairs test. The only word on which no spelling errors were made was a control word, author.

The small overall error difference in this comparison and succeeding comparisons is probably an underestimate of the size of the effect under these experimental conditions. The control words were overcontrolled as indicated previously, and a larger number of the experimental than the control words were removed from the data. Many of the words removed probably represented true spelling errors. The main point was to provide a stringent test of the RE in spelling and writing, not to assess the magnitude of the effect in this first experimental examination of

Table 4

Incidence of Spelling Errors: Whole Word Level

Error words	Experimental words	Control words	Difference	*T*
Number	261	225	36	
Percentage	35.36	29.18	6.18	74[a]*

[a]There were 19 subjects with positive differences, 6 with negative differences, and 1 subject with a zero difference.

*$p < .01$

Ranschburg's assertions about spelling and writing.

Critical items. For an experimental word to be scored as an error word in the critical item analysis, a word had to have at least one error on one repeated letter of the set of repeated letters. For the control words, a word had to have at least one error on one letter of the set of letters in the positions corresponding to the positions of the repeated letters. Since the repetition patterns varied in the experimental words, the matched experimental and control words had to be analysed in pairs so that the proper elements were examined in the control words, e.g., curious versus destroy, gigantic versus obstacle (critical items underscored). A critical item was scored as incorrect if it was omitted, or in the wrong order, or if it was erroneously repeated.

As Table 5 shows, there were more spelling error words in the experimental versus the control list when only critical items were examined, and the difference was significant. Errors on critical items do contribute to the overall spelling error difference between repeated letter words and control words.

Although there were five subjects with negative differences (subjects who had more error words for control than for experimental words) there were only two negative subjects in common between the critical item analysis and the whole word analysis. That is, there

Table 5

Incidence of Spelling Errors: Critical Items

Error words	Experimental words	Control words	Difference	*T*
Number	192	143	49	
Percentage	26.02	18.55	7.47	42[a]*

[a]There were 20 subjects with positive differences, 5 with negative differences and 1 subject with a zero difference.

*$p < .005$

were two subjects who did not show the RE up to this point in the analysis. This finding suggests the possibility, to be examined further, that some subjects will be negative for each positive finding for the group as a whole but that these negative subjects will not be the same ones. If this is the case, then the observation of negative cases may more properly be a consequence of the stringent test of the RE, the conservative strategy employed in this experiment, than of a subject variable among this group of subjects.

Noncritical items. The scoring of noncritical item error words was analogous to that described for critical items with one addition. Characters representing nongiven phonemes were scored as noncritical item errors, e.g., mutualy for mutual.

There was no significant difference between the spelling error words of the two lists when only noncritical items were considered (see Table 6.) The probability of occurrence of the observed Wilcoxon *T* statistic was greater than .18 ($z = -.82$).

Absence of the RE in Handwriting

All categories of malformed character errors were grouped together to determine the presence of the RE in writing. Breaks in the continuity between characters in cursive writing, although a writing error, were excluded. The raters were not asked by the rules to judge which

Table 6

Incidence of Spelling Errors: Noncritical Items

Error words	Experimental words	Control words	Difference	*T*
Number	152	149	3	
Percentage	20.60	19.32	1.28	143[a]

[a]There were 16 subjects with positive difference and 10 subjects with negative differences.

character the break was closest to, and there were very few such errors, 17 in experimental words and 11 in control words out of roughly 10,000 possible occurrences (between each character in each written word across words and subjects).

Whole word level. To be scored as an error word, there had to be at least one malformed character in a word. No significant difference was found between writing errors on experimental versus control words. Almost one third of the subjects (8 out of 26) had more errors on control than on experimental words. The probability of the observed Wilcoxon T statistic (see Table 7) was greater than .05 ($z = -1.44$). At the whole word level, there is no support for the RE in writing as defined in this study. This negative finding is further supported by the critical item analysis.

Critical items. An error word contained at least one writing error on a critical item wherever that item occurred, that is, even if it was misplaced or erroneously repeated.[11] No significant difference was found between experimental and control words for writing errors on

[11]None of the experimental malformed critical items were misplaced; three of the control malformed critical items were misplaced. Three experimental malformed critical items were erroneous repetitions; one control item was an erroneous repetition. All four of the latter were also erroneous repetition critical item spelling errors.

Table 7

Incidence of Writing Errors: Whole Word Level

Error words	Experimental words	Control words	Difference	*T*
Number	133	116	17	
Percentage	18.02	15.04	2.98	119[a]

[a]There were 18 subjects with positive differences and 8 subjects with negative differences.

critical items. Only slightly more than half of the subjects (14 out of 26) had more writing errors on experimental than on control words. The probability of the observed Wilcoxon T statistic (see Table 8) was greater than .05 ($z = -1.51$). The data do not support the RE in writing.

Noncritical items. The method of scoring error words was analogous to the method used for the critical item analysis of writing errors with the addition, as in the noncritical item spelling error analysis, that errors on characters representing nongiven phonemes were counted. No significant difference was found between experimental and control words. The probability of the observed Wilcoxon T statistic (see Table 9) was greater than .04 ($z = -1.17$). The maximum acceptable probability of any result had been set at .01, as indicated previously, and so the null hypothesis was not rejected.

To summarize thus far, there is no support for the RE in writing as defined in this experiment, that is, more malformed characters in experimental than in control words. The data do show the RE in spelling and show the effect, thus far, to concord with the RE as observed with digit strings, i.e., more errors on experimental than on control strings and the difference attributable to errors on critical items. Could this positive finding be due to some artifact of stimulus control such that the

Table 8

Incidence of Writing Errors: Critical Items

Error words	Experimental words	Control words	Difference	T
Number	60	52	8	
Percentage	8.13	6.74	1.39	97[a]

[a]There were 14 subjects with positive differences, 10 with negative differences, and 2 subjects with zero differences.

Table 9

Incidence of Writing Errors: Noncritical items

Error words	Experimental words	Control words	Difference	T
Number	81	74	7	
Percentage	10.98	9.60	1.38	119[a]

[a]There were 17 subjects with positive differences, 8 with negative differences, and 1 subject with a zero difference.

experimental words were actually harder to spell than the control words independently of the RE? Could it be due to a confound with pronunciation? Were subjects making spelling errors on the repeated letter words because there happened to be many acceptable pronunciations of these words and subjects spelled in accord with these pronunciations? The following four analyses together deal with these issues: (a) stimulus control, (b) word length and word frequency, (c) spelling errors as nongraphemic options, and (d) control study of the spelling difficulty of the stimulus words.

Analysis of Stimulus Control

Following the conservative strategy of the design the intent was to overcontrol the nonrepeated letter words. Ten of the 32 control words were drawn from the computer incorrectly spelled list whereas all 32 experimental words were drawn from the computer correctly spelled list, and control words with lower frequency than the experimental words were selected.

Frequency differences between experimental and control words. The mean frequencies in log units for control and experimental words were 1.0266 and 1.1746, respectively. The control words were significantly less frequent than the repeated letter words ($t(31) = 2.50$, $p < .01$, t-test for correlated means) and so were overcontrolled with respect to frequency.[12]

Computer correctly spelled versus computer incorrectly spelled control words. Subjects should have made more spelling errors on the computer incorrectly spelled words than on the computer correctly spelled words. There was no significant difference in the percentage of spelling error words across subjects between the control words the computer did not spell correctly and the control words the computer did spell correctly. (The error percentages were 27.46% and 29.98%, respectively; there were 16 subjects with positive differences and 10 subjects with negative differences; the observed Wilcoxon T statistic was 138.5, $z = -.94$, $p > .30$, two-tailed test.) Apparently, for these human subjects, the 10 words the computer found hard to spell were as hard, or as easy, as the 22 words the computer was able to spell. It may be noted that the 22 computer correctly spelled words had a lower mean log frequency than the 10 computer incorrectly spelled words therefore making them harder to spell for humans but not for a computer. (The mean log frequencies were .9969 and 1.1578, respectively.) However, the 22 words were also somewhat shorter than the subset of 10 words therefore making the 22 computer correctly spelled words easier than the subset of 10 words. (The mean number of

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[12]Frequency was expressed in log units since it is log word frequency rather than word frequency which is normally distributed (see Howes, 1967).

letters were 7.27 and 8.10, respectively.) From the data to this point it is not clear that the nonrepeated letter words were overcontrolled with respect to phonologic, i.e., phoneme-grapheme, difficulty.

For the computer, word length and word frequency were irrelevant variables. For humans they are not irrelevant variables. Word length is positively correlated with spelling errors and word frequency is negatively correlated with spelling errors. Are the magnitudes of these correlations the same for repeated and nonrepeated letter words? If length and frequency account for different proportions of spelling error variance in experimental versus control words, the issue of stimulus control might be clarified and the results pertain to mechanisms contributing to the RE.

Word Length and Word Frequency

Spelling errors at the whole word level across subjects for each experimental and control word were correlated with word length and log word frequency for the experimental and control words respectively. Multiple correlation coefficients for the repeated letter and nonrepeated letter words were obtained to assess the amount of spelling error variance accounted for by length and frequency combined, as well as to assess the contribution of each of these variables separately.

The Pearson product moment correlations of errors with length and errors with frequency were both significant for the experimental words, as Table 10 shows ($t(30) = 6.40$ and -3.20, respectively). For the control words the correlation of errors with frequency was significant ($t(30) = -6.25$) but the correlation of errors with length was not ($t(30) = 1.89$, $p > .025$). The multiple correlation coefficients were significant for both experimental and control words ($t(29) = 4.39$ and 4.11, respectively) with length and frequency accounting for two-thirds of the spelling error variance for the experimental words and 58% of the variance for the control words.

Estimates of the relative contributions of length and frequency to the total amount of error variance accounted for are presented in Table 11.[13] More than half of the spelling error variance in the repeated letter words is accounted for by variance in length, whereas the opposite is true for the nonrepeated letter words. For the control words, variance in word length contributes almost nothing to the total variance (4%), while variance in word frequency accounts for over half of the spelling error variance (54%). From these data, word length is virtually irrelevant for the spelling of nonrepeated

[13]Estimates of the relative contributions of each of the independent variables are directly obtainable when the multiple R is computed with beta weights (Guilford & Fruchter, 1973).

Table 10

Correlation Coefficients for Spelling Errors,

Word Length, and Log Word Frequency

Word type	Errors and length	Errors and log frequency	Length and log frequency	Multiple R	Multiple R^2
Experimental	.76**	− .50*	− .29	.82**	.66
Control	.33	− .75**	− .26	.76**	.58

*$p < .0025$

**$p < .0005$

Table 11

Percentage of Spelling Error Variance Accounted for by Variance in Word Length and Word Frequency

Variables	Experimental words	Control words
Length	51	4
Frequency	16	54
Total	66	58

letter words. Word frequency is not irrelevant for spelling errors in repeated letter words as shown both by the significant correlation and by the amount of error variance accounted for (16%), but it is clearly not as important a variable for these words as is length.

These results clarify the question concerning the error rates on the 22 computer correctly spelled control words versus the 10 computer incorrectly spelled control words. The subset of 10 words should have been harder to spell than the subset of 22 words but they were not. It appears, from these data, that the greater phonologic difficulty of the computer incorrectly spelled words was offset by the lower frequency of the computer correctly spelled words, so that there was no net significant error difference for these two subsets of control words. Since the 32 control words were significantly less frequent than the experimental words, and since frequency is so important a variable for the nonrepeated letter words, it would appear that the latter were indeed overcontrolled relative to the experimental words.

Control Analysis of Spelling Errors as Nongraphemic Options

The words in which the subjects made spelling errors were examined to determine whether the errors resulted in spellings that were not graphemic options for any acceptable pronunciations.

Whole word level. To be scored as a nongraphemic option error word, there had to be at least one such spelling error in the word. As Table 12 shows, there were significantly more spellings that resulted in nongraphemic options for the repeated letter words than for the control words. However, unless a similar finding obtained when only the critical items were considered the RE in spelling would remain questionable. It might still be argued that subjects were merely making spelling errors in accord with the variable pronunciation of the experimental words and that the locus of errors sometimes coincided with the locus of repeated letters.

Critical items. The words that were error words in the critical item analysis of spelling errors were examined. To be scored as a nongraphemic option error word, each experimental word had to have at least one spelling error in the set of repeated letters, and each control word had to have at least one error in the set of letters in corresponding position, such that the spelling of the word was not a graphemic option considering critical items only. That is, irrespective of the presence or absence of other spelling errors, the errors on at least one critical item had to be sufficient to result in the word not being a graphemic option. For example, the response inaagrarate was scored as a nongraphemic option error word for this analysis because of the erroneously repeated a since aa is not a graphemic option for the vowel sound between n

Table 12

Incidence of Nongraphemic Option Spelling Errors:

Whole Word Level

Error words	Experimental words	Control words	Difference	T
Number	157	114	43	
Percentage	21.27	14.78	6.49	62[a]*

[a]There were 20 subjects with positive differences and 6 subjects with negative differences.

*$p < .005$

and g in the word inaugurate. In this example, ra is also erroneously repeated, by itself being sufficient for the word to be scored as a nongraphemic option; however, in this case, it is the erroneous repetition of the noncritical item r which results in a nongraphemic option, since the a of the first ra pair is a graphemic option for the vowel between g and r in the stimulus word. Five experimental words and six control words had no errors by this analysis.

There were significantly more such spellings for repeated letter words than for the control words (see Table 13). The RE in spelling is not artifactual due to pronunciation.

Comparison of the number of error words in Tables 5 and 13 shows that for critical items when spelling errors that result in nongraphemic options are removed there is no difference between experimental and control words. There are 83 remaining words in each list that are graphemic option spelling errors. Analogously, comparison of Tables 4 and 12 shows essentially the same result at the whole word level. When spelling error words that are nongraphemic options are subtracted from all error words, there are 104 remaining experimental error words and 111 remaining control words in which the spelling errors result in graphemic options (.14% error words for each).

Noncritical items. The words that were error words

Table 13

Incidence of Nongraphemic Option Spelling Errors:

Critical Items

Error words	Experimental words	Control words	Difference	*T*
Number	109	60	49	
Percentage	14.77	7.78	6.99	27[a]*

[a]There were 23 subjects with positive differences and 3 subjects with negative differences.

*$p < .005$

in the noncritical item analysis of spelling errors were examined. There had to be at least one error on a non-critical item such that the error alone was sufficient for the word to be scored as a nongraphemic option. As in the previous analysis of spelling errors, the same word could be counted in both the critical item and noncritical item analyses if there were errors on both critical and noncritical items which met the scoring criteria. The response inaagrarate is an example.

There was no significant difference between the number of nongraphemic option error words for the experimental and control words considering only such noncritical item errors in the words (see Table 14). The probability of the observed Wilcoxon $\underline{T}$ statistic was greater than .08 ($\underline{z} = -1.38$).

Control Study of the Spelling Difficulty of the Stimulus Words

Error words were words with at least one spelling error. To enable comparison with the main experiment, corrections such that the character did not represent a spelling error were not scored as errors.

Whole word level. The average error for experimental words was about one-half of one word more than for the control words, as Table 15 shows. The difference was not significant ($\underline{t}(24) = 1.20$, $\underline{p} > .10$). Since the RE has sometimes been defined as the production of more errors

Table 14

Incidence of Nongraphemic Option Spelling Errors:

Noncritical Items

Error words	Experimental words	Control words	Difference	T
Number	97	83	14	
Percentage	13.14	10.76	2.38	121[a]

[a]There were 15 subjects with positive differences and 9 subjects with negative differences.

Table 15

Incidence of Spelling Errors in the Control Study:

Whole Word Level

Error words	Experimental words	Control words	Difference
Number	133	119	14
Mean	5.32	4.76	.56

on the repeated items or on the experimental list in general (e.g., Hinrichs et al., 1973), errors on the critical items were examined although there was no significant difference at the whole word level.

Critical items. The critical item analysis was performed similarly to the critical item analysis of spelling errors in the main experiment. As Table 16 shows, the average error for experimental words was about three-fourths of one word more than for the control words. The difference was not significant ($t(24) = 2.08$, $p > .01$). This negative finding is further supported by the following two analyses of the control study spelling errors as nongraphemic options, at the whole word level and for the critical items. Both of the following analyses were performed similarly to the comparable analyses of the main experiment.

Nongraphemic option spelling errors: Whole word level. As Table 17 shows, there were very few nongraphemic option spelling errors in the control study, and the experimental minus control difference averaged about one-fourth of a word. There were almost as many subjects that showed a negative experimental versus control difference as there were subjects that showed a positive experimental versus control difference (six and seven subjects, respectively), and 12 subjects showed no difference. A comparison of Tables 17 and 15 shows that

Table 16

Incidence of Spelling Errors in the Control Study:

Critical Items

Error words	Experimental words	Control words	Difference
Number	96	77	19
Mean	3.84	3.08	.76

Table 17

Incidence of Spelling Errors as Nongraphemic Options in the Control Study: Whole Word Level

Error words	Experimental words	Control words	Difference
Number	31	24	7
Mean	1.24	.96	.28

about 80% of the spelling errors in the control study were graphemic option errors. Out of 133 spelling error words in the experimental list, only 31 were nongraphemic option error words. Out of 119 spelling error words in the control list, 24 were nongraphemic option error words.

Nongraphemic option spelling errors: Critical items. The results from this analysis are similar to the results of the analysis of nongraphemic option spelling errors at the whole word level, as Table 18 shows. The mean experimental minus control difference was about one-third of a word. There were 16 subjects with zero differences, 6 with positive experimental versus control differences, and 3 with negative differences.

The results from the control study show that the control words were as hard to spell as the repeated letter words when the difficult experimental conditions were removed and the words were given as a spelling test. This was true both at the whole word level and when only critical items were examined. The errors tended to be "phonetic", that is graphemic option errors, both for the experimental and for the control words.

In summary, the control study and the control analyses dispel doubts that the results supporting the RE in spelling can be attributed to errors following acceptable pronunciation variation, or to the experimental words having greater spelling difficulty independently of the

Table 18

Incidence of Spelling Errors as Nongraphemic Options in the Control Study: Critical Items

Error words	Experimental words	Control words	Difference
Number	21	13	8
Mean	.84	.52	.32

RE. Moreover, the results indicate that if graphemic options alone are considered there is no RE. The RE in spelling manifests itself as nongraphemic option versions of repeated letter words.

Given that there is an RE in spelling, the natural question is: What is the nature of the spelling errors that repeated letters induce, aside from these errors being nongraphemic options? The question pertains to the RE in general. If the RE is defined by more errors in responses to stimuli containing a repetition structure than to those that do not have such a structure, what sorts of mistakes do subjects make?

Types of Spelling Errors

The set of words examined was the set of error words that had nongraphemic option critical item errors. There were four types of errors:

1. Erroneous repetitions, e.g., inaagrarate for inaugurate and bangueut for banquet.

2. Omissions with substitutions, e.g., stature for statute, and cafeful for careful.

3. Omissions without substitutions, e.g., barbous for barbarous, and bankrupty for bankruptcy.

4. Order errors, e.g., strenght for strength, and protible for portable.

The first and last categories, erroneous repetitions of critical items and order errors, were defined for this analysis as they were for the spelling error critical item analysis. The definitions of the two types of omissions were as follows. An omission with substitution occurred when a critical item was missing but replaced by another letter. An omission without substitution occurred when a critical item was missing but not replaced by another letter.

Since almost half of the experimental words had more than one pair of repeated letters, e.g., barbarous, it was possible that there were two different kinds of errors on two different critical items. In such cases, the word was counted more than once in the analysis of types of errors. For example, in the response parbeous both types of omission occur, each by itself being sufficient for the word to be scored as a nongraphemic option. The first b is replaced by p, and the second r is missing.[14] The word was counted once in the omission with substitution category, and once in the omission without substitution category. There were seven such experimental words and seven control words which were multiply scored. All of these cases involved both types of omissions.

The predominant types of errors on critical items were omissions with or without substitutions, as Table 19 shows. There were significantly more of both of these

[14]The e following b is not sufficient by itself for the word to be scored as a nongraphemic option critical item error word since barberous is a graphemic option for barbarous.

Table 19

Incidence of Various Types of Spelling Errors

Types of Errors	Experimental words	Control words	Difference	T
Erroneous repetitions	11	6	+ 5	
Omissions with substitutions	42	27	+ 15	53[a]*
Omissions without substitutions	48	20	+ 28	25[b]**
Order errors	14	16	- 2	

Note. Entries represent the number of error words.

[a]There were 16 subjects with positive differences, 6 with negative differences, and 4 subjects with zero differences.

[b]There were 21 subjects with positive differences, 2 with negative differences, and 3 subjects with zero differences.

*$p < .01$

**$p < .005$

types of errors for experimental versus control words. The experimental versus control difference was larger for omissions without substitutions than for omissions with substitutions. For omissions without substitutions there was 6.50% error for experimental words and 2.59% error for control words with a difference of 3.91%. For omissions with substitutions there was 5.69% error for experimental words and 3.50% error for control words with a difference of 2.19%.

There were relatively few of the other two types of critical item errors, as Table 19 shows. Comparing experimental and control words on erroneous repetitions and on order errors, there were 10 subjects with zero differences, 4 with negative differences, and 9 subjects with positive differences for erroneous repetitions; and 13 subjects with zero differences, 7 with negative differences, and 9 subjects with positive differences for order errors.

The only types of spelling errors which resulted in significant differences between experimental and control words were omission errors. Either a repeated letter was completely missing or it was replaced by another letter.

<u>Differential Locus of Critical Item Omission Errors</u>

Spelling error words were examined to determine whether the errors tended to be located on the second item of a pair of repeated letters rather than on the first as reported for the RE (Jahnke, 1969b). Error words were words that were nongraphemic options because of either type of omission error on critical items.

The data were analysed to be comparable to the RE studies. Two analyses were performed. In the first analysis, experimental and control words were compared with respect to the number of error words which had errors located on the first item of a pair. In the second analysis, the experimental and control words were compared for the error words which had errors on the second item of a pair.

Since about half of the experimental words had more than one pair of repeated letters, the data were scored as follows for the two analyses. Where there was one error on one repeated letter and the experimental word had one, two, or three pairs of repeated letters, the word was counted in the first analysis if the error was on the first occurrence of a letter of any pair, or the word was counted as an error word in the second analysis if the error was on the second occurrence of a letter of any pair. Where there were two or three pairs of repeated letters, and more than one pair had an error on the first occurrence of the letter of the pair, the word was counted only once in the first analysis. For example, given the word amendment, if the subject made errors on the first m, e, and/or n, the word was counted only once as an error word. Similarly, where there were two or three pairs and more than one pair had errors on the second occurrence of the letter of the pair, the word was counted only once in the second analysis, e.g., amendment (locus of errors underscored). Where there were one, two, or three pairs of repeated letters and more than one error occurred such that there was an error on the first occurrence of any letter of a pair and another error on the second occurrence of any letter of a pair, the word was counted twice, as an error word in both analyses. There were four experimental words which contained triplets: statute, unusual, and banana. As a conservative decision, the words were counted in the second analysis only when the error was on the last occurrence of the letters of the triplet. If the error was on the second or on the first occurrence, the word was counted in the first analysis. If the error was on both the first and on the second occurrence, the word was counted only once, in the first analysis. If there were errors on the last and on the second or first occurrence, the word was counted once in both analyses. The letters in the 32 control words, corresponding in position to the repeated letters, were scored similarly to the letters in the experimental words they matched.

Errors on the first occurrence of a repeated letter.

As Table 20 shows, there were more experimental words with errors on the first occurrence of a repeated letter than control words with errors on a letter in a corresponding position. The difference in the present study was not significant. The probability of the observed Wilcoxon $\underline{T}$ statistic was greater than .037 ($\underline{z}$ = -1.77).

Errors on the second occurrence of a repeated letter. There were more than twice as many experimental error words with errors on the second occurrence of a repeated letter than control words with errors on a letter in a corresponding position, as Table 21 shows. Comparison of Tables 20 and 21 show the experimental minus control difference to be larger for the second occurrence of a repeated letter than for the first, and Table 21 shows the difference to be significant for the second occurrence. The present data are in accord with observations from the RE literature concerning the size of the effect and its locus.

Analysis of Critical Item Omission Errors

Both types of nongraphemic option critical item omission errors were further analysed to answer two questions. Does erroneous repetition of other items replace correct omission of critical items as Jahnke and

Table 20

Incidence of Critical Item Omission Errors on the First Occurrence of a Repeated Letter

Error words	Experimental words	Control words	Difference	*T*
Number	30	17	13	
Percentage	4.06	2.20	1.86	57.5[a]

[a]There were 13 subjects with positive differences, 7 with negative differences, and 6 subjects with zero differences.

Table 21

Incidence of Critical Item Omission Errors on the Second Occurrence of a Repeated Letter

Error words	Experimental words	Control words	Difference	*T*
Number	64	30	34	
Percentage	8.67	3.89	4.78	24.5[a]*

[a]There were 22 subjects with positive differences, 2 with negative differences, and 2 subjects with zero differences.

*$p < .005$

Melton (1968) observed?[15] What is the fate of the remaining omissions with substitutions when there is no erroneous repetition; i.e., if the critical items are not replaced by erroneous repetition of other items, by what are they replaced? As in the previous analysis of types of errors, only the omissions of critical items which resulted in nongraphemic options were examined.

Following Jahnke and Melton, the minimum condition was that erroneous repetition of other items occurred conjointly with omissions. Erroneous repetitions did not have to be direct replacements of critical items; they could be merely concurrent with omissions. Examples of direct replacements are: curiois for the experimental word curious, and careeul for the control word careful in which the noncritical item, e, replaced the critical item, f. Examples of concurrent erroneous repetitions are: fundamen for the experimental word vitamin, and occupant for the control word opulent in which the o and the l are the critical items. Both kinds of erroneous repetitions were grouped together to enable comparison with the literature.

[15]Erroneous repetitions occurring with either type of omission of critical items are different events from erroneous repetition of critical items occurring as a type of spelling error. In the latter category of critical item spelling errors, all critical items had to be present so that erroneous repetitions were additions to word length. In this more detailed analysis of omission errors the first condition is that at least one critical item is not there.

Since the notion underlying the Jahnke and Melton investigation was that subjects may detect a repetition structure but not remember which elements to repeat and so erroneously repeat the wrong item, erroneous repetition of critical items occurring conjointly with omission of other critical items was also considered. In the present study, there was frequently more than one pair of repeated items. Subjects detecting repetition but forgetting what to repeat correctly might leave out a critical item and replace it with erroneous repetition of another critical item, e.g., amendeent for amendment, and bannna for banana. There were few such cases in the sample, six experimental words and six control words.

In the studies in which this issue concerning erroneous repetitions was examined, the tendency for the RE to be located on the second critical item rather than on the first was not taken into account (Jahnke & Melton, 1968; Jahnke, 1969b). The omission of a critical item was counted whether that omission occurred on the first or on the second critical item. For purposes of comparison with the previous experiments, an analogous procedure was followed. The locus of the omission of a critical item was not taken into consideration.

In the RE literature there is no distinction made between omissions with substitutions and omissions without substitutions. For the first level of analysis both types of omissions were grouped together.

The relation of erroneous repetitions to the RE. As Table 22 shows there were significantly more omissions for experimental than for control words when there were no erroneous repetitions. Although there were several more omissions for repeated letter words given erroneous repetitions than for control words with the same condition, the difference was not significant (9 zero differences, 12 positive, and 5 negative differences).[16] Inspection of Table 22 reveals that this result was due to the distribution of omission errors in experimental words. There were almost twice as many such errors in experimental words when there were no erroneous repetitions as when erroneous repetitions occurred (58 and 32, respectively). There were almost equal numbers of control words in both conditions (24 and 23).

According to these data, the replacement of critical items by erroneous repetition of other items is not an

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[16]Two-tailed significance tests were used when the issue of omissions and concurrent erroneous repetitions were examined because there are conflicting findings. Jahnke and Melton (1968) and Jahnke (1969b) reported more erroneous repetition of noncritical items for experimental than for control words, while Usprich et al. (Note 3) reported opposite results. For readers particularly interested in the issue of erroneous repetitions replacing correct critical item emission, and with statistical tastes different from the author, the Wilcoxon test was applied to these data resulting in an observed T of 36, $p > .05$.

Table 22

Incidence of Erroneous Repetition of Other Items Concurrent with Both Types of Omission Errors

Concurrent condition	Experimental words	Control words	Difference	*T*
Error words with erroneous repetition	32	24	8	
Percentage	4.34	3.11	1.23	
Error words without erroneous repetition	58	23	35	
Percentage	7.86	2.98	4.88	30[a]*

[a]There were 20 subjects with positive differences, 3 with negative differences, and 3 subjects with zero differences.

*$p < .002$

important mechanism in the RE. Since the support for Mechanism III of the RE is based on such evidence (Jahnke, 1969b), the present data do not support Mechanism III as contributing to the RE.

Further analyses provide additional evidence for these statements. Each kind of omission error and its relation to erroneous repetition of other items was examined. As Tables 23 and 24 show, in both cases the experimental versus control differences are greater when there are no erroneous repetitions than when erroneous repetitions occur. In fact, the difference between experimental and control words for the case of omissions without substitutions when there are no erroneous repetitions is large enough and consistent enough to be significant at the .002 level as Table 23 shows ($\underline{z} = -3.23$).

Although the data do not provide support for Mechanism III, an analysis was performed of erroneous repetition of noncritical items irrespective of concurrent omission of critical items. There were two reasons for this analysis. One reason was to complete the investigation of this issue concerning the RE. Jahnke and Melton (1968) and Jahnke (1969b) had observed more erroneous repetitions of noncritical items in experimental than in control strings in an analysis pertaining to Mechanism III but separate from the analysis concerning such erroneous repetitions concurrent with omissions of

Table 23

Incidence of Erroneous Repetition of Other Items Concurrent with Omissions without Substitutions

Concurrent condition	Experimental words	Control words	Difference	*T*
Error words with				
erroneous repetition	9	5	4	
Percentage	1.22	.65	.57	
Error words without				
erroneous repetition	39	15	24	
Percentage	5.28	1.94	3.34	27[a]*

[a]There were 19 subjects with positive differences, 3 with negative differences, and 4 subjects with zero differences.

*$p < .002$

Table 24

Incidence of Erroneous Repetition of Other Items Concurrent with Omissions with Substitutions

Concurrent condition	Experimental words	Control words	Difference
Error words with erroneous repetition	23	19	4
Percentage	3.12	2.46	.66
Error words without erroneous repetition	19	8	11
Percentage	2.57	1.04	1.53

critical items. The second reason was to enable some comparison of the present data of experimental dysgraphics to the data of Lecours' (1966) developmental dysgraphic. Erroneous repetitions of noncritical items, per se, in repeated letters constitute a type I error (Lecours, 1966).

As Table 25 shows, there were more error words with erroneous repetitions of noncritical items for the experimental than for the control words. However, 16 out of the 26 subjects did not show positive experimental versus control differences. Almost half of the subjects showed zero differences (12 subjects), 4 subjects showed negative differences, and 10 subjects showed positive differences.

Omissions with substitutions in the absence of erroneous repetition of critical items. The data were then examined to answer the second question. What is the fate of the remaining omissions with substitutions when there is no erroneous repetition?

When omissions with substitutions occur and critical items are not replaced by erroneous repetitions, they are replaced either by letters representing phonemes which are one phonological feature different from the correct critical item or noncritical item, or they are replaced by intrusions. Intrusions were defined as letters representing phonemes which have several phonological features different from correct critical or noncritical items. For example, the substitution of p for b as in parbarous

Table 25

Incidence of Erroneous Repetitions of Noncritical Items

Error words	Experimental words	Control words	Difference
Number	40	26	14
Percentage	5.42	3.37	2.05

for barbarous is a one feature difference substitution. The substitution of r for t in stature for statute constitutes a four feature difference and so was labelled an intrusion.[17]

There were seven experimental and three control words in which the substitutions represented single feature differences. In the experimental cases, five out of the seven were substitutions one feature different from the correct critical item. The remaining two cases were one feature different from a correctly written noncritical item. In the control words, two out of the three cases were substitutions one feature different from the correct critical item. In the remaining case the substitution was one feature different from the correctly written noncritical item.

There were 12 experimental words and five control words in which the substitutions were labeled intrusions. In the experimental words, eight out of the 12 intrusions were substitutions of a vowel for a vowel or substitutions of a consonant for a consonant, e.g., uniseal for unusual, and stature for statute. In only four cases were vowels and consonants interchanged, e.g., gnemy for enemy. In the control words no vowels and consonants were interchanged.

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[17]The analysis of feature differences follows Chomsky and Halle (1968). Features represent the components of phonemes depending on their manner of production by the vocal apparatus. For example, /t/ and /d/ are similar in all features except that /t/ is voiceless while /d/ is voiced. Therefore, /t/ and /d/ have one feature difference.

In all five cases, the substitutions were vowels for vowels or consonants for consonants.

Associative Intrusions

Associative intrusions occur when the items succeeding the correctly reproduced repeated items are inverted, forward intrusions, or when the items preceding the correctly reproduced repeated elements are inverted, backward intrusions. Backward intrusions were not predicted by Wickelgren (1966). However, he stated that there is no way to guarantee that the subject did not recall items in a backward direction instead of a forward direction, and so he admitted backward intrusions as part of the associative intrusion phenomenon.

Wickelgren's papers are not clear concerning the definition of these order errors for either the forward or the backward case. In his 1965 paper, he indicated that the inversion must be complete. That is, both of the items immediately succeeding the repeated items must be reversed. In the 1966 paper, he suggested that his definition of associative intrusions would be satisfied if but one of the items succeeding or preceding a correctly recalled repeated item were inverted. Although he did not use the term such events might be called partial associative intrusions. Both repeated items must still be correctly recalled.

To provide the maximum possibility of observing associative intrusions in the present study, the data were examined for both backward and forward associative intrusions, and partial as well as complete associative intrusions. Following Wickelgren (1965, 1966), the 17 experimental words with only one pair of repeated letters and their matched control words were examined. The control as well as experimental words were examined because there should be significantly more of these intrusions for the experimental than for the control words since in the latter there is no reason for their occurrence at all (Wickelgren, 1965). Spelling errors were either graphemic options or nongraphemic options, again to provide latitude for finding associative intrusions.

Across all subjects for the subset of the 17 experimental and 17 control words, there was one experimental error word and two control error words that might be considered to contain associative intrusion errors. All three error words were of the forward and partial types.

Since there were so few of this particular kind of noncritical item order error, the 17 experimental and their matched control words were re-examined to assess the occurrence of noncritical item order errors. Where order errors occur both critical items and noncritical items are usually involved. For example, in <u>vitiman</u> for <u>vitamin</u> both a critical item, <u>i</u>, and a noncritical item, <u>a</u>, are misplaced. However there were cases in which only the noncritical items were inverted, e.g., stregnth for strength. Examining the subset of experimental and control words for noncritical item order errors, there were 24 such error words found for the experimental words and 26 for the control words. Of the 24 experimental words with order errors on noncritical items, as indicated, only one word met even a loose interpretation of Wickelgren's definition of associative intrusions. These data do not support Wickelgren's findings.

Boundary Condition for the RE

A subset of experimental words and their matched control words were examined to see whether there must be at least two elements intervening between repeated items for the RE to occur, that is, whether or not there must be a separation of at least two. For comparability with the RE literature, only those experimental words with a single pair of repeated letters, and their matched control words, were analysed. There were 17 such words out of the 32 experimental words. Error words were words with spelling errors on critical items that resulted in nongraphemic options since from these data neither noncritical items nor errors that were graphemic options showed the RE.

The results, summarized in Table 26, show the data to be in agreement with the restriction on the RE. There were more experimental than control error words, and a positive difference percentage, only when there were at

Table 26

Spelling Error Percentages in Relation to Separation of Repeated Letters

Degree of separation		Experimental words			Control words			Difference
Category	No. words	Num	Den	% error	Num	Den	% error	% error
One	5	3	101	2.97	4	126	3.17	- .20
Two	5	14	108	12.96	10	112	8.93	+ 4.03
Three	6	16	146	10.96	7	145	4.83	+ 6.13
Four	1	3	26	11.54	1	25	4.00	+ 7.54

Note. Numerators are the number of error words. Denominators are the number of words in each category that were written, minus missing and substituted words.

least two intervening noncritical items, that is, for separations two, three, and four, but not for separation one.[18] Furthermore, four out of the five experimental words on which no errors were made had a separation of one when errors were nongraphemic options for critical items. By contrast with the experimental words, only one of the six control words on which no errors were made by that analysis had a separation of one.

Repetition Structure

The experimental words had several types of repetition structure. Although the experiment was not designed for this purpose, the data were examined to see if there were differences in error rates for the different repetition patterns. Error words were words with either type of omission spelling error on critical items that resulted in nongraphemic options. The repetition patterns were summarized into five types: one, two, or three pairs of repeated elements, triplets, and a triplet with a pair. The last four patterns are referred to as complex repetition patterns to contrast them with the first pattern,

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[18]Due to the small number of words in this partitioning of the data, inferential statistics could not be used for separations two and three separately, or combined. There were 15, 14, and 13 zero differences, respectively. There were in each case more positive than negative differences, 7 vs. 4, 9 vs. 3, and 11 vs. 2, respectively. It should be noted that within these separation categories the position of the repeated elements within the words varied. Further partitioning of the data to take position within separation categories into account was not feasible because of the small numbers of words.

one pair of repeated letters.

As Table 27 shows, with one exception the patterns with more than one pair of repeated letters produced the largest experimental minus control differences. The exception is the last pattern listed in the table, a triplet plus a pair, for which the experimental versus control difference was not only small but negative. There was however only one word representing this pattern, the experimental word, banana, opposed to its matched control word, arouse. This single pair of words may or may not be typical of the effect of the triplet plus pair repetition pattern. An attempt to observe a trend among different stimuli which takes into account only one example of a type of stimulus seems likely to lead to error. The data for the triplet plus pair pattern are included for the interested reader, but this pattern will not be further discussed.

The small difference for one pair of repeated items was further examined. There were some words in this category with a separation of one between repeated letters, and a separation of one had been shown not to produce the RE (see Table 26). Without these five experimental words and their matched control words, the error difference for one pair of repeated letters was 3.90% instead of 3.62%.

The mean log frequencies of the summarized repetition types were examined. If the mean log frequencies of the

Table 27

Spelling Error Percentages in Relation to Repetition Structure

Repetition Patterns			Experimental words			Control words			Difference
Type	No. words	Mean word length	Num	Den	% error	Num	Den	% error	% error
One pair	17	7.00	25	381	6.56	12	408	2.94	+ 3.62[a]
Two pair	7	8.57	21	166	12.65	10	172	5.81	+ 6.84
Three pair	4	8.75	19	98	19.39	6	95	6.32	+13.07
Triplet	3	7.00	14	67	20.90	8	72	11.11	+ 9.79
Triplet & pair	1	6.00	5	26	19.23	5	24	20.83	- 1.60

Note. Numerators are the number of error words. Denominators are the number of words in each category that were written minus missing and substituted words.

[a]When words with degree of separation one are removed, the error difference is 3.90%.

control words of the complex repetition types were greater than the mean log frequencies of the corresponding experimental words, given the differential effect of frequency on these two sets of words, the control words would have been easier and the experimental words harder suggesting that the large differences might be accounted for in part by frequency differences. In general, such was not the case. The mean log frequencies for the control words of the various types were less than for the experimental words of the corresponding types except for one pattern, two pairs of repeated letters, and in that case the difference was small. For that repetition pattern, the mean log frequency for the control words was slightly larger than the mean log frequency for the experimental words, .8451 and .8188, respectively, a difference of .0263 log units. The mean log frequency differences for the other types, in which the control words were less frequent than the experimental words, were as follows: for one pair, .1550; for three pairs, .2131; and for the triplet pattern, .5099. The frequency of the control words relative to the frequency of the experimental words does not appear to account for the greater experimental versus control error differences of the complex repetition patterns relative to a single pair of repeated letters.

To some degree word length co-varied with repetition structure, as Table 27 shows. Comparison of the mean word lengths with the percentage spelling error differences of the various repetition types suggests that word length may not account for the effect on error rate of the more complex repetition patterns. The two pair and three pair repetition types had the longest mean word lengths (8.57 and 8.75, respectively), and the corresponding error difference percentages (6.84% and 13.07%) were greater than the spelling error difference for one pair of repeated letters, as Table 27 shows. However, the mean word length of the triplet pattern, 7.00, was the same as the mean word length of one pair of repeated letters, but the error difference was larger, 9.79% for the triplets versus 3.90% for the single pairs, even when the single pairs difference was corrected for degree of separation one.

These data suggest that the RE may increase as repetition structure gets more complex and suggest a possible explanation for the observation that word length accounted for so much more of the error variance in the experimental words than in the control words. Word length and repetition structure covary, but it may be the latter, not the former, which determined the observation.

It should be noted that the five types are summarized not only across the position of the repeated letters within the word, but also across degree of separation of the repeated letters. The number of words representing each type vary considerably, as Table 27 shows. The results are at best suggestive of a relationship between repetition structure and the RE.

Lecours' Type III Spelling Error in Experimental Dysgraphia

The data were examined for the presence of Lecours' type III error, modification of letters between a pair of repeated letters (Lecours, 1966). This type of error constitutes a kind of noncritical item error, at a particular locus, in experimental words. Error words were words that were nongraphemic option misspellings because of noncritical item errors. Two experimental words were excluded from this analysis, banana and barbarous, since in these cases there were no noncritical items between repeated letters. The two matched control words were also excluded.

In each of the 30 remaining experimental words, only the noncritical items between repeated letters were examined. For example, in the experimental word, hectic, the characters representing letters intervening between the first and the second c were examined. Any characters preceding the first c or succeeding the second c, if such occurred, were not examined. Following Lecours (1966) the only error words counted were those containing deletions of a relevant noncritical item, not those with substitutions or misplacements of noncritical items. For example, the experimental words athetic for athletic and alumium for aluminum were counted, but not qunntity for quantity nor stregnth for strength. The letters in corresponding positions in the 30 matched control words were similarly analysed. There were a few cases in which critical items were also deleted. These cases were included in this analysis. There were four such experimental words and two control words.

There were very few type III errors in the present data. There were only 14 such error words for the experimental list and 10 for the control list. This count included the four experimental words (and the two control words) that also had missing critical items. Lecours may have scored such cases as type II errors, destruction of a pair, rather than as type III errors, modification of letters between repeated letters. His paper (1966) is not clear with respect to the exclusiveness of his counts in the three categories of errors. If these ambiguous words are not counted, there are 10 type III error words for the experimental list compared to 8 for the control list.

Type III errors can only occur in repeated letter words (Lecours, 1966). The small difference between the experimental and control lists suggests that at least for experimental dysgraphics the type III error is neither an important nor a systematic error.

Subjects Who Do Not Show the RE

With each significant positive finding concerning the RE in spelling there were some subjects who did not show the effect as indicated with each analysis. These subjects showed negative differences, that is, more control than experimental error words. There was only one subject in common among all negative subjects across all the positive findings. In other words, some subjects were negative for each positive finding for the group as a whole, but these negative subjects, with one exception, were not the same ones.

The exceptional subject was neither a particularly poor nor a particularly good speller in terms of the numbers of experimental and control error words. This subject made errors on both lists, but made more errors on control words relative to errors on experimental words.

CHAPTER VII

DISCUSSION

Major Findings

The major results of this study are: (a) substantiation of the RE in language sequences, specifically in spelling, (b) the finding that a consequence of the effect in spelling is not only to produce misspellings but misspellings that are bizarre, i.e., nonphonetic or more precisely nongraphemic option versions of words, (c) determination by direct analysis of the kinds of errors associated with the RE, (d) the finding that the RE does not occur in writing as tested in this study, and (e) the development of a procedure for deciphering experimentally dysgraphic writing.

The Ranschburg Effect in Spelling: Its Presence and Nature

The purpose of the study was to test for the RE in spelling and writing. The issue was defined in terms of the isomorphism of repetition effects in spelling and writing to the RE as seen in the alpha-numeric experiments. In other words, the question was how closely do repetition effects in spelling and writing resemble the referent for the RE.

Isomorphism between repetition effects in spelling and the RE. The referent for the RE was summarized as follows:

1. The RE is the production of more errors on

sequences containing repeated elements relative to control sequences containing all different elements.

2. The effect occurs primarily on the repeated elements themselves.

3. The number of errors on the nonrepeated items of the experimental sequences is not significantly different from the number of errors on corresponding items in control sequences.

4. The boundary conditions for the effect are: (a) there must be at least two nonrepeated items between the repeated elements, (b) the stimulus sequences must be drawn from a small set of items, and (c) there must be interserial as well as intraserial repetition.

5. The effect on the repeated elements themselves may be manifested by omissions, substitutions, and misplacements.

With respect to spelling, the effect of repetition of letters within words was shown to be isomorphic to the effect of repetition within alpha-numeric strings. There were significantly more error words in the experimental list than in the control list with the difference attributable to errors on the critical items, the repeated letters themselves. There was no significant difference between the number of error words of the two lists when only noncritical items were counted as errors. The data of this study are consonant with the first boundary condition that there must be at least two nonrepeated elements between repetitions for the RE to occur. Before considering the match of the present data to the remaining two boundary conditions, set size and intraserial repetition, the reasons for the statement of two conditions instead of one merit analysis. In any RE experiment there is of necessity a close relationship between these conditions.

If total set size is small and the subject is given a series of experimental strings, it follows that interserial repetition will occur. The stipulation of interserial repetition as a boundary condition distinct from set size arises from concern with the mechanisms of the RE, and in particular with the postulation of a role for proactive inhibition (see Jahnke, 1972b, 1974, Note 1). It stems from viewing the RE as a paradox for ordinary associationism "which presumes that the effect of repetition of an element is always to increase the trace strength of that element" (Jahnke, 1969b, p. 604).

The argument for interserial repetition as a separate boundary condition is as follows (see Jahnke, 1972; Jahnke, Note 10). It is reasonable to suppose that intraserial repetition does increase the trace strength of the repeated element. The RE has been observed after a few trials have taken place. The proactive effects of short-term memory are also built up within a few trials. Therefore, it is reasoned, interserial repetition produces proactive effects which overcome the natural facilitation produced by repetition. The paradox is explained in part at least. For this explanatory value, interserial repetition is viewed as a boundary condition separate from set size.

Since interserial repetition must occur when set size is relatively small in any single experiment, and since it is interserial repetition which has been singled out as aiding in the explanation of the RE, it is not entirely clear why set size is stipulated as an additional condition. Apparently, the reason is that there are some parametric data concerning the set sizes which are too large for the RE to occur. Hinrichs et al. (1973), using letters as items, did not obtain an RE with set size 24, but they did obtain a significant RE with set size 8. Jahnke (1974), using words in random sequence, obtained a significant RE only with set size 8, no difference between experimental and control critical items with set size 10, and a facilitation for the repeated items, relative to control items, with set sizes 14 and 78.

The data of Hinrichs et al. (1973) and Jahnke (1974) are best interpreted as follows. Under certain conditions, if a very large set size is used, the RE may not be found, and a facilitative (von Restorff) effect may even be observed for the repeated items. The alpha-numeric literature and logical analysis indicate that the data of these two studies do not provide actual parametric limits for the RE. While Jahnke (1974) did not find the RE with set sizes larger than eight, in the RE digit studies a significant RE had been found with the set size of digits, that is, ten items. With letters as stimuli, the RE had been found with set sizes of twelve (Crowder, 1968a; Jahnke, 1972a), thirteen (Lee, 1976), and eighteen (Crowder & Melton, 1965).

If the set size 24 is ruled out as a set size for the RE, based on the Hinrichs et al. data, it would be impossible, a priori, to consider repetition effects in spelling isomorphic to those in the alpha-numeric literature, no matter how similar they appeared to be. There are more than twenty-four letters in the English alphabet. The question of the presence of the RE in spelling must be decided on grounds other than that the possible set size exceeds the size demonstrated to show an RE in the alpha-numeric studies. The grounds are the other similarities between repetition effects in spelling and the RE as demonstrated in the alpha-numeric experiments. It may be observed however that set size 26 is small relative to the largest set sizes for which no RE has been found, 74 and 300 (Jahnke, 1974 and 1972, respectively).

The third boundary condition, interserial repetition, was clearly met in the present experiment. The letters of the alphabet were iterated interserially in the 64 sentences that the subjects wrote.

The types of errors that were stated in the RE referent as possibly associated with the effect on the repeated elements were omissions, substitutions, and misplacements. In the present experiment, the direct analysis of types of spelling errors provided the first answer to the question: Given the Ranschburg effect, what kinds of errors do subjects make? They make omissions and substitutions, but not order errors or erroneous repetitions of repeated items. There were significant differences between experimental and control words only for the first and second type of error , but not for the third or fourth type of error.

A careful reading of the alpha-numeric RE literature suggests the following. Had prior data been directly analysed for the nature of the errors, the observation would have been made earlier that omission and substitution errors are the general RE errors on repeated items.[19] As has been indicated previously, a questionable inference was the main basis for the inclusion of order errors as one of the types of RE errors. The only two studies which have any data supporting the point were by Wolf and Jahnke

[19] If free recall scoring is used, order errors could not be found. By definitiion in free recall scoring misplacements are not counted as errors. However, ordered recall scoring has been used in a number of RE studies.

(1968) and by Wickelgren (1965). Neither study provides a substantial basis for attribution of order errors to the RE. On the other hand, the use of the term "loss" in connection with explanatory mechanisms for the RE suggests that RE researchers were noticing omissions and substitutions and considering that these were the kinds of errors that required explanation, not order errors, even though they did not analyse their data directly for types of errors (e.g., Jahnke, 1969a, 1970; see also Mewaldt & Hinrichs, 1973).

Experimental conditions would alter the kinds of errors that may be found, perhaps artifactually. If subjects are strictly instructed to leave no spaces blank, there will be a tendency for fewer omissions and more substitutions. An examination of the data from a recent study is a case in point (Usprich & Balderman, Note 8). Subjects were strictly instructed to fill in all spaces on the response sheets and, moreover, they were monitored to make sure that they followed the instructions. As might be expected, inspection of the data reveals that there were no omissions. On the other hand an experiment with varying string length would be conducive to omission errors, as would experiments in which, by instruction, subjects are permitted blanks in their responses. The former experimental condition perhaps more than the latter might result in the best reflection of the nature of the RE errors.

While the lengths of some strings, such as telephone numbers, are constrained in everyday life as in laboratories, the subjects more common experience is with sequences of numbers, letters, words, etc., of varying length.

Additional similarities between the present data and those in RE studies. Although not stated as part of the referent for the RE (see Jahnke, 1969b) it is usually observed that the effect is most pronounced on the second of two repeated items[20] (Crowder & Melton, 1965; Crowder, 1968a; Harris & Jahnke, 1972; Hinrichs et al. 1973; Jahnke, 1969a, 1969b; Mewaldt & Hinrichs, 1973; Wolf & Jahnke, 1968). The present data are in agreement. There was a differential locus for repeated item omission errors. The experimental versus control difference was larger for the second item of a pair than for the first, and indeed, was found to be significant only for the second item.

The simplest interpretation of both the present and the past findings on this point is in terms of serial position effects. Most RE studies have used only a single pair of repeated elements such that the second element of a pair occurs just after the middle of the string, e.g., repeated items are in positions two and five, or three and six in a seven or eight element string. The position of the second repeated item, therefore, is in the position at

[20]The study by Malmi and Jahnke (1972) may be an exception. From inspection of the published graph, the size of the effect appears the same for each of the repeated items.

which serial position curves show the largest bow or dip regardless of whether or not the series contains repeated elements. In other words, when the stimuli strings are constructed, the second member of a pair of repeated items is placed in the most difficult serial position. In the present study, despite the varying repetition patterns, almost all of the experimental words had the second member of a pair in similarly difficult serial positions, making the experimental list overall comparable to the usual digit studies.[21] In serial position terms, it may be considered that the placement of the second member of a pair adds to the processing difficulty of the repeated item accounting for the reported observations of a differential locus. The RE is a systematic error to which the human system is vulnerable. Subjects do not always make errors, random or systematic, which is what is to be expected if they are considered as biological organisms evolved for adaptation. However, the greater the load placed upon the system, the greater the probability that errors will occur.

There are some data suggesting that explanation of the differential locus of the RE in terms of serial position effects is insufficient. Lee (1976) placed pairs of

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[21]There were four experimental words that were exceptions. These words had the second member of a pair in the first half of the word, or as the last letter. The remaining 28 experimental words fit the above description.

repeated items along the strings such that separation, or lag as she called it, was constant while serial position locus varied. Using an analysis of variance, she found a significant RE. She did not find a significant interaction between serial position and condition (experimental versus control critical items).

The present data are consistent with some of the negative findings in the alpha-numeric research concerning erroneous repetitions and associative intrusions. Erroneous repetition of noncritical items was found as an aspect of the RE in two studies (Jahnke & Melton, 1968; Jahnke, 1969b). There were two parts to this finding. The first was the observation of more erroneous repetition of noncritical items in experimental than in control strings. That observation was stated as the precondition for the second, but it was the second observation which was held to be the important one. The second finding was the association of erroneous repetition of noncritical items with the loss of a critical item so that it was argued that erroneous repetition replaces correct repetition. In a study by Usprich et al. (Note 3), using digits as stimuli, the data were analysed for erroneous repetitions. No confirmation of the Jahnke and Melton (1968) and Jahnke (1969b) results was found. An opposite result was obtained. More erroneous repetition of noncritical items was observed in control strings than in experimental strings. Further analysis showed that this was true whether none, one, or both critical items were incorrect. In a communication Jahnke (Note 6) reported that in his subsequent studies he also had been observing more erroneous repetition of noncritical items in control strings than in experimental strings. In the present study, there was no positive significant difference found between erroneous repetition of noncritical items of experimental versus control words, a result compatible with the Usprich et al. findings, and with Jahnke's later results. Moreover, there was no indication from the present data, when they were directly examined, that erroneous repetition significantly replaces correct repetition, i.e., that erroneous repetitions were concurrent with the omission of a repeated letter.[22]

Associative intrusions were reported by Wickelgren (1965) and Jahnke (1969b, citing Wickelgren's work) as part of the RE. Crowder (1968b) had expressed doubt about the relation of this kind of error to the RE. Wolf and Jahnke (1968) in the only published attempt at replication

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[22] In the only other study pertaining to the issue Lee (1976) found more erroneous repetitions of noncritical items for experimental than for control strings excluding trials on which the correct item was reported. Her results are similar to Jahnke's earlier findings. However for one of the two cases where she found a significant RE, the experimental minus control difference for erroneous repetitions was 1%. In the other case it was 6%. In neither case was the difference evaluated for chance. This was also true of one of the two Jahnke studies in which only descriptive data supported the points concerning erroneous repetitions.

other than Wickelgren's work, found no support for Wickelgren's observation. The present writer was also unable to replicate the finding in an RE study with digits (Schapiro & Usprich, Note 9). In the data of this language study there is no support for associative intrusions in relation to the RE. The RE is defined by more errors on experimental strings and particularly on critical items, the repeated elements themselves. As the present data show, those errors will be the loss of a critical item which will be either missing or replaced. The precondition for associative intrusions is that both items of a repetition pair be present in the response (Wickelgren, 1965, 1966). Both data and logical analysis indicate that associative intrusions are not part of the RE.

Complex repetition patterns, sequence length, and the RE. The role of complex repetition structure, more than one pair of repeated elements, has been relatively unexplored in the alpha-numeric studies. The only two papers of relevance are by Wickelgren (1965) and Jahnke (1969a). Both studies indicate that the RE may be found when the repetition patterns are not as simple as in the usual RE experiment.

Wickelgren's study does not permit further comment on the role of complex repetition patterns. Jahnke specifically compared the magnitude of the RE with a variable repetition structure to the magnitude of the effect with an invariant repetition structure. In the invariant repetition strings, there was only one pair of repeated elements in each string. The variable repetition strings contained two of each of the following patterns: (1) the simplest type, a single pair, (2) two pairs, (3) a triplet, and (4) a pair together with a triplet. Jahnke found no difference in the magnitude of the RE between the invariant repetition pattern, simple structure, and the variable repetition patterns, complex structures. The data of the present study are not in agreement. The data suggest, descriptively, that as repetition structure becomes more complex, the RE increases.

The design of the present study is not directly comparable to Jahnke's experiment. In his study, string length was constant, and relatively short, seven items. In the present investigation, word length was variable, between 5 and 10 letters, and covaried with repetition structure in such a manner that the more complex repetition patterns tended to be in the longest words.

The present data, in the correlation of length with errors, clearly show that sequence length is a more important variable for the experimental words than it is for the control words. Word length accounted for more than half the error variance in the former (a statistically significant result), and an insignificant portion in the latter, numerically and statistically. However, word length covaried with repetition structure, and correlational analysis does not readily permit causal inference. The question remains open. Does the RE increase with complex repetition patterns, with longer sequences, with both, or only when there is an interaction of both of these variables? Considering that Jahnke did not find errors to increase with complex repetition patterns, one interpretation of the present data is that it is sequence length, not repetition structure, which accounted for the results.

There are data that counter this interpretation. In the present study closer examination of the data suggests that word length by itself does not completely account for the observed increase of errors as repetition structure became complex, despite the covariance of word length and structure. The mean word length of the triplet pattern was the same as the mean word length for the simplest type, one pair of repeated letters. However, the experimental minus control difference was larger for the triplet pattern than for the simplest pattern as shown in the second repetition structure analysis in which only omission errors of both types were counted as errors. In the only alpha-numeric study in which length was an independent variable, a smaller RE was observed as string length increased (Mewaldt & Hinrichs, 1973). In that experiment repetition structure was constant, one pair of repeated items per string.

The present data are at best suggestive. The experiment was not designed to answer any question concerning repetition structure. One consequence was that statistical inference could not be applied to the relevant data. Moreover, there was considerable variation in the position and in the degree of separation of the repeated letters within each of the summarized repetition types. Both of these two variables, position and degree of separation, have been shown to have bearing on the RE.

The possible interpretations of descriptive data, which could not be evaluated for chance, were presented to underscore the importance of systematic examination of the variables sequence length and repetition structure. The contribution of the present data with respect to repetition patterns, sequence length, and the RE is the indication that the RE will be better understood when these variables are parametrically investigated. The experimental designs should take the position and spacing of the repeated elements into account and permit the partialing out of main effects and interactions. From the present data, it would appear that such studies would make a considerable contribution toward understanding the RE.

The result of repeated letters in spelling: Nongraphemic option misspellings. The analysis of errors as nongraphemic options was an obligatory control analysis. The finding that the effect was solely due to nongraphemic option misspellings was a surprising result with a possibly fortuitous consequence.

Graphemic option misspellings are permissible, although incorrect, renditions of the phonemes of the words. Nongraphemic option misspellings are impermissible versions of the given words. The RE was manifest only with the nongraphemic option misspellings. When only graphemic option misspellings were scored as errors, the RE disappeared. There was virtually no experimental versus control difference.

It is possible that the effect of repeated letters in spelling is to produce significantly more graphemic option errors as well as more nongraphemic option errors in experimental versus control words. The design of the present experiment did not permit acceptance of such a result even if it had been observed. The experimental and control words were controlled across both lists for spelling difficulty. The words were matched in pairs for word length and word frequency. The pairs of words were not matched for the number of graphemic option misspellings which were possible for any single pronunciation. Neither were they matched for the number of pronunciation variants. The larger the number of acceptable pronunciation variants of a word, the larger the number of possible graphemic option misspellings since for each pronunciation there are several possible graphemic option misspellings. If the RE in the present data were due solely to more graphemic option misspellings, the result would have had to be dismissed as a possible stimulus artifact.

Incidental data from the control study provide some support for the interpretation of repeated letters in spelling as producing solely nongraphemic option misspellings and not graphemic option misspellings. The main purpose of the control study was to check on whether or not the experimental and control lists were indeed matched for general spelling difficulty. It was reasoned that if the test conditions were made sufficiently simple and if the two lists were adequately matched for general spelling difficulty, then there should not be a significant experimental minus control error difference. No significant difference was found either at the whole word level or when only the critical items were examined. There was no RE in the control data. The experimental words of the main experiment were not harder than the control words in terms of general spelling difficulty. The incidental finding was that there were very few nongraphemic option misspellings in the control study and that this was true for the experimental words as well as for the control words. By contrast, in the main experiment, where the

RE was clearly present, it was manifest only in terms of nongraphemic option misspellings. These data, therefore, provide some support for the notion that the RE in spelling signifies nongraphemic option misspellings.

The analysis of types of spelling errors suggests a simple explanation for the finding that the RE in spelling means misspellings that are nongraphemic options. The type of error which appears to characterize the RE is an omission of a repeated letter. The complete absence of a grapheme to represent a phoneme within a word would, in many cases, result in that misspelled word being scored as a nongraphemic option. The possibility must be considered that the two observations, types of spelling errors and nongraphemic option misspellings, should not be treated as separate manifestations of the RE in spelling. It might be that the latter is entirely due to the former. The question is whether or not omissions of graphemes completely account for the finding that the RE misspellings are nongraphemic options.

Such a simple interpretation of the data is inadequate for two reasons. First, the words were scored as graphemic options based upon acceptable pronunciation variants as well as upon permissible graphemes for any given phoneme. Almost one-fourth of the experimental words, 7 out of 32 words, (miniature, mutual, auxiliary, ridiculous, unusual, perform, and quantity) had admissible pronunciation variants which included the omission of a phoneme such that the graphemic match for the phoneme was a repeated letter.[23] If the phoneme could be omitted and the word accepted, the omission of the corresponding repeated letter grapheme also had to be accepted. Such misspellings of experimental words were scored as graphemic options. They were not counted among the nongraphemic options. For example, mutal for mutual and unusal for unusual were scored as graphemic option misspellings. In each case the omission of the phoneme for the grapheme, u, resulted in an acceptable pronunciation of the word and the remaining graphemes were permissible for the remaining phonemes according to the Stanford study. Similarly, minature for miniature, auxilry for auxiliary, ridiclous for ridiculous, peform for perform, and quanity for quantity were all scored as graphemic option misspellings. In the present study, the complete omission of a repeated letter did not inevitably result in the word being scored as a nongraphemic option. Secondly, substitutions as well as complete omissions occurred among the nongraphemic option errors. In such cases, the replacements might have been graphemic options. However, the effect of the RE was to produce nongraphemic

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[23]By contrast with the 7 experimental words, only 1 of the 32 control words had an admissible pronunciation variant which included the omission of a phoneme corresponding to a critical item.

option replacements. There were significantly more nongraphemic option substitutions for the experimental than for the control words. Although omissions of repeated letters contributed to the result, they do not completely account for the observation that the RE misspellings were nongraphemic options.

The finding that the RE resulted in nongraphemic option errors is a result over and above the finding that the errors tended to be omissions and substitutions. It is a finding that has no analogue in the alpha-numeric literature. Such an analogue is not possible with strings in which the order of elements is random. It would only be observable in sequences in which the order of items is lawful, i.e., a priori constrained, as in language. It is an observation which adds interest to the RE above the main result that the RE occurs within language sequences, specifically spelling. With alpha-numeric strings, the subjects responses are nonsense whether they are correct or not. In the former case, they are of course correct nonsense. When the effect of repeated letters is to turn written language responses into nongraphemic options, the result means an overriding of the sense inherent in language sequences. The linguistic orderliness is fragmented as a consequence of the difficulty in processing the repetition structure of the sequences. The misspellings, making no apparent sense, appear peculiar.

Additional requirements of the demonstration of the RE in spelling. In several personal communications with the present writer, Jahnke (Note 1, Note 4, Note 5, Note 6) had stipulated three requirements of any demonstration of the RE in spelling. The first was that adequate controls be provided. Since the stimuli were language sequences, adequate controls appeared to be a particularly difficult problem. The second was that response biases or guessing habits be excluded as interpretations of positive experimental minus control word differences. The third was that the psychological mechanisms underlying repetition effects in language be shown to be the same as those underlying the RE in the alpha-numeric studies.

The first requirement, adequate controls, was simultaneously the most important and the most difficult to meet. The information about what makes some words harder to spell than others is less than optimal. The dominant concern in the present study was with such controls. The general strategy was to overcontrol when in doubt and to provide a control study and control analyses. The various results, together, indicate that the requirement was reasonably well met in this first experimental attempt to test for the RE in spelling.

The second requirement, exclusion of interpretations of the data in terms of response biases or guessing habits was met in large measure by the control analysis of errors as nongraphemic options. There were two important sources of bias in these data. First, selection of incorrect graphemic options for phonemes, particularly vowels, may be considered to be due to a guessing habit. That is, if uncertain of the correct grapheme for a phoneme, the subject might make an incorrect guess based on a likely or a possible alternate grapheme. Second, many of the words had more than one acceptable pronunciation. If, as is likely, the subjects varied in their pronunciations of the stimulus words or had been exposed to several acceptable pronunciations of a word, the errors might have been biased in the direction of such pronunciations. Both of these cases were excluded as interpretations of the data by the control analysis in which only nongraphemic options were counted as errors. In terms of spelling, i.e., phoneme to grapheme correspondences, graphemic options for phonemes may represent the most important response bias or guessing habit (see Gibson, Pick, Osser & Hammond, 1962; and Gibson, 1964). The RE in the present data cannot be explained, or explained away, in such terms.

The third requirement concerning psychological mechanisms bears several comments. In some papers the effect is interpreted in terms of output mechanisms (e.g., Crowder, 1968b), in others in terms of input mechanisms (e.g., Malmi & Jahnke, 1972), and in still others in terms of both output and input mechanisms (e.g., Hinrichs et al., 1973). In a very recent paper, the mechanism or mechanisms responsible for the effect were considered quite puzzling (see Lee, 1976). The best summary statement that can be made is that the mechanisms producing the RE are not really known.

If in this conceptual context the output-input distinction is pressed, it may be noted, as was done previously, that the published RE data support output mechanisms more clearly than they support input mechanisms. From this point of view, the present data are in accord with the literature. The data seem more compatible with an output interpretation than with an input interpretation. The experimental and control words were not new words to the subjects--as expected and as indicated by verbal reports after the experiment was completed. Yet their performance on the repeated letter words was poorer than their performance on the control words, and the errors were such that they resulted in nongraphemic options for the phonemic input.

The most important consideration is the following one. Parsimony requires the postulation of identical mechanisms for identical events. Repetition effects in spelling do not appear to be any different from repetition effects with alpha-numeric strings. Rather, both sets of effects appear to be part of the same phenomenon, the

Ranschburg phenomenon. The pattern of repetition effects in spelling found in this study is so similar to the RE in the alpha-numeric literature as to suggest that any differences that appear in future studies might be most productively viewed as local differences, that it is the similarities which are more important, and that the effect will be best understood when questions concerning mechanisms stem from viewing the RE as a much more general phenomenon than previously thought. The productive questions at present may concern the extent of the generality of the RE and a more complete description of its nature.

The Absence of the Ranschburg Effect in Handwriting

In order to be comparable to the alpha-numeric referent for the RE, the requirements for the demonstration of the RE in handwriting in the present study were made similar to those for spelling. The essential requirements were that the RE in handwriting be manifest by more handwriting errors in experimental than in control words, and that the errors occur primarily on the repeated letters themselves. If these results were not observed, further analysis to show the RE in handwriting, e.g., with respect to boundary conditions, would be precluded.

The data do not support the presence of the RE in handwriting as that presence was defined. There were numerous handwriting errors. The subjects' writing was so difficult to decipher that a special scoring method had to be devised. They were dysgraphic in terms of handwriting as well as in terms of spelling. However, there were no significant differences between the number of handwriting errors on the experimental versus the control words. This was true both at the whole word level and when only the repeated letters themselves and the letters in corresponding positions in the control words were examined.

The discovery of the types of spelling errors which characterized the RE in the present study, and which probably characterize the RE in general, provides an explanation of the results. The omission of repeated letters, the predominant type of RE spelling errors, precluded the observation of the RE in handwriting. If the repeated letter was not there, it could not be scored as malformed. With the largest source of error removed, there were no significant differences between the experimental and the control words.

The Ranschburg Effect and Dysgraphia

The term dysgraphia lacks a precise definition (see Kinsbourne & Rosenfield, 1974). In the clinical literature of neuropsychology, the word has been used to refer to the disintegration of acquired writing skills, either handwriting or spelling or both, as a consequence of a lesion. Developmental dysgraphia refers to an apparent inability to acquire these skills in the absence of a demonstrable lesion, given adequate intelligence and education.

Dysgraphia, developmental or acquired, is denoted by the production of an unusually large number of errors (e.g., Lecours, 1966).

The subjects of the main experiment were experimentally dysgraphic in terms of both handwriting and spelling. While there was no apparent pattern to their dysgraphia in handwriting, there was a pattern to their dysgraphia in spelling. The temporarily induced spelling dysgraphia in the normal subjects bears comparison to the pattern of spelling errors described for a developmental dysgraphic by Lecours (1966). The comparison is of particular interest for the following reasons. Lecours maintained that his subject's writing was not an exception but an illustration of the pattern underlying the "bizarre" misspellings of dysgraphia whether (a) it is a temporary stage in skill acquisition by school children, (b) it persists, as in developmental dysgraphia, (c) it is the result of a lesion after spelling skills have been acquired, even appearing as the last remnant of global dysphasia in adulthood, or (d) it occurs occasionally in normal adults who write when fatigued, rushed, or distracted (Lecours, 1966, pp. 221, 233, and 234).

Lecours viewed the bizarre misspellings as failures of serial order mechanisms in the sense in which Lashley posed the problem of serial order. Lecours stressed that the sequential errors were not random, but systematic.

The crucial aspect of the sequential errors was that they involved repeated letters. The systematic errors were of three types: type I, the creation of a pair; type II, the destruction of a pair; and type III, the omission of a letter or letters between a pair.

The second type of serial order error, destruction of a pair, is the RE, as Lecours observed, and it accounted for the largest proportion of his subject's sequential errors. In the experimental dysgraphia of the present study, the type II error was manifest. There was destruction of the correct repetition pattern by loss of a repeated letter, either by complete omission or by substitution.

In the report of the present results, the loss of a repeated letter was termed an omission without substitution or an omission with substitution for suggestive purposes. The use of completely different names for these two types of errors in the RE literature emphasizes, by implication, the difference between them. What may be more important is their similarity. Lecours presented an interpretation of substitution errors as a two stage process. The first stage was omission of a letter, succeeded by the second stage, addition. It is suggested, along with Lecours, that substitutions are a consequence of omissions. It is further suggested that it is the latter type of error, omission of a repeated letter, which is the key RE error.

The data do not support the notion that the type I error, as tested in this study, is of any importance in experimental dysgraphia. The case is similar for the type III error. From the present data, it is only the type II error, the RE, which is the systematic sequential error of normal adults under conditions of haste, distraction or fatigue.

It is likely that true dysgraphics, developmental or acquired, display sequential errors in an exaggerated manner compared to temporarily dysgraphic normal adults. Under the best of circumstances their writing skills are inadequate. In true dysgraphia all three types of errors might be visible. In experimental dysgraphia, only the most sizeable type of error, the RE, was visible.

The Ranschburg Effect and the Serial Order Problem

Lashley posed the problem of serial order thirty years ago.[24] He considered it to be the most important and the most neglected problem in neurophysiology. Instead of taking correct sequential behavior for granted, he raised questions about the mechanisms that account for it.

[24]The paper to which reference is usually made is "The Problem of Serial Order in Behavior" which Lashley presented at the Hixon Symposium in 1948, and which was published in 1951. There was an earlier statement of the problem in his 1937 paper "Functional Determinants of Cerebral Localization" which contained many of the ideas he later elaborated.

Viewing the subjects of psychological experiments as biological organisms, he observed that most adaptive acts require the production of a succession of movements in a particular order (Lashley, 1937). The range of actions to which he referred included such diverse events as the trotting and pacing gaits of a horse, the rat running a maze, the architect designing a building, and the woodworker sawing a board (Lashley, 1951). Although he emphasized the ubiquity of the problem, he considered language to be a prime exemplar of it.

Lashley (1951) was fully aware that his attempts at a theory of serial order did not provide an adequate explanation. In that paper, the essence of his contribution to neuropsychology was that he raised the problem, cogently argued its crucial importance for an understanding of brain and behavior, and convincingly showed that pursuit of the solution via an association model of brain organization would prove fruitless.

At present there is no adequate explanation either for the specific effect, the RE, or for the larger problem, the nature of serial ordering mechanisms. There is reason to think that further research concerning the RE may provide clues to the structure of temporal order mechanisms.

The relation of the RE to the serial order problem. Why should one think that the RE is related to the serial order problem? Neither the ubiquity of serial ordering mechanisms (which enter into virtually every activity above the level of spinal reflexes, Lashley, 1937), nor the nature of the present data, written language, is sufficient reason. There are several more pointed reasons: (a) the analysis of Lashley's illustrations of failures of serial ordering mechanisms in writing, more precisely typewriting, in relation to the present data, (b) the crucial experimental conditions in which the RE is and, conversely, is not found, and (c) the conceptualization of repetition effects and the RE in terms of the serial order problem from an association viewpoint in which the problem was admitted but Lashley's approach rejected (Wickelgren, 1969).

Lashley noted that errors in writing provided support for his idea that there were several mechanisms involved in serial order. His illustrations from his own typewriting errors are striking to anyone interested in the RE:

> These is typed t-h-s-e-s, look as l-o-k-k, ill as i-i-l....Earlier, in preparing this paper, I wrote the phrase, "maintain central activities." I typed min, omitting the a, canceled this out and started again; ama. The impulse to insert the a now dominated the order. I struck out the a and completed the phrase, only to find that I had now also dropped the a from activities. (Lashley, 1951, p. 118)

All of the errors involve repeated letters. It may be noted that not one of these errors, which are all examples of the failure of serial ordering mechanisms, are direct order errors, i.e., inversions or reversals. They all involve either the complete omission of a repeated letter or a substitution for a repeated letter. The sequence ama appears to be simply an erroneous repetition of a repeated letter but, as Lashley observed, it also was intrinsically related to an omission; the a from activities was subsequently dropped.

Lashley's illustrations include repeated letters with separations of zero and one, as well as with a separation of three (in the word maintain). As has been noted (MacNeilage, 1964), these examples are incidental observations which were not intended to be other than selective and unsystematic. They serve therefore as a source for hypotheses which can be examined in experimental studies in which the data are subject to systematic analysis. When the present data were first inspected, erroneous repetitions of repeated letters were as striking to the experimenter as they were to Lashley. In some cases they looked like written stuttering. The replacement of one repeated letter by the erroneous repetition of another, which is another way to look at several of his examples, was also noted. Although they are visually dramatic, as are reversals, and so are easily noticed, the systematic data analysis showed that these types of errors were relatively infrequent. By contrast the less noticeable types of errors, omissions of and substitutions for repeated letters, were the systematic errors.

The examples of typewriting errors suggest that sequences containing repetition produce an overload on serial ordering mechanisms. In the context of the present data, they are very suggestive of the RE as the result of that overload.

In all the RE experiments in which the effect has been observed, subjects have been instructed to produce all the items of the stimulus strings in the correct order.[25] When this requirement has not been made, the RE has not been found. In several experiments partial recall techniques were used to determine whether or not subjects detected or perceived the repeated items (Wolf & Jahnke, 1968; Jahnke, 1970; Harris & Jahnke, 1972). The subjects did not have to produce all the stimulus items of a string in their correct order. Instead they had to produce only the items the examiner asked for. Such experiments, in which the subjects were freed from the requirement of correct serial order output involving repeated items, have shown that there were no more errors on repeated items than on corresponding control items.

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[25]The response string may then have been scored by the free recall method in which order errors are ignored, but the subjects nevertheless were instructed to produce all the items in their given order.

Wickelgren (1969, see also his 1965 and 1966 papers for the data to which his 1969 paper refers) made a particular point of the relation of the RE to Lashley's serial order problem. Wickelgren's point was that Lashley was in error, that association models could and should be used to explain serially ordered behavior in preference to any nonassociative model. His RE data (Wickelgren, 1965, 1966), especially the attendant effect he discovered, associative intrusions, were presented as being explicable only by an association model of serial order. Since the RE findings could not be explained by a nonassociative model but could be explained by an associative model, the data were argued to be compelling evidence for association notions of brain organization. An incisive critique of most of Wickelgren's arguments has already been provided, showing them to be untenable on grounds unrelated to the RE (see Halwes & Jenkins, 1971). The following remarks, therefore, are addressed specifically to the evidence for an associative model from RE data.

There were three findings on which Wickelgren based his conclusions: (a) the presence of the RE when free recall scoring was used, (b) the finding that the nonrepeated items in experimental strings were facilitated relative to corresponding items in control strings, and most importantly, (c) the finding of associative intrusions (Wickelgren, 1965, 1966).

Wickelgren was curiously selective in the RE data he chose as support for an associative model. In his 1965 paper, he found the RE when the data were scored by both methods, free recall and position recall which is a form of ordered recall scoring. Nowhere does he provide an associative explanation of the RE when it is found by any form of ordered recall scoring.[26] Yet a crucial basis for his rejection of nonassociative models is that they cannot explain RE data.

The second support for Wickelgren's associative view was his finding that nonrepeated items in experimental strings were facilitated relative to corresponding items in control strings by free recall and by position recall (Wickelgren, 1965). Jahnke (1969b) noted in his review paper that little attention had been given to this result. A more descriptive statement can be made now. Wickelgren's result has not been observed in subsequent experiments. It

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[26]Wickelgren's 1965 paper had an unfortunate effect on RE research. He presented an argument to show that ordered recall scoring artifactually reduced the observed RE. The essence of the argument was as follows. Transposition errors of repeated items cannot be detected whereas transposition errors of corresponding control items are scored as errors thereby reducing the experimental minus control difference which defines the RE. The assumption that identical items can be transposed was accepted along with Wickelgren's argument in a series of later papers with the result that free recall scoring was favored. Using computer simulations and probability analyses, Usprich et al. (Note 3) showed that in the typical RE digit experiment with free recall scoring in which serial position functions are obtained, the observed RE may be completely artifactual.

has not been reported in any alpha-numeric study subsequent to the review paper. It has not been observed in the digit studies of the present writer (Usprich et al., Note 3). It does not occur in the present data nor in another recent experiment in which the RE has been found with language stimuli, within pseudo-words presented tachistoscopically (Usprich & Balderman, Note 8). Contrary to Wickelgren's result, the definition of the RE has come to include the observation that there is no significant difference between errors on nonrepeated items in experimental sequences relative to errors on corresponding items in control sequences. The RE literature does not support the statement that these nonrepeated items are facilitated.

Wickelgren asserted that the most compelling evidence for an associative model was the discovery of the effect attendant on the RE, the presence of associative intrusions (Wickelgren, 1965, 1966). As has been noted previously, in several investigations including the present study, there have been attempts to replicate this finding. The results of these attempts have been consistently negative. No data, other than Wickelgren's data, have been found to support associative intrusions as an effect of repetition.

In summary, although Wickelgren considered findings from RE studies to be crucial support for an associative view of brain organization, evaluation of the relevant RE evidence shows his conclusions to be unwarranted. In so far as an associative model of serial order rests on these RE findings, it has little foundation. In general, the RE has not been explained by association notions.[27] The present writer agrees with Wickelgren on the following point. The RE has a relation to Lashley's serial order problem.

Potential contribution of the RE to the serial order problem. The contribution of the RE to the problem of serial order lies in the precise questions that RE findings raise and not in the immediate answers that they provide. MacKay (1969) saw what he called the repeated letter effect as presenting a general problem for models of serial order, i.e., an effect that an adequate model would have to account for. The data of this study along with the alpha-numeric studies of the RE suggest that more precise statements can be made about what sort of problem the model would have to account for. For example, from the data to date it appears that errors occur when there are at least two intervening elements between repeated items and that the essential nature of the errors may be the complete omission of a repeated item.

[27]The assumption underlying the argument that ordered recall scoring artifactually reduces the RE is based on an associative model of brain organization, i.e., that each item presented has its special individual internal representation, its own neuron (Wickelgren, 1965, 1969). Since the evidence for an associative model of brain organization is not compelling, RE researchers may feel free not to beg the question of a model. Ordered recall scoring is permissible if these associative assumptions are not made.

At present, even these refinements are inadequate statements of the problem the RE presents for serial order models. They are inadequate because the phenomenology of the RE is insufficiently known. The present study contains the first direct analysis of the nature of the errors. Surely, replication of these findings is necessary.[28] An obvious further question concerns the effect of different repetition patterns. Are some more troublesome than others? The present study, together with the experiment by Usprich and Balderman (Note 8) shows that the RE occurs in language, within words, not merely in alpha-numeric strings. Wickelgren (1969) suspected that similar repetition effects would be found if skilled motor behavior were examined. What is the full extent of the generality of the RE?

It is clear that neither the mechanisms of the RE nor the extent of its contribution to the serial order problem can be understood until the full phenomenology of the effect is known. To paraphrase Luria (1973), but to preserve his heuristic point, a careful study of the nature of the effect must precede efforts to ascertain the

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[28] Jahnke (Note 5) sent unpublished data to the present writer who had raised questions about the nature of the errors. They were in summary form across subjects and trials so the present writer was not able to analyse them statistically. Descriptively, his data are in accord with the present analysis of the nature of RE errors; omissions and substitutions characterize the errors on repeated letters while order errors do not.

mechanisms in question. The potential contribution of the RE to the problem of serial order lies in its specification of questions which an acceptable model will have to answer.

Implications of the Study

The results of the present work have relevance for research in dyslexia and for experimental investigations of dysgraphia.

Dyslexia and the RE. The symptoms of dyslexia are so variable and so heterogeneous that it has been exceedingly difficult to provide a definition of the disorder in other than negative terms, as unexpected reading failure (e.g., Boder, 1973; Eisenberg, 1962; see Symmes and Rapoport, 1972, for coinage of the term unexpected reading failure). Amidst the disarray of possible signs, there is one correlate of the reading deficit which is almost always observed with children and with adults.[29] That correlate is the attendant difficulty with spelling. There is frequent observation in the literature that the spelling difficulty remains and is untractable after the dyslexia has been purportedly cured (e.g., Critchley, 1970, 1975; Lecours, 1966). The adult who can function adequately in reading is often, despite assiduous effort, unable to

[29] The major evidence for the dissociation of dysgraphia and dyslexia comes from Czechoslovakia. Kucera, Matejcek, and Langmeier (1963) reported four classifications of dyslexics. The largest part of what they called the purely hereditary class were not dysgraphic. However, the purely hereditary group had a very mild and easily treatable reading disability, and the overall proportion of dyslexia-dysorthographia versus pure dyslexia was 2:1.

write or type without excessive numbers of misspellings. The spelling, or misspelling, of dyslexics has been described as pathognomic and bizarre. Although the dysgraphia has been considered a pathognomic indicator of dyslexia (e.g., Critchley, 1970) very little is known of its nature other than that it is almost always present and that it appears strange. In the voluminous research literature on dyslexia relatively scant systematic attention has been given to the associated dysgraphia. Part of the cause may have been the absence of hypotheses concerning the kinds of systematic errors which may be present in the peculiar writing.

The data of the present study in conjunction with the data of the developmental dysgraphic and possible dyslexic, Lee Harvey Oswald (Lecours, 1966), suggest a direction for investigation. The RE in spelling was manifest only when nongraphemic option errors were examined. As Lecours observed (1966), these systematic nonphonetic errors, or more properly nongraphemic option errors, appear bizarre to the normal reader. This suggests at least a partial definition of the interesting term, bizarre, which has been applied to dyslexic spelling errors. It is the occurrence of nongraphemic option errors which appear to make no sense but which are actually systematic errors involving repeated items. It is a definition which is amenable to direct test.

In one of the few systematic studies of the spelling of dyslexic children, Boder (1973) observed that the errors and the children, could be classified into three categories, dysphonetic (i.e., nonphonetic errors), dyseidetic (i.e., phonetic errors), and mixed. The dysphonetic children formed the largest class. Apart from the classification, there was no further analysis of the dysphonetic errors. It now seems reasonable to ask the question: Do they tend to make these errors on repeated items?

There is cause to think that in a very real sense dyslexia is never cured (Usprich, 1976), although with educational therapy dyslexics can largely overcome their reading difficulty (Rawson, 1968). Among other unknown correlates the spelling problem tends to persist. Having mastered the grapheme-phoneme relations necessary to reading, and to some degree, the phoneme-grapheme relations in spelling, do these adults nevertheless tend to find the processing of repetition patterns particularly difficult?

The present writer is inclined to agree with Lecours (1966) that examination of the writing of adult dyslexics, particularly "cured" dyslexics, is likely to reveal basic morphological aspects of the syndrome; and to suspect that upon analysis it will be shown that dyslexics are particularly vulnerable to the RE. The statement requires qualification. There is increasing suspicion, and in some quarters conviction, that dyslexia is not a unitary syndrome. It is suggested, along with Boder (1973) that an approach to classification that emphasizes spelling errors may be especially fruitful. The particular relevance of the present research is in indicating that the nonphonetic errors can be further analysed, and that such analysis may reveal a large systematic error, the RE.

The consequences for reading as well as for writing would be considerable. Written language is based on a small set of symbols whose permutations and repetitions form a huge corpus of words. In reading and in writing repetition must be continually processed. If dyslexics are more vulnerable than normals when processing repetition, it would be expected that they would have difficulty with both forms of written language. The present study provided evidence of the RE in spelling. There is now evidence to support its occurrence in reading (Usprich & Balderman, Note 8). The hypothesis that the RE might be a large effect in dyslexic writing has as its corollary the hypothesis that it might account for an important portion of dyslexic reading errors, particularly in the oral reading of "cured" adults.

It is not yet clearly established which repetition patterns produce the most difficulty for normals. There is evidence that not all repetition structures produce errors, that some patterns may produce facilitation (Jahnke, 1969; Lee, 1976). It is certainly not known what patterns produce the most difficulty for dyslexics and whether the differences, if any between normals and dyslexics are quantitative or qualitative. While reporting the singularly low incidence of dyslexia in Japan, Makita (1968) speculated that differences in the structure of written language might account for the data. An examination of the patterns of repetition in written Japanese and English, as well as in other languages, might be informative.

Further study of the phenomena described by Lecours (1966) seems warranted. The data of the normals who were temporarily dysgraphic exhibited only the RE and not Lecours' other two types of errors. It may be that with a greater vulnerability to the RE, dyslexics would be prone to the other repetition effects as well. In other words, they may show in a magnified form the effects which are too small to be significant in normals.

These speculations may be based on an unfounded conception of the importance of repetition effects in connection with dyslexia. The intuitions of Lecours and the present writer may prove wrong. However these hypotheses have the virtue of being readily testable. Whether or not deficit processing of repetition plays any important role in dyslexia, or in some subcategory of dyslexia, will be evident as soon as the appropriate tests are conducted.

A method for the study of experimental dysgraphia. Dysgraphia has been most widely studied in the context of aphasia, as the result of a lesion. Analogous to the case of dyslexia, the writing disorder has been much less investigated than the speech disorder whether it is coextant with the speech deficit or, apparently, dissociated from it. There have been assiduous attempts at the classification of aphasia since Broca. The lesser interest in acquired dysgraphia is reflected by its being generally dealt with as a unit, a distinction being made only between deficit spelling and deficit spatial organization of the script or writing as a whole (see Kinsbourne & Rosenfield, 1974).

Linguistic approaches to the study of aphasia, a language disorder, have not only become common but even mandatory as the discipline of linguistics has come into increasing prominence (e.g., see Lecours, 1975). With a new interest by linguists in written language it is to be expected that the study of dysgraphia will accordingly receive an impetus.

Of what use is a method to study dysgraphia, experimentally, in normals? The answer rests upon the notion that disordered behavior is on a continuum with normal behavior (see Jenkins, Jimines-Pabon, Shaw & Sefer, 1975, on aphasia). The study of normal behavior under temporarily disruptive circumstances, i.e., experimental dysgraphia, can provide useful information to further an understanding of the disordered system. It is well known that brain insult produces behavior that is extremely variable, intraindividually, as well as interindividually (Joynt & Goldstein, 1975). Research reports concerning dysgraphia generally involve small samples. In some sense, to paraphrase Jenkins et al. (1975), the study of dysgraphia is swamped in as much noise as the system of the acquired dysgraphic. The intact organism does not show so much variability. The study of normals who are temporarily dysgraphic can furnish useful comparative data and hypotheses with which to separate the signals from the noise.

The scoring method developed for the present investigation of the RE in spelling and handwriting can be applied to other studies, with other hypotheses, concerning experimental dysgraphia. Whatever the questions, the writing must first be deciphered. For that purpose the method described in this study provides a highly reliable procedure where none previously existed.

APPENDIX A

INSTRUCTIONS TO THE RATER: GENERAL PROCEDURE

Your job requires many difficult judgments and you will be prone to make errors. Please make sure that when you work, you select an interruption free time and place, and that you avoid working when you are fatigued. When you have finished a single subject, check your work completely before you proceed to the next subject. After you have completed an entire set of data, check your work again. If during any of the check steps you alter your scoring, make sure to make the alteration one you have confidence in, i.e., alter your scoring only when you are persuaded that your initial scoring was your error.

There are two main sources of difficulty in scoring these data. Firstly, you will be prone to misread a clearly written misspelling as correct. Be on the alert to avoid making this gross error. It is essential that you do not miss such words. Secondly, in many cases making a judgment that a word is correct or incorrect depends upon your prior judgment as to whether or not what the subject did on any given letter is his way of writing that letter, i.e., his style. Since individual variation in writing the English alphabet occurs, those letter formations which occur frequently for any subject are to be considered his style. Rare formations for any given subject will appear peculiar

APPENDIX A

(continued)

and are to be judged as errors in most cases. However, what is rare for one subject may be frequent for another. Therefore it is crucial that you make every effort to understand each subject's style of writing individual letters and letters in sequence before you score his first target word. The best way to do this is to re-read the subject's experimental sample several times before you begin to score, looking for peculiarities of style and forming hypotheses about them.

When you score, avoid the stimulus error, i.e., score what the subject did and not what you think he intended. Make no assumptions about impossible events. As you do the work, you will quickly discover that subjects do surprising things. Your primary job is to determine what rule fits what the subject did and whether to judge that event as correct or as an error.

When you score, and style is at issue, if you are in doubt as to the frequency of the formation in question, you must resort to the counting rules before making a judgment.

Make every effort not to confuse confusable sets of characters. Characters which appear confusable on superficial examination of the subject's style may upon closer analysis prove to have distinguishing features or consistent forms with respect to context. That is, they may be

APPENDIX A

(continued)

distinctively and consistently formed at the beginning or end of a word or preceding or succeeding some other letter of the alphabet.

APPENDIX B

INSTRUCTIONS TO THE RATER: TRANSCRIPTION OF DATA

A separate protocol is to be made for each subject. All target words which are not scored as correct according to the rules are to be transcribed on the protocol along with the rule numbers by which the judgments are made in the following manner.

Write the number of the sentence in which the target word appears. Then print what the subject wrote, determining to your best ability what the subject did, not intended. Indicate the number and category of the rule(s) according to which the word is scored as incorrect and therefore entered on the protocol. Multiple errors within a word and within a character may occur. (A character is a written form representing a letter of the alphabet.) Indicate rule numbers in successive (left to right) order after the word, corresponding to the successive (left to right) order in which errors occur. Separate rule numbers for errors in successive characters within a word by commas, e.g., father written as fatgem should have the numbers 6,8 after the transcription. If more than one error occurs within a character, separate the rule numbers for the errors within a character by hyphens. For example, if a character is a substitution for the correct character and is also malformed, fitting category 12_h, indicate $6\text{-}12_h$. See the

APPENDIX B

(continued)

rules for further transcription details for specific categories of errors.

On the back of the protocol sheet, make notations of any characteristics of the subject's style which made judgment difficult, such as confusable sets, as well as any characteristics which appear unusual or strange in any way.

APPENDIX C

SCORING RULES

1. Score only target words, i.e., words underlined on stimulus material copy, wherever they appear in the written sentence.

2. Missing data (target word)

If the target word is completely omitted from the subject's sentence score as missing; print the target word and then bracket it following the bracket by this rule number, e.g., [abrupt] 2.

3. Incomplete target words

Definition:

Incomplete target words are unfinished target words which do not form resulting English words.

Procedure:

a) If the target word is incomplete (unfinished) and the subject has written subsequent words, part of a word, or number(s) on that writing line, score as an error using this rule number, 3.

b) If the target word is incomplete (unfinished) and the subject has not written subsequent stimulus material score as missing data (see rule 2).

c) If the target word is incomplete and there is no space at the end of that writing line, score as missing data. In other words, if it appears that the

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subject may not have been able to complete the target word because of lack of space at the end of the writing line, score as missing data (see rule 2).

4. Abbreviations

If the target word is abbreviated, score as an error using this rule number, 4.

5. Substitutions

Definition:

A substitution is another English word, e.g., small for miniscule, or another grammatical form of the same word, e.g., closed for close, which has been written in place of the target word.

Procedure:

a) If the possible substitution is grammatically correct within the portion of the sentence written, and is semantically sensible regardless of whether or not the word is spelled correctly, score as a substitution using this rule number, 5; bracket the word the subject wrote, with the symbol s, e.g., [cut] $_s$5.

b) If the possible substitution does not fulfill both of the above criteria, score as a spelling error (see rule 6) adding the subscript s, unless the word is a repetition of another word or part of a word written by the subject. In this case, score as a

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(continued)

substitution. For example:

Given: A green robe was admired by the playboy.

Response: A green play was admired by the playboy.

Score: [play]$_s$5

Response: A green rib was admired by the playboy.

Score: rib 6_s

c) If the possible substitution is so misspelled as to make its referent unclear, such that judgment about substitution cannot be made, score as a spelling error adding the subscript s, i.e., 6_s.

d) If one or more letters of a possible substitution is begun by the subject and the word is left unfinished, score as an incomplete target word adding the subscript s. Judgment cannot be made that the word is a substitution unless it is completely present. Be careful of a word begun with the letter a, which is an English article. Where this case occurs, make a judgment with respect to substitution, or incomplete target word, or missing target word.

6. Spelling errors

Definition:

A spelling error is any misspelling of the first writing of a target word such that there exists an incorrect character(s), added character(s), or missing

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(continued)

character(s). See malformed characters, category g, for exceptions.

Procedure:

British spellings are to be scored as correct, i.e., behaviour for behavior, and aluminium for aluminum. The rule number representing a spelling error, 6, is to be used once per word regardless of the number of different spelling errors. See correction rules for exceptions.

7. Capitalized words

Procedure:

a) If the target word is written with a capital letter and that letter is not corrected by the subject, score as correct, i.e., ignore such capitalization.

b) If the target word is written with a capital letter and that letter has been corrected by the subject, score as a correction.

8. Corrections

Definition:

A correction is any character, part of a character or series of characters added, deleted, or changed by the subject where changed means crossed out or written over in any way. A character is to be considered a correction if it is the initial letter of a word followed by a space, and the word is begun again. A suffix which

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(continued)

is written such that a break in continuity occurs before it, is to be considered a correction unless it is the subject's style to break the continuity of cursive writing. In that event, the suffix is not to be considered a correction. Determine style in this case by inspection of all words in the entire sample. See rule 13 for definition of break in continuity.

Procedure:

Score all corrections as errors regardless of whether or not the correction makes the result correct. Use light and dark stroke analysis to determine whether a character has been written over. In cursive writing, upstrokes will be light and downstrokes will be dark. Where the nature of the correction is indeterminate but the weight of judgment is that the character represents the correct letter, print the corrected character when transcribing the word and underscore the corrected portion using this rule number, 8. Where the nature of the correction is indeterminate but the weight of judgment is that the character represents an incorrect letter, score as a spelling error underscoring the corrected portion. Where the nature of the correction can be determined, transcribe and score the word as follows.

a) Where a correction has been made by writing

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over a character(s), if it can be determined which character the subject wrote first, print that character(s), draw a small slash line through it, then write above it the character the subject used for the correction, e.g., b$\overset{e}{\not a}$d.

b) Where the subject has made a correction by adding a character(s), print that character above the transcription writing line using a caret to signify addition, e.g., let$\overset{t}{\wedge}$er.

c) Where the subject has made a correction by crossing out, print what the subject wrote, then draw a small slash line through the crossed out portion, e.g., bad$\not e$.

d) Where the subject has begun to write the target word, crossed out a sequence of letters and begun again, transcribe and score only the first writing of the target word as the subject wrote it.

e) Where a correction occurs and it can be determined what the first writing of the word was, such that the initial writing before the correction would be scored as a spelling error, score the correction as a double error, 6-8. Such words may contain another spelling error(s). In that case, use the numeral 6, representing spelling errors, twice.

f) Where a correction occurs and it can be

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(continued)

determined what the first writing of the word was such that the initial writing before the correction does not constitute a spelling error but the correction constitutes a spelling error, score as 6-8. If the word contains another spelling error(s), use the numeral 6, representing spelling errors, twice.

g) Where a correction occurs and it can be determined what the first writing of the word was such that the initial writing before the correction does not constitute a spelling error, use this rule number, 8, e.g., father 8.

9. Idiosyncratic symbols for letters

Procedure:

a) If the subject uses a symbol consistently (100% of all occurrences) for one letter of the alphabet such that this symbol uniquely represents a letter of the alphabet, this symbol is to be scored correct for each occurrence that the letter of the alphabet that it stands for would be correct, i.e., this symbol is to be accepted as the subject's writing style. Note this idiosyncratic symbol and what its referent is on the bottom of the subject's protocol.

b) If the subject uses a symbol inconsistently (less then 100% of all occurrences), this symbol will be

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either a variable character or a confusable character (see below).

10. Variable characters

Definition:

A variable character is a character that the subject writes variably, either by using both printed and cursive forms or in a series of ways such as to form a continuum of writing forms for that letter. A variable character may or may not be a member of a confusable set (see below).

Procedure:

If the variable character is not a member of a confusable set none of the forms will have ambiguous referents. Judgment problems in the main will involve "What is it?" not "Which is it?" and then scoring as correct or malformed (see malformed character rules).

11. Confusable characters

Definition:

A confusable character is one from a set of characters, at least one of which is a variable character such that at least one is confusable with another in this set. Judgment problems in the main will involve "Which is which?" followed by scoring as correct, spelling error, or malformed.

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Procedure:

a) Contiguous confusable characters

(1) Apply the following two rules to characters representing all letters of the alphabet except to characters representing the subset of letters u, v, m, n, and w. See the malformed character category g for the procedure for scoring this subset.

(2) If there is a discriminable difference between contiguous members of a confusable set, judge each character as the letter of the alphabet each appears to represent. Then if the characters are not in the correct serial order, score as spelling error; i.e., do not invoke the 10% criterion. (See malformed character rules and counting rules for explanation of the 10% criterion.)

(3) If there is no discriminable difference between contiguous members of a confusable set, score both as malformed; i.e., do not invoke the 10% criterion.

b) Noncontiguous confusable characters

If the confusable character is not contiguous with another member of the confusable set score the character as correct or as malformed depending upon the rarity of occurrence, i.e., the subject's style. Invoke the counting rules and the 10% criterion when in doubt.

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12. Malformed characters

Definition:

A malformed character is a character representing a letter of the alphabet such that the formation does not well represent the letter and is rare for the subject, i.e., not the subject's style.

Procedure:

Score malformed characters as errors. Print the referent letter(s) and underscore such on the subject's protocol using this rule number, 12, followed by a subscript standing for the letter of the category of malformation, e.g., 12_a. Invoke the counting rules and the 10% criterion when in doubt as to the rarity of occurrence except when otherwise specified. The categories of malformed characters are as follows.

a) Non-English characters

A non-English character is a form which looks like no letter of the English alphabet.

b) Characters written much above or much below the writing line

Make a judgment based upon the subject's style. Determine style by inspection of the total experimental sample, not by counting.

c) Contaminated characters

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The character appears to represent a combination of two letters. In some cases the subject may appear to have started writing one letter and continued with another.

d) Uncrossed characters representing t

(1) When counting to determine if uncrossed t is the subject's style, if the cross line is near the t, i.e., if the cross line is present at all, count that character as a well formed t.

(2) If any character written with an upper loop, i.e., b, f, h, k, l, and sometimes d, is contiguous with t and is crossed instead of t, score both as malformed unless it is the subject's style to place the cross line for t near but not upon the character.

e) Vestigial characters

A vestigial character is one that is unusually small sized. Determine style by inspection of the entire experimental sample rather than by counting.

f) Break in continuity within a character

See rule 13 for definition of this category to apply to a single character.

g) Incomplete characters, especially incomplete characters representing m, n, u, v, and w.

Some incomplete formations of members of

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(continued)

this subset of letters may look like well formed erroneous characters, e.g., n for m. Score such characters as belonging to this category, rather than as spelling errors, as well as other characters which appear incomplete in any other way.

h) Any other malformation

13. Break in continuity

Definition:

A break in continuity is a discriminable stop in a cursively written word such that it appears that the subject has lifted his pen off the paper before continuing the word except where a stop occurs in conjunction with a correcgion.

Procedure:

a) If it is not the subject's style to break the continuity of cursive writing, score as an error using this rule number, 13, and underscore the locus. Determine style in this case by inspection of the total experimental sample, not by counting.

b) If the break in continuity occurs before a suffix, score as a correction. See rule 8.

c) If the break in continuity occurs after the letter x, score as correct. The subject may have stopped to cross the x.

APPENDIX D

COUNTING RULES AND THE TEN PERCENT CRITERION TO DETERMINE SUBJECT'S STYLE

1. Appropriate totals to examine

a) Examine only small characters, not capitalized characters. Capitalized characters are differently sized and/or formed.

b) Examine only the character in question for all cases. That is, do not assume that whatever appears to be the subject's style for one character will be his style for another character.

c) Examine contexts for any given character where context is defined as the preceding or succeeding character or space.

(1) If the character in question occurs at the beginning or end of a word, examine beginning or end occurrences to see whether the subject forms the character differently in such contexts from contexts occurring in the middle of a word. If the subject does form the character differently in either or both of such contexts, examine only those contexts when counting.

(2) If the character in question is formed distinctively when preceded by or succeeded by a given character of the alphabet, examine only formations in those contexts.

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(3) If context examination is judged as relevant in any instance and fewer than 11 such contexts appear in any sample, accept all occurrences as the subject's style.

d) When counting occurrences, do not include possible incomplete characters which occur as the last written character of any sentence if no numbers follow. The subject may not have completed the character because of the instruction "Stop." Similarly, do not count an uncrossed t or an undotted i if it occurs in such a last word.

e) When counting occurrences, do not include corrected characters unless the manner of the first writing of the relevant character is unambiguous. A correction may partially or completely obliterate the nature of the first writing of the character. Do not include the correction itself since it is not the first writing of a character and moreover reflects a discontinuity in the communicative flow.

2. Tabulation categories

a) Character formation categories

Use as many categories as are needed to represent formations of the character in question for any given subject. For example, a given subject may form the letter i in the following ways:

yielding five categories along a continuum. Another

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(continued)

subject may form the letter i in only two ways:

Make every effort to use as few categories as possible.

b) Indistinguishable categories (In categories)

(1) In_1: Judgment of the character is doubtful with respect to the character formation category in whcih it should be placed.

The character will appear to be formed in a manner intermediate between any two letter formation categories. For example, in the illustration given above where there appear to be five character formation categories, some cases will occur which appear to be intermediate between categories one and two, or two and three, etc. Use the same notation, In_1, for each such indistinguishable (intermediate) category, placing each such category between the appropriate character formation categories. For example, the above tabulation with inclusion of several In_1 categories will be:

 In_1  In_1  In_1  In_1 

Make every effort to use as few such categories as possible, and when making tabulations make every effort to place entries within character formation categories rather than in the In_1 categories.

(2) In_2: Judgment of the character is doubtful

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(continued)

with respect to some other letter of the alphabet.

Use only one such In_2 category. Place it to the left of the first character formation category on your worksheet.

3. Procedure for obtaining relevant fractions

a) Denominators (d)

d is the summation of all entries in all character formation categories plus all entries in all In_1 categories plus ½ of the entries in the In_2 category.

b) Numerators (n)

n in each case is the summation of all entries in the character formation category in question plus ½ of the entries in only the contiguous In_1 category.

c) Do not round to the nearest whole number; retain all decimals.

4. The 10% criterion and judgment of relevant fractions

a) 10% rule

(1) If $d \geq 11$ and n/d is 10% or less, judge the event as an error (malformed character), i.e., not the subject's style.

(2) If $d \geq 1$ and n/d is greater than 10% judge the event as subject's style, i.e., not as an error.

b) If $d < 11$, judge any event as subject's style, i.e., correct.

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(continued)

c) In the following events, repeat the entire counting procedure including categorizations before invoking the 10% rule:

(1) if $11 \leq d \leq 50$ and n/d = 10% $\pm$8%

(2) if $51 \leq d \leq 150$ and n/d = 10% $\pm$5%

(3) if $151 \leq d \leq 400$ and n/d = 10% $\pm$3%.

d) If $d \geq 11$ and n/d is greater than or less than the above limits in each case, i.e., depending on the size of the denominator, invoke the 10% rule wihtout repeated counting.

e) Do not round to the nearest whole number to make a judgment; retain all decimals.

APPENDIX E

MATCHED EXPERIMENTAL AND CONTROL WORDS

	Experimental Words	Control Words
1.	abundant	duration
2.	aluminum	portable
3.	amendment	franchise
4.	amiable	opulent
5.	athletic	neighbor
6.	auxiliary	duplicate
7.	banana	arouse
8.	barbarous	inoculate
9.	believe	banquet
10.	curious	destroy
11.	enemy	prove
12.	gigantic	obstacle
13.	hectic	oblige
14.	imitate	pastime
15.	inaugurate	playwright
16.	lovely	safety
17.	manual	advise
18.	miniature	signature
19.	mutual	abrupt
20.	partial	surgeon

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(continued)

21.	perform	exhaust
22.	prepare	protein
23.	publicly	category
24.	quantity	cylinder
25.	relevant	tangible
26.	repetition	profitable
27.	ridiculous	bankruptcy
28.	statute	cruelty
29.	strength	behavior
30.	unusual	careful
31.	useful	author
32.	vitamin	pertains

APPENDIX F

EXPERIMENTAL AND CONTROL WORDS IN MATCHED SENTENCES

1. An abundant rainfall is required for these crops.
2. The duration is varied for this other stimulus.
3. What aluminum cookware does is heat uniformly.
4. What a portable stove does is provide convenience.
5. To frame a good amendment is a fundamental need in our times.
6. To obtain a franchise is a familiar problem for a newcomer.
7. Ask Nina which amiable person provoked the bitter controversy.
8. Ask Lila which opulent room interested the noble visitor.
9. Ask John what athletic events to participate in.
10. Ask Peter which neighbor borrowed the lawn mower.
11. That the auxiliary engine failed distressed the astronauts.
12. That the duplicate copies weren't finished frustrated the candidate.
13. That the sculpture resembles a banana strikes John as humorous.
14. That a loud bell is needed to arouse this sleeper strikes John as odd.
15. Preventing a barbarous outcome required strenuous concentration.
16. Sending her to inoculate the children proved an error of judgment.
17. To frequently believe a known liar is an error of credibility.
18. To attend a banquet for the presumptuous upstart is annoying to everyone.

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(continued)

19. That Nona sang that curious song is apparent.

20. That John will finally destroy the calendar is sad.

21. That the defeated enemy was advancing seemed to the generals to be improbable.

22. That Adam attempted to prove the difficult theorem pleased his committee.

23. That the gigantic asterisk be noticed is incumbent on the student.

24. That the obstacle be overcome is mandatory for the athlete.

25. A hectic half hour was spent by everyone.

26. To oblige one's professor is a requirement.

27. To frequently imitate a roaring lion is a questionable accomplishment.

28. To prolong a pastime that brings no pleasure is a burdensome activity.

29. They promised Henry to quickly inaugurate a course in humorous literature.

30. They promised Mary to convince the playwright to change the last act.

31. That the lovely painting is a colossal fraud is a reverberating shock.

32. That the safety of our children is at issue is an irresistible argument.

33. They promised Bobo the instruction manual by Friday at the latest.

34. They promised Eddie to immediately advise the youngster of his rights.

35. Keeping even a miniature poodle in an apartment is impossible.

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(continued)

36. Writing a clear signature while kneeling requires perseverance.

37. That a mutual friendship was formed made them ecstatic.

38. That an abrupt conclusion was presented appalled the audience.

39. That that partial judge sat on the bench yesterday is an outrage.

40. That that surgeon performed the surgery surprised the interns.

41. Ask Lola what to perform on the xylophone.

42. Ask Dad what an exhaust does to a vacuum.

43. To expeditiously prepare an extemporaneous speech is a contradiction.

44. To synthesize a new protein is a triumph of scientific enterprise.

45. To loudly and publicly denounce one's opponent is appropriate in that circle.

46. To complete that category of courses is necessary before proceeding.

47. How great a quantity of oxygen was consumed during the strenuous walk?

48. How large a cylinder was needed to contain the volume of alcohol used?

49. A request for relevant judgments confuses the average undergraduate.

50. The need for tangible results causes ill prepared scientific programs.

51. That the repetition didn't improve memory was a serious sign.

52. That the profitable business failed aroused community concern.

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(continued)

53. That the ridiculous proposal received unanimous approval seems whimsical.

54. That the bankruptcy prevented their continuing operations was to be expected.

55. A formal law or statute to prevent pillage prompted a skeptical remark.

56. An annoyance or cruelty suffered by a child triggered his retaliation.

57. That extraordinary strength in this material is necessary is obvious.

58. That the study of behavior is irresistible to psychologists is clear.

59. What the unusual occurrence did was embarrass the viewer.

60. What a careful appraisal will disclose is that this is an imitation.

61. What is useful to the housewife is a colander.

62. What the author needs is a portable typewriter.

63. That that new vitamin is a dietary need is obvious.

64. That that rhyme pertains to Greek prosody is clear.

APPENDIX G

INSTRUCTIONS FOR THE EXPERIMENT

This is a study of the way people write English and numbers. Your name is needed only for a possible future psycholinguistic study in which you may be asked to participate. Your score on this study will be kept confidential and will be known only to the experimenter whose voice you hear on the tape.

You will hear me say "Ready" and then you will hear me say a sentence. When I have finished saying each sentence, I will say a number. You are to write the sentence as quickly as you can, then the number, and as many numbers backwards as you can until I say "Stop." For example, I might say: "The boy went to the store to buy a lemon meringue pie.16" Write the sentence as quickly as you can then the numbers 16, 15, 14, 13, and so on until I say "Stop." As soon as you hear the word "Stop.", stop writing and get ready for the next sentence. If you reach the number zero on any trial, write as many zeros as you can, until I say "Stop." Do not place commas between your numbers. Continue writing them along the line as you would if you were writing words in a sentence, using as many lines as you need. You are to begin writing as soon as you hear me say the first word so that for a while, you will be writing while I am speaking.

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Write the sentences as correctly in every way as you can. Take care to write as legibly and clearly as possible. In general, try to make each letter look like the written letter of the alphabet you intend it to be. Do not print or abbreviate. Use cursive writing. Use a pen if you have one that writes clearly. If not, you may use a pencil. The examiner has extra pencils.

Do not go back to cross out, rewrite, or in any way correct any word, letter or number you have written. Once you start writing, write as continuously, without stopping, as you can. If you feel that any part of what you have written is wrong, try to make the next part as correct as you can. Remember, it is important that you write as quickly as you can so that you complete the sentences, get to the numbers, and write as many numbers as possible.

If you forget any part of a sentence, try to remember any word within that part, even if it appears out of context. If you can not remember, go on to write the numbers.

You are to start each sentence on a new line. Do not skip any lines. Continue writing down the page until I tell you to stop and to go on to the next page. Write on only one side of each page. As soon as I tell you to go on to the next page, do so, no matter how much space you may have left. Many of you will have space left. A few of you

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(continued)

will not have enough room. If you have used up all the lines on the page before I tell you to go on to the next page, use the bottom margin. Try not to write past the right hand margin.

We will have a number of practice sentences, after which you may ask questions. Once we begin, after practice you may not ask questions.

Remember, turn the page as quickly as you can when I say "Next page, please." You will have only a few seconds before you hear the next sentence on the tape. Please avoid rustling papers as much as possible.

Are there any questions now?

APPENDIX H

INSTRUCTIONS FOR THE CONTROL STUDY

This is a normative study of the spelling of college students. Your name is needed only for a possible future psycholinguistic study in which you may be asked to participate. Your score on this study will be kept confidential and will be known only to the experimenter whose voice you hear on the tape.

You are to write as clearly and correctly as you can. Do not go back over what you have written. Do not print. It is important that you use cursive writing. Do not capitalize any word. Use a pen if you have one that writes clearly. If not, you may use a pencil. The examiner has extra pencils.

You will have three practice words. After the practice period, once we begin, you may not ask questions.

You will hear the word spoken once. Then you will hear a sentence containing the word, after which you will hear the word spoken again. Do not write until you hear the word a second time. You are to write only a word each time, not the sentence.

Are there any questions?

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