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Analysis of Keying Errors

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The performance of keyboard operators can be expressed in terms of keying time and errors; this paper deals with errors. If the causes of errors were known, it might be possible to reduce the percentage of wrong keystrokes. Therefore, an attempt was made to identify these causes by classifying 293 errors, collected in a field study, into seven categories. About 25% of the errors were due to the operator misinterpreting input data; better data presentation may decrease this percentage. At least 40% of the keying errors could be traced to underlying errors in finger movement control, and would not seem amenable to direct error decreasing measures. Automatic punching of repetitive information brings about numerous repetitive errors as well; improved instructions on the use of programmed punching facilities may reduce these errors.

1. Introduction

More and more keyboards are being used for data entry in a wide range of equipment, from telephones to computers. The performance of the increasing number of keyboard operators can be measured in terms of keying time and percentage of keying errors. Of these two parameters, error percentage may well be the more important because of the potential consequences of undetected errors. The possibility of decreasing the error percentage by improving upon source documents, keyboard parameters, methods of keying or any other equipment or procedure used in the keying process, therefore seems attractive enough to warrant the study of keying errors. This is especially so because, in spite of the abundance of publications on keyboards and their operation (Klemmer 1971, Alden, Daniels and Kanarick 1972), only limited data are available on the nature of keying errors. MacNeilage (1964) studied self-detected errors made by psychology students who were typing reports at home from written drafts. Numerals and punctuation marks were not considered. Michaels (1971) compared the standard, 'QWERTY' keyboard with an alphabetically arranged one, in an experiment with subjects who used both keyboards. He did not specify in detail the various errors made. Hale (quoted by Singleton 1972) also compared two different keyboards, with two groups of subjects. In this experiment it was not possible for the operator to verify if an error had been made, nor to check which character in a line of text was next to be keyed. Of the work described by Seibel (1972), no detailed information as to keying errors is available. The present report attempts to relate keying errors recorded in a small-scale field study to causes and to classify them accordingly.

2. Method

A representative sample of jobs from a card punch department with about 25 female operators was chosen while keying these jobs was in progress. The department was located in a modern, well-illuminated office room of sufficient size.

Four operators, with 1–10 yr of experience, each made between 10 000 and 25 000 keystrokes on the jobs that had mostly a mixed alphanumeric text. They were all touch-typing. *IBM Model* 29 *B* 22 card punch machines were used, which print the information punched in a card at the top of it. Visual feedback on what had been keyed was thus available. The layout of the keyboard is shown in Figure 1. Depressing the keys required a minimal force of between 40 and 70 g. The keystrokes varied between 2 and 3 mm, providing clear kinaesthetic feedback. The importance of sensory feedback to the accuracy of keying is not entirely understood (Alden *et al.* 1972). However, since the majority of all keying errors are generally detected by the operator himself (Klemmer 1971, Michaels 1971, and this paper) he evidently uses some kind of feedback. When interviewed on their cues for error detection, our operators mentioned ‘ knowing that something had gone wrong ’ during keying, and then checking this visually. This answer fits in with results from experiments by Rabbitt (1968). He made subjects respond to visual presentations of one of the digits 1 to 8 by pressing a corresponding key with one of their forefingers. Twelve of his subjects, who had to signal their errors by making the correct response, detected 71% of all errors, with a shorter reaction time than for their direct correct responses. This suggests a comparison of some form of the motor programme for a response with the actual response executed.

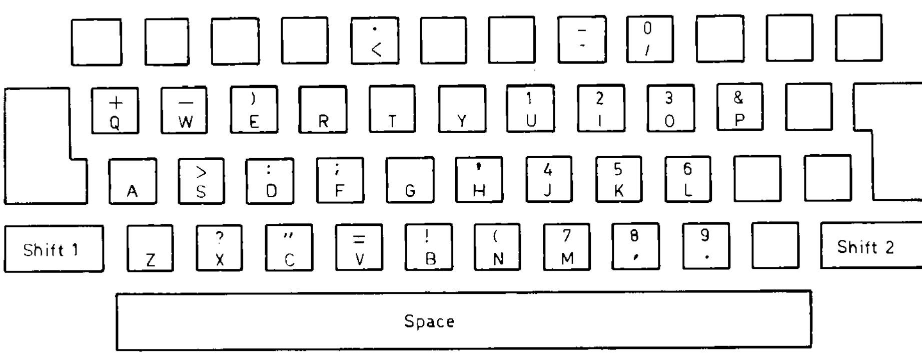

Figure 1. Keyboard layout. All keys are depicted, but key top designations which are irrelevant for the present analysis are omitted.

The operators kept the faulty cards with their self-detected errors for the purposes of this study. The printing on these cards shows approximately how soon after the occurrence of an error it was detected. All jobs were verified almost completely by another operator on *IBM Model* 59 machines; practically all cards with errors undetected by the first operator were caught in this procedure. All errors were classified using the source documents which contained the statements that had been keyed. The operators were not observed during actual keying of the jobs investigated in order to avoid extra errors resulting from nervousness.

The Appendix tabulates examples of all 13 types of error described below. Apart from providing a general illustration of the source material, this sets each example of error in its context. Thus the following assignment of errors to specified causes can be assessed from the source material surrounding the error.

Errors were classified on the basis of a three-fold division of processes that may be assumed to occur in keying, analogous to De Greene's (1971) division into ' inputs ', ' decisions ' and ' outputs '.

The first process is associated with identifying, reading and storing the information to be keyed from a source document. During this stage, errors may be caused by misreading single symbols, reading from a wrong line or column, neglecting changes in information that had remained constant for several statements, etc. Examples of single-symbol reading errors from our material are:

(1) E instead of B
(2) < instead of L

The second process involves removing the information from a short-term store, and converting it in a series of movement commands to the appropriate fingers. A large fraction of the recorded keying errors, consisting of symbol-sequence aberrations, can be ascribed to this second, motor programming stage. This assumption seems justified because of the analogies between groups of such keying errors and classes of errors occurring in motor acts such as speaking (Cohen 1968, Nooteboom 1969, MacKay 1969) and handwriting (Stoll 1913, Van Nes 1972). In the following, (3) to (6) are examples of motor-programme keying errors.

(3) NA instead of JAN

This may be called an anticipatory error, *i.e.* one showing a symbol that is keyed before its proper time in a sequence. The operator stopped keying after the A, which shows that such errors may be detected rapidly. Also, the interruption in the middle of keying a word demonstrates that this error cannot be attributed to *e.g.* misreading the source text.

(4) LEINDING instead of LEIDING

Another anticipatory error, the dominant subcategory of motor-programme errors, but in this case the word concerned was keyed completely.

(5) 0601171 instead of 061171

This may be called a persistent error, the opposite of an anticipatory one, because this type of error is characterized by the repetition of a symbol that was keyed earlier.

(6) RPINTEN instead of PRINTEN

Such a permutation of two consecutive symbols is a particular type of anticipation. It might be caused merely by a reversal of the order of activating the key-pressing fingers concerned.

The third process consists of actually depressing the target keys in the programmed order. Errors may arise during this stage through aiming inaccurately, or depressing keys inadvertently at the left or right of the required one by the adjacent fingers, or by rocking the finger on the correct key until it hits the key above or below it. Such finger movements have actually been observed by high speed filming (Vail, Norbury and Hale 1972). Examples of vertical and horizontal ' adjacent-key ' errors, respectively, are:

(7) 163 instead of 160
(8) A*V instead of A*C

For ergonomic purposes, the value of the classification described lies in its possible utility for guiding efforts to decrease the occurrence of errors, *e.g.* by improving the quality of source documents. Then it must be known, in the first place, with which degree of certainty an error was classified. It is of course always possible to proclaim an error ambiguous, *e.g.*, any keyboard error could in principle be caused by the operator simply hitting a wrong key as a result of not paying enough attention. Usually, however, only one or two plausible causes for an error remain. The cause ' misreading ' may be eliminated, for instance, by considering similar statements that were keyed correctly immediately before the one that was keyed wrongly. The errors with two plausible causes make the three basic categories overlap somewhat. For instance, taking the source document into account, the error

(9) SAN 2 instead of SAN 5

could be interpreted as being caused by reading from the wrong line, or by making an adjacent-key error.

An example of an error which may be classified both as a reading and motor programming error is

(10) KWALITEITBELEID instead of KWALITEITSBELEID

i.e., either the letter S was overlooked on the source document, or the letter B was anticipated while keying. Finally, the immediately discovered error

(11) O instead of PERIODE

may represent an adjacent-key error, or/and an anticipation of the fifth letter of that word. In particular as regards the latter type of error, which can equally well be ascribed to the motor programming as to the keying stage, it appears reasonable to assume that two causes of an error can cooperate in actually producing it. Such cooperation of two error causes has been described for typing by MacNeilage (1964) and is also found in handwriting (Van Nes 1972).

To demarcate the boundaries of the three error categories more sharply, much more effort would have to be expended. This appears justified only if the fraction of errors with two plausible causes is considerable compared to that with just one cause. Careful observation of the fingers of an operator would represent such an effort. An error such as

(12) B instead of N

may then be classified as a motor programme in lieu of a formal adjacent-key error, *viz.* one of assigning the key-pressing command to the left instead of the right index finger; at least if the operator was using the orthodox system of touch-typing she had learned. However, this system was not adhered to rigidly by our operators during keying, because the jobs concerned often required keying long strings of numerals, done with the right hand on the numeric section of the keyboard. Meanwhile the left hand took care of most or all of the alphabetic keying in between. Finally, a small number of errors remained which could be placed equally well in each of the three categories. Together with a few errors of unknown origin, like

(13) /O instead of UG

they were classified in a residual group.

Table 1. Distribution of keying errors in seven categories, based on: (i) reading, (ii) transforming into finger movement commands, (iii) keying, of information from source documents. See text for description of subcategories. At the foot of each column the percentages of (*a*) keystrokes in error and (*b*) alphabetical characters, as well as the total number of machine-duplicated errors in the jobs concerned can be found. Operators 1, 2, 3 and 4 respectively had 1. 1·5, 2·3 and 10 years of card-punching experience.

	OPERATOR 1				OPERATOR 2			OPERATOR 3			OPERATOR 4		
	Percentage	Number			Percentage	Number		Percentage	Number		Percentage	Number	
READ	27	20	sym	7	28	24	1	25	24	2	3	1	–
			line	4			2			1			1
			space	–			17			16			–
			r-oth	9			4			5			–
MOTOR PROGRAMME	37	27	ant	18	37	32	16	35	34	20	61	22	8
			pers	4			4			5			2
			perm	2			6			3			3
			m-oth	3			6			6			9
ADJACENT KEY	11	8	hor	6	9	8	4	13	12	11	6	2	1
			vert	2			4			1			1
READ-KEY	4	3			6	5		2	2		3	1	
READ-PROGR.	5	4			1	1		11	11		8	3	
PROGR.-KEY	7	5			5	4		4	4		8	3	
REST	9	7			14	13		10	9		11	4	
Total	100	74			100	87		100	96		100	36	
Percentage keystrokes in error	0·34				0·90			0·59			0·15		
Approximate percentage alphabetical characters in source material	40				1			25			50		
Number of machine-dupl. errors	35				145			4			3		

The complete error collection with source material may be surveyed on request.

3. Results

3.1. *Self-detected vs. undetected errors*

Of the 293 errors collected in this study, 71, *i.e.* 24%, were not detected by the operator who made them. The range of undetected errors for the individual operators was 15–40%.

No significant differences between the proportions of self-detected and undetected errors in the error categories defined can be discerned. One might expect, for instance, that more reading errors would remain undetected by the operator, compared with errors from the other categories. The material keyed by our operators was not homogeneous enough to permit this type of conclusion.

3.2. *Error distributions*

Table 1 shows the distribution of all errors made by the four operators in the categories and subcategories described in section 2. The ' READ ' category is divided into single-symbol (sym), wrong line (line), incorrect number of spaces (space) and other (r-oth) reading errors. Contrary to expectations raised by complaints from the operators about the poor legibility of the often handwritten characters on their source documents, only few single-symbol errors were made. Of course it is not possible to judge the difficulty of interpreting documents of low legibility exclusively from this type of error. It is even conceivable that poor document quality causes more errors in the second and third stages of keying, through stress; or, alternatively, less errors, through increased concentration or lowered keying speed. The considerable number of ' space ' reading errors by operators 2 and 3 is due mainly to the type of work they had to key. The ' MOTOR PROGRAMME ' category is divided into anticipatory errors (ant), persistent errors (pers), permutations (perm) and other motor programme errors (m-oth). The 'ADJACENT KEY ' category is divided into horizontal (hor) and vertical (vert) adjacent-key errors. Errors like example (9) in section 2 constitute the category READ-KEY; errors like example (10) the category READ-PROGR. and those like example (11) the category PROGR.-KEY.

Global information on the keying speed of our operators was obtained from a report provided by their supervisor. This report indicated that, averaged over a variety of jobs with different degrees of difficulty, operators 3 and 4 had the highest keying speed. Specifically, operator 2, who made six times as many errors as operator 4, was certainly not trading accuracy for speed, nor was operator 4 keying slower than the other operators.

Figure 2 depicts the error distribution in seven categories, averaged over all four operators.

3.3. *Machine-duplicated errors*

The machines used in the card punch department of this study all have automatic punching facilities that can be selected with special programme cards. When an operator receives a new job, she prepares a programme card which she considers appropriate for the requirements of that particular job. Part of her work, *e.g.* selecting the alphabetical or numerical field of the

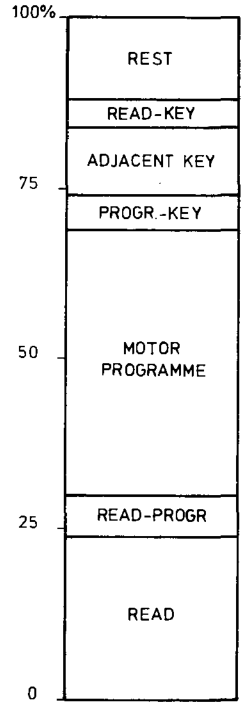

Figure 2. Distribution of 293 keying errors made by four operators, in the seven categories of Table 1.

keyboard, or duplicating the characters in certain positions of the cards, is then performed by the machine. Programmed automatic punching is thus of great help in relieving an operator of repetitive keying. On the other hand, it can cause piles of completely punched cards to be worthless if one single error was not noticed in a programme card or in a string of characters which is duplicated from card to card. As to the latter case, it may occur rather frequently that changes are not noticed in text which for many consecutive statements had remained the same. Our operators 1 and 2 both produced about 30 wrong cards because of one such (not-) reading error.

Errors in programme cards are notorious in the card punch department of our study. Although the operators are instructed to check carefully the first card keyed after insertion of a new programme card, forgetting this check is not an exception. The results can be serious: operator 2 completed 104 wrong cards before she discovered her error in the programme card concerned.

At the bottom of Table 1 the total numbers of machine-duplicated errors are given for each operator. They are, of course, not represented in Figure 2.

3.4. *Avoidable errors*

The previous paragraph illustrated the dangers of using the automatic facilities of key punch machines. However, *not* using these facilities, *i.e.* manually keying information that could be produced automatically, can obviously be a source of errors as well. For example, operator 3 might have avoided 35% of her errors by employing the automatic tabulating feature. Using this would have been especially advisable in her case because the source documents concerned showed a discontinuous column numbering. See the

Appendix, errors (2), (8) and (11). Even operator 4, who had most experience and made very few errors, could have further reduced her error percentage by using some, rather obvious, automatic punching features.

4. Discussion

A few years ago Alden *et al.* (1972) commented on the specificity as to tasks and keyboards of almost all data on keyboard design and operation in the literature. This specificity made it impossible to relate keyboard parameters and operator performance quantitatively.

The present study, of course, also suffers from a lack of generality. However, it does permit some comparisons among different types of keying errors and thus is suggestive of the relative cost effectiveness of alternative error reduction measures among full-time operators.

In the first place it appears likely that a large proportion, at least 40% in our case, of all keying errors arise in the motor programming stage and thus are inherent in the way human movements of this type are controlled. Such errors are largely outside the scope of designers of documents, keyboards or related equipment.

Secondly, the maximum proportion of errors that could possibly have been caused by hitting a key in the neighbourhood of the correct one is around 20%. However, about half of this fraction could well be attributable to other causes, *viz.* errors in the input or programming stages. These figures, obtained with a keyboard providing clear kinaesthetic feedback, may indicate the upper limit to any error reduction obtainable if improvements on similar keyboards are considered.

Thirdly, measures to improve the quality of data which the operators have to read and interpret in our case would deal with at least 25% of all errors. Such measures are rather obvious, and consist in providing (i) high contrast documents of (ii) unambiguous layout with (iii) typewritten characters. The quality of input data also influences the overall speed of performing a job, especially when it is necessary to stop keying in order to decide on the meaning of, *e.g.*, handwritten characters which are written in an idiosyncratic style.

Fourthly, at least in the department where our operators worked, there seems to be room for improving instructions on the use of programme cards. For some jobs this would result in considerably fewer errors, either real or duplicated, as well as shorter keying times.

A preliminary version of this paper was presented at the 5th International Congress on Ergonomics (Van Nes 1973). The author is indebted to his colleagues and to the referees of *Ergonomics* for helpful comments on the present paper.

APPENDIX

For each error described, the first or last half of the text-line or statement in which it occurred is reproduced, together with the corresponding half of the lines immediately above and below it, if such lines were present. The errors occurred while keying the underlined symbol(s). Errors (3) and (12) were made in the last half, i.e. columns 41–80 of the line; the other errors in the first half, i.e. columns 1–40. The vertical lines separated text sections on the source documents. The small numbering at the text of errors (2), (8), (11) and (12) was printed at the top of the relevant pages and corresponds to the column

```
(1)          |B C     | P  |2 6 1 6 2 0 |5 |K W A L . L A B . M A T E R I A L E N
             |B C     | P  |2 6 1 6 3 0 |5 |K W A L . L A B . A L G E M E N E   L E I D I
             |B C     | P  |2 6 1 6 3 0 |5 |K W A L . L A B . A L G E M E N E   L E I D I

      1-2       5-10           12  27                 29-80
(2)   L C |2 8 3 9 4 5 |    | 0|       * I N   D E   P E R
      L C |2 8 3 9 4 5 |    | 3|4 1              . -

      41                                                                        80
(3)   I O D E   J A N . 7 2 * 1 - 1 - 7 2 * T O T A A L          * N O G   B E
            . -     1 6 . -       1 6 . -     2 6 . -      5 0 . -        2 4 .

(4)          |E C Y |  4 |8 2 0 5 8 0 |1 |A D M I N I S T R A T I E   K I N D E R B I J
             |E C Y |  4 |8 2 1 1 1 0 |1 |L E I D I N G   E N   S E C R E T A R I A A T
             |E C Y |  4 |8 2 1 1 6 0 |1 |I . S . A .

(5)   D 0 3 |D |4 5 2 2 1 1 0 0 2 0 4 1 |0 6 1 1 7 1 |          |H L P |4 5 2 2 1 1 0 0
      D 0 3 |D |4 5 2 2 1 1 0 0 2 0 4 1 |0 6 1 1 7 1 |          |H L P |4 5 2 2 1 1 0 0

      4 0 4 |4 3 0 | |         |        |A D D   B E I G R   T O   E I G U R 4      A
(6)   4 0 4 |4 4 0 | |         |        |G O   T O   P R I N T E N .
      4 0 4 |4 5 0 | |I F   B |U R B E |T   =   ' 5 '

      1         R   4 5 |  |1 9 7 5 | |  1 6 6 . |     |     |     |
(7)   1         R   4 5 |  |1 9 7 6 | |  1 6 0 . |     |     |     |
      1         R   4 5 |  |1 9 7 7 | |  1 5 0 . |     |     |     |

        1-3          5-10       11-12   13-16     17-20    21-22   23-26     28-31   32-33   34-37    39-42
      A C     |D 2 1 8 2 8 |6 0 |6 0 1 2 |6 0 1 4 |3 2 |B B M N |      1 |    |      |
(8)   A * C   |D 2 1 8 2 8 |    |6 1 0 2 |6 1 0 4 |    |        |        |    |      |
      A C     |D 2 1 8 2 8 |6 1 |6 1 0 2 |6 1 1 0 |2 4 |E O A R |  1 5 8 |    |      |

(9)          |S A N  |  2 |3 2 9 1 4 0 |3 |O L I E   M A G A Z I J N
             |S A N  |  5 |8 7 1 0 0 0 |3 |V E R B O U W I N G   T . B . V .   R . G . T

             |S D M  | 4 A |3 3 2 6 1 0 |3 |V E R P A K K I N G S   O N T W E R P B U R E
(10)         |S D M  | 4 A |3 3 2 6 2 0 |3 |K W A L I T E I T S B E L E I D
             |S D M  | 4 A |3 3 2 9 1 0 |3 |G E R E E D S C H A P M A G A Z I J N

      1-2       5-10           12 27                 29-80
(11)  L C |2 8 3 8 4 5 |   |0 |      * I N   D E   P E R I O D E   J A N . 7 2 * 1 - 1 - 7 2
      L C |2 8 3 8 4 5 |   |3 |4 1              . -             . -             . -        .

      39-42                                           49-80
         |S Y S T E E M   O N T W .
(12)     |I N B O U W   I N   M E E T L I J N
         |O V E R N A M E

(13)  2 1 5 |4 8 0 | |        |0 2 |U F
      2 1 5 |4 9 0 | |        |0 2 |U G     P I C T U R E   X ( 3 0 )   V A L U E '
```

numbering of the punched cards. Intermediate columns had to be skipped. The quality of several of the source documents was worse than suggested here because of low contrast or handwritten characters.

Les performances d'opérateurs se servant de claviers peuvent être exprimées en terme de temps de frappe et d'erreurs. Cet article se propose d'analyser les erreurs. Si la cause des erreurs était connue, il serait possible de réduire le pourcentage des frappes erronées.

Dans ce but, nous avons tenté d'identifier ces causes en classant 293 erreurs, provenant d'une situation réelle, en 7 catégories. Environ 25 p. 100 des erreurs étaient dues à une mauvaise interprétation, par l'opérateur, des données; une meilleure présentation des données pourrait réduire ce pourcentage. Au moins 40% des erreurs de frappe sont attribuables à un contrôle défectueux des mouvements des doigts. Ce taux ne semble pas pouvoir être réduit. La perforation automatique de l'information répétitive introduit également un certain nombre d'erreurs répétées. De meilleures consignes relatives à l'utilisation de la perforation programmée pourraient réduire ces erreurs.

Die Leistung von Schaltbrett—Bedienten kann als Bedienungszeit und als Fehlerzahl erfasst werden; diese Arbeit beschäftigt sich mit den Fehlern. Wenn die Ursachen der Fehler bekannt wären, wäre es möglich, die Prozentzahl falscher Schaltbewegungen zu reduzieren. Es wurde daher versucht, diese Ursachen zu identifizieren, indem 293 Fehler klassifiziert wurden, die in einer Feldstudie in 7 Kategorien gesammelt wurden. Etwa 25% der Fehler waren dadurch bedingt, dass der Bedienungsmann die eingehenden Daten falsch deutete; eine bessere Darbietung der Daten könnte diesen Prozentsatz verringern. Wenigstens 40% der Schaltfehler konnten auf Fehler der Fingerbewegungen zurückgeführt werden. Sie schienen nicht durch direkte Verringerung der Fehlerzahl beeinflussbar zu sein. Automatisches Punzen wiederholter Informationen führt ebenfals zu zahlreichen wiederholten Fehlern; verbesserte Instruktionen über die Verwendung programmierten Punzens und seiner Erleichterung vermag seine Fehler zu reduzieren.

References

Alden, D. G., Daniels, R. W., and Kanarick, A. F., 1972, Keyboard design and operation: a review of the major issues. *Human Factors*, **14**, 275–293.

Cohen, A., 1968, Errors of speech and their implication for understanding the strategy of language users. *Zeitschrift für Phonetik, Sprachwissenschaft und Kommunikationsforschung*, **21**, 177–181.

De Greene, K. B., 1971, *Systems Psychology* (New York: McGraw-Hill).

Hale, D. J., 1972, Speed/accuracy interaction in human performance. *Report to the Social Science Research Council, London.*

Klemmer, E. T., 1971, Keyboard entry. *Applied Ergonomics*, **2**, 2–6.

MacKay, D. G., 1969, Forward and backward masking in motor systems. *Kybernetik*, **6**, 57–64.

MacNeilage, P. F., 1964, Typing errors as clues to serial ordering mechanisms in language behaviour. *Language and Speech*, **7**, 144–159.

Michaels, S. E., 1971, QWERTY versus alphabetic keyboards as a function of typing skill. *Human Factors*, **13**, 419–426.

Nooteboom, S. G., 1969, The tongue slips into patterns. In *Nomen, Leyden studies in Linguistics and Phonetics* (The Hague: Mouton and Co.). Pp. 114–132.

Rabbitt, P. M. A., 1968, Three kinds of error-signalling responses in a serial choice task. *Quarterly Journal of Experimental Psychology*, **20**, 179–188.

Seibel, R., 1972, Data entry devices and procedures. In *Human Engineering Guide to Equipment Design* (edited by H. P. Van Cott and R. G. Kinkade) (Washington: U.S. Government Printing Office). Pp. 335–337.

Singleton, W. T., 1972, Techniques for determining the causes of error. *Applied Ergonomics*, **3**, 126–131.

Stoll, J., 1913, Zur Psychologie der Schreibfehler. In *Fortschritte der Psychologie und ihrer Anwendungen*, **2** (Leipzig: K. Marbe and W. Peters).

Vail, F., Norbury, J., and Hale, D. J., 1972, Keyboard human factors experiments. *Appendix H of Speed/accuracy interaction in human performance, by D. J. Hale (ibid.).*

Van Nes, F. L., 1972, Motor programming and errors in handwriting. In *Neurophysiology studied in Man* (Excerpta Medica International Congress Series No. 253. Ed. G. G. Somjen) (Amsterdam: Elsevier), 420–425.

Van Nes, F. L., 1973, Analysis of keying errors made by card punch operators. *Ergonomics*, **16**, 333.