The repeated letter effect in the misspellings of dysgraphics and normals¹

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The study consisted of a comparison of the spontaneous misspellings of a dysgraphic (L. H. Oswald) with the ease of perception and recall of similar misspellings by normal Ss. The main results were as follows: (1) Oswald frequently misspelled repeated letters in words (e.g., ELDERY). Similarly, normal Ss found repeated-letter misspellings more difficult to perceive and recall than nonrepeated-letter misspellings. (2) Oswald frequently misspelled repeated letters which were close together as in ANLYZE (for ANALYZE), but he rarely misspelled widely separated repeated letters as in MISPELLNG. Similarly, normal Ss found repeated-letter misspellings hardest to perceive and recall when the repeated letters were close together, and very easy when they were widely separated. (3) Oswald misspelled the second of two repeated letters (as in ELDERY) more frequently than the first (as in EDERLY). Similarly, normal Ss found repeated-letter misspellings easier to perceive and recall when the first of the repeated letters was misspelled, as in EDERLY, than when the second was misspelled. (4) Oswald sometimes repeated a letter on his own, as in HABITUATED—but more frequently he dropped a repeated letter as in ELDERY. However, repeated-letter misspellings involving deleted letters were easier for the normal Ss to recall than those involving deletions. Evidence suggesting that repeated phonemes induce analogous errors in normal speech production was discussed, and implications for general models of the serial order of speech behavior were pointed out.

Lecours (1966) discovered a "repeated letter effect" in the spontaneous misspellings in the diary of L. H. Oswald (1964), whom he classified as dysgraphic (someone who chronically misspells simple words due to cerebral lesion or developmental deficit). In our first study we were interested in examining Oswald's misspellings further in order to determine whether the repeated letters were usually close together as in the misspelling COPERATION or far apart as in MISPELLNG. In our second study, we were interested in determining the ability of normal Ss to perceive and recall misspellings. The main question which motivated this study was whether normal individuals find repeated-letter misspellings difficult to perceive and recall. If this were the case, repeated letters might be considered a general problem for models of the serial order speech. In particular we were interested in whether repeated-letter misspellings could be viewed as support for a chain association theory as claimed in Wickelgren (in press).

STUDY 1: A REANALYSIS OF THE REPEATED-LETTER MISSPELLINGS OF L. H. OSWALD

The Nature of the Repeated-Letter Errors

Usually Oswald would drop a repeated letter in a word as in ELDERY, but he would sometimes add a repeated letter of his own as in HABITUATED and DECEMBER. We were interested in whether repeated letters were more frequently dropped or added. The misspellings analyzed involved repeated letters within a single word.

About 64% of these repeated-letter misspellings were deletions and 36% were additions. This difference was significant at the .01 level, using a chi-square test, confirming that the greater tendency was to drop repeated letters rather than add them (after Lecours, 1966).

Order Effects

Sometimes Oswald dropped the first of two repeated letters as in SATUE for statue, and sometimes the second as in LETTR. Similarly, repeated letters were added either before or after the original letter in the word. We were interested in which type of repeated-letter misspelling was more common: those involving the first of the repeated letters or those involving the second. About 32% of Oswald's repeated-letter misspellings were found to involve the first letter and 68% the second. This difference was significant at the .02 level using a chi-square test (1 by 2 contingency table).³

Thus, the second of two repeated letters tended to be misspelled much more frequently than the first, demonstrating an order effect in Oswald's repeated-letter misspellings.

The Degree of Separation of the Repeated Letters

We next asked whether the repeated-letter deletions in Oswald's misspellings were usually close together as in MISPELLING or widely separated as in MISPELLNG. For this purpose, 62 words, each containing one repeated-letter deletion, were obtained from Oswald's diary and the number of letters separating the repeated letters were counted. For example, the repeated-letter error in COPERATION would be designated Separation 0 since no letters separated the repeated letters, that in ANLYZE, Separation 1, and so on.

The frequency of repeated-letter deletions of various degrees of separation was calculated and is shown in Table 1. Oswald dropped a repeated letter most frequently when one letter separated the repeated letters and less frequently as more and more letters separated the repeated letters.

Our next question was whether the above result was a statistical artifact (reflecting the frequency of repeated letters in the language and specifically Oswald's language). We did this by calculating the frequency of repeated letters in a sample of Oswald's diary (with errors in spelling corrected). From this sample (about 8% of the diary) we estimated the frequency of repeated letters of various degrees of separation in the entire diary (see Table 1). This allowed us to calculate the probability of correctly spelling a repeated-letter sequence as shown in Table 1. As can be seen in Fig. 1, the probability of correct spelling was least with Separation 1 and greatest with Separation 6. Thus, the degree of separation phenomenon in

Table 1
The frequency of repeated letter Deletions of various degrees of separation in L. H. Oswald's (1964) diary, along with the frequency of repetition of letters in the diary, and the probability of correct spelling (the frequency of misspelling divided by the frequency of repeated letters in the corpus).

Degree of Separation of Repeated Letters	Frequency of Misspelling	Frequency of Repetition of Letters in Corpus	Probability of Correct Spelling
0	8	96	.92
1	20	84	.76
2	13	108	.88
3	8	108	.93
4	5	84	.94
5	4	60	.93
6	2	72	.97
7	2	60	.97

Fig. 1. The probability of correct spelling in L. H. Oswald's (1964) diary, as a function of the degree of separation between repeated letters (e.g., the error ELDERY would be scored as Separation 3 since three other letters separated the repeated letters).

Table 1 was not due to the structure of the spelling of the words that Oswald used.

Discussion

Recently, Wickelgren (in press) claimed that the repeated-letter misspellings of dysgraphics support a chain association theory of speech production. In Wickelgren's chain association models, one phoneme in a word is joined to the next by an associative bond, and each phoneme has one and only one internal representation. Thus, repeated phonemes in a word present difficulties since several bonds lead from a repeated phoneme. Consider the representation of the word ABRACADABRA in Wickelgren's context-free model,⁴ shown in Fig. 2. Since four associative bonds lead from the repeated A, the wrong one might be activated, giving ABRADACABRA or ADACABRABRA. That is, letters following the repeated letter would be frequently inverted according to this model.

However, our data do not support this view. In no case did Oswald invert the letters following repeated letters as would be expected in Wickelgren's model.

Moreover, repeated letters have several bonds leading to them in chain association theories, unlike nonrepeated letters which have only one (see Fig. 2). We would thus expect that these multiply determined repeated letters would be least frequently omitted, if associative bonds were a major determinant of errors in spelling. However, it was the repeated letters rather than the nonrepeated letters which were most frequently misspelled. Eighty-one per cent of Oswald's misspellings involved repeated letters, as compared to only 19% involving nonrepeated letters.

Clearly, serious revision of chain association models is necessary if they are to explain spontaneous errors in spelling.

STUDY 2:

THE PERCEPTION AND RECALL OF MISSPELLINGS

When cerebral injury or developmental deficit cannot be demonstrated, dysgraphics are operationally distinguished from normal individuals by the frequency with which they

misspell simple words. Another criterion of dysgraphia is that the misspellings cannot be attributed to educational or learning deficits (Lecours, 1966).

In our second study we wished to determine whether normal spellers would have difficulty in perceiving and recalling experimentally constructed misspellings, which were similar to those which Oswald produced most frequently.

Our plan was to have college Ss rapidly read sentences containing misspellings involving repeated and nonrepeated letters. They would then indicate the words in which they perceived a misspelling and attempt to recall how the word was misspelled. If repeated letters have similar effects on both the spontaneous misspellings of dysgraphics and the perception and recall of misspellings by normals, the repeated letter phenomenon could be extended to a general problem in the series order of behavior.

Materials

Thirty sentences, typed on index cards made up the materials. Each sentence contained four misspellings. Two of these were repeated-letter misspellings and two were not. The two types of misspellings occurred equally often in various positions in words. The words involving repeated- and nonrepeated-letter misspellings were balanced for length and frequency (Thorndike-Lorge, 1959). None of the misspellings resulted in a new word as would be the case if POT were misspelled as PIT, PAT, PUT, or PET. The order of the two types of misspelling was counterbalanced within the 30 sentences and the sentences were shuffled for each S.

Subjects and Instructions

Eleven students at M.I.T. were paid for their participation in the 1-h experiment. Each S was instructed as follows:

"The purpose of this study is to see how easy it is to perceive and recall different types of misspellings in sentences. Your task is as follows: Flip over the card when I give you this signal (a pencil tap on the table) and read the sentence as fast as you can until told to stop. Then slip the card over and write down the sentence exactly as it was spelled, guessing at misspellings if necessary. You will then be shown the card again and asked whether or not you noticed each misspelling when reading the sentence."

Practice Trials

Each S was given three practice sentences: the first for 9 sec, the second for 7 sec, and the third for 5 sec. The presentation time was measured by stop watch. The purpose of varying the presentation times for the practice sentences was to find an interval long enough for the S to finish reading the sentence but not so long as to enable him to recall more than half of the misspellings. That particular presentation time was then maintained throughout the experiment. This procedure ensured that different Ss did not recall either all or none of the errors, which would defeat the purpose of the present experiment.

Fig. 2. The chain association representation of ABRACADABRA, after Wickelgren (in press). The associative links are represented by arrows.

Table 2

A comparison of the frequency of errors in perception and recall of repeated and nonrepeated-letter misspellings. The possible frequency in Perception represents the number of misspellings in the sentences multiplied by 11—the number of trials. Trials on which an S failed to detect a misspelling were not counted in the possible frequency of Recall

Frequency of Errors In		Repeated-Letter Misspellings	Nonrepeated-Letter Misspellings
Perception	Data	34	14
	Possible	610	610
Recall	Data	311	263
	Possible	576	596

Results

The repeated-letter effect. The number of errors in perceiving the two types of misspellings is shown in Table 2. The repeated-letter misspellings such as ELDERY were harder to perceive than the nonrepeated-letter misspellings such as ELDELY. More errors in perceiving repeated- than nonrepeated-letter misspellings were found, a difference significant at the .05 level (chi-square test).

Most of the Ss reported rehearsing the sound of the misspelled words to themselves while writing out the sentences. Failures to perceive a misspelling were not counted as errors in recall. The number of errors in recalling repeated- and nonrepeated-letter misspellings is shown in Table 2. Misspellings that involved repeated letters were more difficult to recall than those that did not. More errors in recall were found for repeated- than nonrepeated-letter misspellings, a difference significant at the .01 level, chi-square test. For some reason, repeated-letter misspellings were difficult for normal Ss to perceive and recall, and easy for Oswald to produce.

The degree-of-separation effect. The probability of detecting repeated-letter misspellings is shown as a function of the degree of separation of the repeated letters with the broken

line in Fig. 3. When 0 to 3 letters separated the repeated letters, the probability of detecting a misspelling was about .92, but with more than three letters separating the repeated letters, the probability of detecting the error was almost 1.0 (see Fig. 3).

The probability of detecting nonrepeated-letter misspellings was about .98, and is represented by the solid line in Fig. 3.

The repeated-letter misspellings were more difficult to recall when one or two letters separated the repeated letters. But when four or five letters separated the repeated letters, the repeated-letter misspellings were easier to recall than those not involving repeated letters (see Fig. 4).

Thus, the ability to perceive and recall repeated-letter misspellings varied as a function of the number of letters separating the repeated letters. Moreover, the functions for perception and recall were independent since trials on which a misspelling passed undetected were not included in the mean probability of recall. That these degree-of-separation functions

Fig. 4. The probability of recall of repeated-letter misspellings as a function of the degree of separation of the repeated letters for a group of M.I.T. undergraduates.

are similar in shape to that for Oswald can be readily seen by comparison with Fig. 1.

The nature of repeated letter misspellings. There were two basic types of repeated-letter misspellings planted in the sentences. For half of the misspellings a letter was added to form a repeated-letter sequence, as in ELDERDLY. For the other half of the misspellings, a repeated letter was omitted, as in ELDERLY.

The number of errors in perceiving these two types of repeated-letter misspellings is shown in Table 3. Errors in perceiving deletions were as frequent as errors in perceiving additions.

As before, failures to perceive a misspelling were not counted in the recall analysis. The number of errors in recall are shown in Table 3. Deletions of repeated letters, as in ELDERY, were easier to remember than additions, as in ELDERLY. About 60% of the errors in recall were additions, and 40% were deletions. This difference was significant at the .05 level, using a chi-square test.

Fig. 3. The probability of correct perception of repeated-letter misspellings as a function of the degree of separation between the repeated letters for a group of M.I.T. undergraduates.

Table 3
The frequency of errors in the perception and recall of two types of repeated letter misspellings.

Frequency of Errors In		Additions	Deletions
Perception	Data	17	17
	Possible	305	305
Recall	Data	189	122
	Possible	288	288

These findings contrast with the dysgraphic data, where more repeated-letter deletions than additions occurred.

Order effects. To simulate Oswald's misspellings, half of the repeated-letter misspellings involved the first of the pair of repeated letters as in EDERLY.

The number of failures to detect these two types of repeated-letter misspellings is shown in Table 4. An order effect was found. Misspellings involving the first of the repeated letters were perceived more frequently than those involving the second (see Table 4). About 38% of the failures to detect a repeated-letter misspelling were of the first type, and 62% of the second. However, this difference missed significance at the .05 level using a 2 by 2 contingency chi-square test.

The errors in recalling these two types of repeated-letter misspellings are also shown in Table 4. Again, trials on which the S failed to detect an error were not counted as errors in recall. The difference in recall for errors involving the first and second of the repeated letters was not statistically significant (chi-square, .05 level). But when a separate analysis of additions was carried out, the order effect was more pronounced. Misspellings involving the first of the repeated letters in additions, such as ELDRELY, were easier to recall than those involving the second, as in ELDERDLY (see Table 4). However, this difference just missed significance at the .05 level using a chi-square test.

Discussion

The main purpose of the study was to compare the parameters in the perception and recall of spelling errors with those in the spontaneous production of misspellings by dysgraphics. Three of these parameters turned out to be similar: (1) Repeated-letter misspellings were more frequently produced and harder to perceive and recall than nonrepeated-letter misspellings. (2) Spontaneous misspellings frequently involved repeated letters which were close together rather than far apart. Similarly, perception and recall of repeated-letter misspellings was more difficult when the repeated letters were close together than far apart. (3) Errors involving the second of two repeated letters, as in ELDERY, were more frequently produced by the dysgraphic and harder to perceive and recall

Table 4
The frequency of errors in perception and recall of two types of repeated letter misspellings—those involving the first letter, and those involving the second. Misspellings with immediately repeated letters as in COOPERATION were not included in this analysis.

Frequency of Errors In		First Letter	Second Letter
Perception	Data	16	26
	Possible	251	251
Recall	Data	146	165
	Possible	235	225
Recall	Deletions	63	59
	Additions	83	106

by the normal Ss than those involving the first of the repeated letters, as in EDERLY.

One major difference between the dysgraphics and normals was found. The dysgraphic tended to delete repeated letters more frequently than he produced them. However, the normal Ss were able to recall repeated-letter additions better than repeated-letter deletions. Conceivably this finding may reflect a basic difference in the production and recall processes.

Another question was whether repeated phonemes constitute a problem in normal speech production. The difficulty in rapidly producing sentences such as (1) suggests that this is the case.

(1) Peter Piper picked a peck of pickled peppers.

However, further research is needed to determine the exact nature of this difficulty. Nonetheless, there is some evidence that repeated phonemes present a problem in natural speech production. Merringer and Meyer (1895) showed that errors in natural speech frequently involved repeated phonemes. Often a repeated letter would be dropped. For example, an individual attempting to say *Im Institut* (German for "in the institute") came out with *Im Stitut*, dropping the repeated I. Another said *Instut* for *Institut*, leaving out the repeated I and T. And sometimes repeated letters were added and substituted as when *klassische Sachen* came out as *klassische Schachen*.

There is even some evidence that repeated phonemes play a role in other "higher order" errors in speech. For example, Merringer and Meyer (1895) reported synonymic errors which sometimes involved repeated phonemes. For example, an individual attempting to say (2) came out with (4) instead, where (3) is clearly playing a role in the error.

(2) *Ich auch* (me too)

(3) *Wi miteinander* (we're together)

(4) *Ich miteinander* (me together)

Such errors are also common in English. For example, the author observed the following error:

(5) He is totally responsible.

On subsequent questioning, the individual explained his error as a fusion of (6) and (7), his intended output at the semantic level.

(6) He is totally responsible.

(7) He is solely responsible.

Here the errors are clearly a combination of synonyms, but one cannot help but wonder, as did Lecours (1966), whether the repeated phonemes (the ch's in *ich auch*, the t's in "totally" and the l's in "solely") did not also contribute to the errors. Such multiple determination of behavior is a well-established phenomenon in other areas of psychology [see the law of heterogeneous summation in Tinbergen (1951) and MacKay (1968) for a general model of heterogeneous effects on errors in speech production].

In any case, the repeated-letter effect may reflect a general property of nervous action, such as postexcitatory inhibition upon generation of a phoneme or letter, followed by postinhibitory rebound or facilitation [see Bullock (1965) for details on the generality of this process]. This inhibitory tendency following the production of graphemes may be exaggerated in dysgraphics, contributing to the inordinate occurrence of repeated-letter misspelling. This hypothesis fits other details of the repeated-letter effect, such as the degree of separation between the repeated letters, the unusually low probability of spontaneous errors and errors in perception and recall for widely separated repeated letters, and the order effects discussed above.

The hypothesis is also consistent with the difference between the production and recall of repeated-letter deletions.

When a dysgraphic attempts to spell ELDERLY, the model predicts the ELDERY-error tendency (QED). And when normal Ss rehearse and attempt to recall an added letter as in ELDERDLY, the added letter would be dropped for the same

reason. However, deletions as in ELDERY would be easily remembered because of a tendency to omit the repeated L anyway. Consequently, the model would explain the ease in recall of deletions (QED).

However, the mechanism for perception of repeated-letter deletions and additions necessitates a different prediction. If, as suggested in the model, a repeated letter in a word is not perceived at a given rate of reading, then omission of that letter would pass undetected.

Similarly, an added letter as in ELDERDLY would pass undetected because of the assumed inhibitory tendency. Consequently, no difference would be expected in the perception of repeated-letter additions and deletions, as was found.

Of course, there are other mechanisms in the perception and recall of spelling errors in general (see MacKay, 1968) and repeated-letter spelling errors in particular. For example, a wide-band scanning mechanism as proposed by Lashley (1951) might be required to explain the fact that misspellings involving the first of two repeated letters (as in ELDERLY) were more difficult to recall than misspellings not involving repeated letters (e.g., ELDELY). Further research on this question is needed.

The most obvious prediction from this model of the repeated-item effect concerns the pattern of phoneme repetition in the structure of languages. If immediate repetition of phonemes is difficult for general neurophysiological reasons, then the structure of languages should evolve so that immediate repetitions of phonemes is rare. Similarly, if phoneme repetition after some interval is extremely easy, then repetition of phonemes after a corresponding degree of separation should be highly likely in the structure of languages. This hypothesis was examined in detail in MacKay (forthcoming) with results supporting the "recovery cycle" hypothesis proposed above. Phoneme repetition was also shown to be a factor in evolutionary changes in the history of languages (e.g., the change from *stipendium* to *stipendium* in the history of Latin). Finally, neurophysiological evidence was discussed which directly supported the recovery cycle principle for the production of speech (see MacKay, forthcoming).

SUMMARY

The main purpose of this experiment was to compare the spontaneously produced misspellings of a developmental dysgraphic (L. H. Oswald) with the ease of perceiving and recalling these misspellings by normals.

Study 1, an examination of Oswald's 1964 diary, showed the significance of the following parameters in his misspellings: (1) Repeated letters: Oswald frequently misspelled repeated letters in words, as in ELDERY. (2) The nature of the repeated-letter misspellings: Oswald sometimes repeated a letter on his own, as in HABITITUATED, but more frequently he left out a repeated letter, as in ELDERY. (3) Order effects: Oswald more frequently misspelled the second of two repeated letters, as in ELDERY, than the first, as in EDERLY. (4) Separation of the repeated letters: Oswald frequently misspelled repeated letters which were close together, as in ANLYZE (for ANALYZE), but he rarely misspelled widely separated repeated letters, as in MISSPELLNG.

In Study 2, in order to determine whether similar parameters were important in the perception and recall of spelling errors, normal Ss rapidly read sentences containing

spelling errors and later attempted to recall the misspelled words. The results of this study were as follows: (1) Repeated letters: Misspellings involving repeated letters were more difficult for normal Ss to perceive and recall. (2) The nature of the repeated-letter misspellings: No difference was found in the perception of repeated-letter deletions such as ELDERY and additions such as HABITITUATED. But the repeated-letter deletions were easier to recall than the additions. (3) Order effects: Misspellings involving the second of two repeated letters were more difficult to perceive and recall than those involving the first. (4) Separation of the repeated letters: Perception and recall of misspellings was most difficult when the repeated letters were close together and easiest when they were far apart.

Evidence that repeated phonemes present a similar problem in normal speech production was discussed, and implications for general models of the serial order of behavior were pointed out. The hypothesis was advanced that repeated letters present a problem in the perception and recall of spelling errors because of an inhibitory process following the internal generation of speech units. It was suggested that this process may be exaggerated in dysgraphics, contributing to their frequent errors in spelling.

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NOTES

1. This work was supported by UCLA Grant 2428, NASA Grant NsG 496, and M.I.T. intramural research fellowship, and a grant from John A. Hartford Foundation to Dr. H. L. Teuber. The author wishes to thank Dr. H. L. Teuber, Dr. J. Fodor, Dr. M. Garrett, and Dr. T. Bever for their excellent suggestions, and Dr. A. R. Lecours for inspiring the study.
2. Address: Department of Psychology, University of California, Los Angeles, Calif. 90024.
3. A 2 by 2 contingency table might have provided a more appropriate statistic here but was not carried out because of the difficulty in determining the total N for the dysgraphic data.
4. Wickelgren's context-dependent chain-association model is formally similar to the context-free model except that the internal phoneme units are marked for the immediate context in which they occur, i.e., the units for the second A in ABRACADABRA are different from those for the third because of the difference in context (Wickelgren, 1968).

(Accepted for publication October 7, 1968.)